DEVELOPING AN INTEGRATED MODEL BETWEEN QFD AND AHP FOR ASSEMBLY LINE: CASE STUDY AT AN ELECTRONIC COMPANY

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ABSTRAK

Barisan pemasangan kejat adalah merujuk kepada kaedah penyelesaian atau cadangan yang dapat meminimumkan masa kitaran bagi tempoh kerja harian. Ianya tidak mempunyai kaedah yang terperinci; ia merangkumi keseluruhan aliran pengeluaran dari awal hingga akhir untuk mengenalpasti masalah semasa proses pengeluaran. Walaupun pelbagai inisiatif dibuat untuk mengoptimumkan pelaksanaan sistem pengeluaran kejat lebih praktikal, namun, status pencapaian semasa dan strategi penambahbaikan yang berterusan oleh industri di Malaysia tidak dianalisis secara meluas. Oleh itu, matlamat penyelidikan ini adalah untuk mengenalpasti amalan pengeluaran kejat dan strategi penambahbaikan berterusan yang penting kepada industri pembuatan Malaysia termasuk perbezaan antara keutamaan dan pencapaian semasa praktis tersebut. Selain itu, penyelidikan dilakukan untuk membangunkan kerangka penggunaan fungsi hierarki kejat untuk meningkatkan prestasi pemasangan di samping mencadangkan amalan terbaik aliran pemasangan kejat menggunakan analisis simulasi. Kajian kaji selidik dan kajian kes telah dipilih dalam kajian ini. Dalam mengenalpasti tahap pencapaian dan faktor-faktor LP dan LS, satu set soal selidik telah dibangunkan berdasarkan parameter yang diperolehi daripada kajian literatur. LHFD dibangun berdasarkan AHP dan QFD; di mana AHP pada asalnya dibangunkan untuk pembuatan keputusan untuk masalah kompleks; manakala QFD dibangunkan untuk reka bentuk proses dan pembangunan. Metodologi LHFD ini menggunakan AHP dan QFD untuk mengkaji hubungan antara aliran pemasangan kejat dan strategi penambahbaikan berterusan. Dalam kajian ini, data tinjauan daripada 61 firma perkilangan di Malaysia digunakan untuk mengesahkan status pelaksanaan amalan kejat di kalangan firma pembuatan dan mengkaji hubungan penting antara semua parameter secara umum. Sementara itu, satu kajian kes dilakukan di firma pemasangan produk elektrik untuk mengesahkan semula parameter amalan kejat menggunakan LHFD. Hasil kajian menunjukkan bahawa terdapat empat kriteria utama yang dapat dikategorikan sebagai amalan kejat iaitu pemendekan masa pemprosesan (STPT), penggunaan pekerja dan mesin (MMU), kawalan inventori dan penyimpanan (ISC) dan pengoptimuman ruang kerja (WO). Turut didapati bahawa kaedah penambahbaikan, susunatur stesen kerja dan penggunaan helah pengeluaran bagi penjimatan masa adalah tiga strategi pembaikan berterusan paling utama dan berpotensi memberi kesan ke atas empat amalan kejat seperti yang telah dikategorikan di atas. Analisis pemodelan dan simulasi mendapati bahawa pelbagai jenis strategi menyumbang hasil akhir yang berbeza. Kaedah penambahbaikan memerlukan pengetahuan khusus dan pengalaman bekerja di stesen kerja manakala penggunaan helah pengeluaran dalam penjimatan masa memerlukan kreativiti penyelia pengeluaran untuk mengubah atau mengatur semula spesifikasi pekerjaan dan waktu kerja. Untuk menambahbaik susunatur stesen kerja, firma perlu memberi tumpuan kepada pengurangan ruang kerja serta meminimumkan masa kerja dalam masa pengangkutan produk. Penemuan ini mempunyai implikasi yang signifikan, secara teori dan praktikal untuk menterjemahkan strategi dan dasar ke dalam polisi tindakan sepertimana yang terdapat pada LHFD, terutamanya untuk mencipta perubahan atau ketidakpastian dalam isu produktiviti. Para penyelidik, pengamal perindustrian, kerajaan dan pihak berkuasa tempatan boleh merujuk model yang dicadangkan untuk memahami kesan-kesan integrasi amalan kejat dan strateginya, serta mengenal pasti kekuatan dan kelemahan dalam menetapkan dasar untuk mencapai pelaksanaan untuk aliran pemasangan kejat.

ABSTRACT

The lean assembly line refers to a solution or a suggestion that is able to minimise cycle time for a daily basis working period. There is no specific method; it will take a look at the production lines from first till the end of line to observe where the problems are. Despite the broad efforts that have been made to make the lean production system more reasonable, however, the status of the current achievement of lean practices and lean continuous improvement strategies by Malaysian industry has not been analysed extensively. Thus, the objectives of the present research are to investigate which lean practices and lean continuous improvement strategies are important to the Malaysian manufacturing industry and how significant the difference between priority and current achievement. Moreover, the research was carried out to develop a lean hierarchical function deployment model for assembly line performance improvement and to propose lean assembly line model best practices for production operation system using simulation analysis. Survey and case study approaches were chosen in this research. In investigating the level achieved and factors of the lean practices (LP) and lean improvement strategies (LS), a set of questionnaire has been developed based on the parameters from the literature. The Lean Hierarchical Function Deployment (LHFD) model is based on Analytic Hierarchy Process (AHP) and Quality Function Deployment (QFD); where AHP was originally developed for making the decision making for the complex problem; while QFD was developed for the design of process and development. This LHFD methodology was focused and elaborated more on the extended AHP and QFD used for finding the relationship between lean assembly line and lean continuous improvement strategies. In this research, the survey data from 61 manufacturing firms in Malaysia were used to confirm the status of lean implementation among manufacturing firms and the significant relationship between all parameters in general. Meanwhile, a case study was performed in an electrical product assembly firm to reconfirm the lean assembly essential parameter using LHFD model. The findings showed that there are four main criteria can be categorised for lean practices which is shortening process time (SPT), man and machine use (MMU), inventory and storage control (ISC) and workspace optimisation (WO). Besides, method of improvement, improve workstation layout and production time saving tricks are three main lean continuous improvement strategies that most potential effect on the four categorised of above mentioned lean practices in the assembly line performance improvement. The modelling and simulation analysis found that different types of strategies had contributed different end result. The method of improvement requires specific knowledge and working experience in the workstation meanwhile, using about the time saving tricks need creativity of a line supervisor to alter or re-arrange the job specification and working time. To improve workstation layout, it focuses on the workspace reduction through minimising of work on progress product transportation time. These findings have significant implication, theoretically and practically for translating the strategy and policies on preparing the deployment approach as a sub activity in the LHFD model, especially to absorb any changes or uncertainty in productivity issues. The other researchers, industrial practitioners, government and local authority can refer the proposed framework to understand the diverse effects of the integration of lean practice and the strategies, as well as to identify the strength and weaknesses in setting the policies to achieve the basis of performance improvement implementation for lean assembly line.

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
APDC	Asia Pasific Development Center
CCA	Customer Competitive Assessment
CIR	Customer Important Rating
CR	Critical Ratio
DOSM	Department of Statistics Malaysia
E&E	Electrical & Electronics industry
GDP	Gross Domestic Products
H	Hour
HOQ	House of Quality
ISC	Inventory And Storage Control
LA	Lean Assembly
LHFD	Lean Hierarchical Function Deployment
LP	Lean Practices
LS	Lean Strategy
MATRADE	Malaysia External Trade Development Corporation
MAV	Matsushita Audio Video (M) Sdn. Bhd.
MITI	Ministry of International Trade and Industry
MMU	Man and Machine Use
OEM	Original Equipment Manufacturer
PCs	Personal Computer
QFD	Quality Function Deployment
R&D	Research and Development
RAM	Random Access Memory
SPR	Strategic Planning Room
SPT	Shortening Process Time
USA	United State of America
VBA	Visual Basic for Applications
WIP	Work-In Process
WO	Workspace Optimisation
WS	Workstation

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CHAPTER 1

INTRODUCTION

1.1 Background of the Research

In the past, manufacturing activities were driven solely by profit to ensure the survival of the organisations in a competitive environment. However, in tandem with changing times, the objective of maximising the financial growth is becoming more complex. Global competitions, shorter product life cycle, dynamic changes of demand pattern, product varieties, and uncertainties of internal operations have influenced the performance of manufacturing operations (Feng & Joung, 2009). To remain competitive, the manufacturing activities should consider the multidimensional of strategies that significance with all aspects (Bhasin, 2012). An effective solution is required to cope with the deviations in market circumstances or customer needs (Womack & Jones, 2003). Although globally the manufacturing sector continues to grow, but the performance of overall production practices in this sector is still lacking behind (Bergmiller, 2006). In fact, many manufacturing firms are still reluctant to consider using proactive action strategy (Lai et al., 2010). Therefore, the strategy in encouraging the best practices through several management approaches should be emphasised (Yusup, 2017). These are expected to become the new driving force in creating a responsive practice in manufacturing operations, and thus allow manufacturing firms to improve the performance, and competency of manufacturing society in producing the products at the minimum cost and economically (Wei et al., 2017).

Lean production is a management philosophy that drawn from Toyota Production System (Wilson, 2010). Before the term 'Lean' began, there are various similar terms and ideas used to describe this philosophy, such as continuous flow manufacturing, world-class manufacturing, just-in-time and zero inventory production (King, 2009). It is a philosophy that encompasses many principles, aims to meet the primary rationalisation of value-added activities and eliminating waste in the manufacturing processes in order to reduce costs and satisfy customer demand. Lean is applied to improve the flow of information and materials. Waste stems mainly from unnecessary delays, tasks, costs and errors (Wader, 2005). The seven wastes of lean include overproduction, transportation, unnecessary inventory, over processing, waiting time, movement and defects. Lean implementation within an organisation has shown considerable financial results, however, expanding the lean implementation to the responsive manufacturing has shown to be more difficult and often disorganised (Albliwi et al., 2014). Part of the challenge is due to the most complicated of applying lean tools that require tailoring to different production needs (Ramadas & Satish, 2018).

As in other countries, manufacturers in Malaysia also underlined lean production as a preferred approach for continuous improvement activities, mainly to improve operational efficiency and competitiveness (Yusup et al., 2017). The pressure to reduce the operating costs, improving product quality and productivity has prompted manufacturers to adapt lean production practices in many forms and names (Martínez & Pérez, 2001). The positive impact of lean production is not only recognized by the manufacturers, even the Malaysian government also supports the implementation of this practice in both manufacturing and services sectors as a good management tool in increasing the productivity (MPC, 2013). The support was translated through the establishment of Malaysia Productivity Corporation, also known as MPC as an agency that is responsible to promote the lean production to all industry players in all sectors within this country.

In promoting the lean production practices, MPC has established the MPC's National Roadmap for Lean. This roadmap consists of 6 phases: foundation, awareness, pilot projects, lean system for public sectors, lean enterprise and phase of the lean culture in encouraging the lean production practices as a complement to quality and productivity initiatives that have been implemented, primarily to enhance organisational excellence and economic competitiveness (MPC, 2014a). Initially, the MPC starts the foundation platform of lean production implementation by emphasizing the concept of 5S, TQM, ICC and work study. In 2011, Lean awareness program was launched for the

SMEs sector together with the Introduction of Module Capacity Building for MPC members. Next in 2012, MPC has established a Lean Centre of Excellence (CoE) to manage several Lean pilot projects. This was followed by several conventions and roundtable discussions to increase the awareness of the benefits obtained from the organization that implement the lean production practice (MPC, 2013). On 11 June 2014, the Minister of MITI has launched the Manual for Implementation of Lean Management Projects as a reference for the organisation to understand and implement the activities of waste elimination and maximise added value in the continuous improvement activities (MPC, 2014b). In 2015, the formation of Lean Cultures within the organisation has become the ultimate goal. This is to ensure the implementation of the lean production is always in line with the national agenda to improve productivity, economic, social, technological, and legal environment through waste elimination in maximising the customer value.

A considerable amount of literature has been published on lean production suggests that assembly line to be mainstreamed in cultivating the practices. The assembly line system can be defined as the controlling of job movement between every workstation in a line (Cohen, 2013). Paced line condition can be referred as the assembly system that has a different value of cycle time at each station (Calvo et al., 2006). In a standard case, each of the workstations applies standard or same cycle time, so the number of part product transferred would be in the same time, the number of output product would be fixed where it is equal to the reciprocal of the cycle time system. This happened in the automated assembly, but not in the manual assembly system. There is some condition that the cycle times are different and kept in average, this happened after the mixed model line where a single production line consists of two models or more (Barbazza et al., 2017). Each of different models consists of different cycle time and target of production due each of model face different types of problem and solution. This scenario is difficult to see in every production line using the manual system because of the bottleneck or problem occurs due to human error, differences in process cycle time, etc. (Yilmaz & Yilmaz, 2015).

1.2 Problem Statement

In general, there are varieties of tools and techniques used in determining effective manufacturing performance in a company. In spite the fact that lean has received enormous attention over the years, which is reflected in the amount of the literature work, research so far has neglected to monitor the ongoing progress of the lean production philosophy (Mourtzis et al., 2016).

There are several literatures had addressed lean implementation failure in industry (Rathje et al., 2009; Pedersen & Huniche, 2011; Albliwi et al., 2014). Ramadas and Satish (2018) reported that the failure was due to difficulty to have employee engagement in problem solving approach. In contrast, Al Amin & Karim (2013) stated that the selection of the unappropriated decision making method was the main reason for lean failure. In fact, Crute et al. (2003) recognised that the employees or lean practitioner fails to identify the best method in lean practice because of unable to prioritise the lean continuous improvement strategies.

On the other hands, employee sometimes considered that all lean practices are equally important without measuring the interrelationship between lean practices and lean continuous improvement strategies, and how both factors can be integrated simultaneously in enhancing the performance (Brown et al., 2006; Martinez-Jurado & Moyano-Fuentes, 2012; Worley & Doolen, 2015). Thus, the employees or managers have to spend more hours to identify a significant method to improve operational efficiency with the lean production system implementation (Yusup et al., 2017).

In Malaysia, the manufacturing sector contributes largely in the development of Malaysia's economy, primarily in the export market and continuously increases from year to year. According to the progress report of the eleventh Malaysia plan, manufacturing sector in Malaysia has recorded positive growth performance, averaging at 4.8% from year 2011 to 2015 (EPU, 2015). As reported in Malaysia Economic Report 2014/2015 (MOF, 2014), trading performance of the export of manufactured goods is more than RM 500,000 million starting from 2011.

In the middle of year 2018, the manufacturing sector is predicted to contribute 23% of the domestic production, second highest after services (56%) (DOSM 2018). Manufacturing sector is also estimated to contribute significantly to Gross Domestic Product (GDP), and is projected to continue positively to increase towards the year 2019. As shown in Figure 1.1, the GDP in Q2 and Q3 recorded an increase of al least 5%. This shows that attention should be given to the manufacturing sector to ensure this sector can continue to grow, and drive the growth of Malaysia's economy especially for electronic and electrical product sectors.

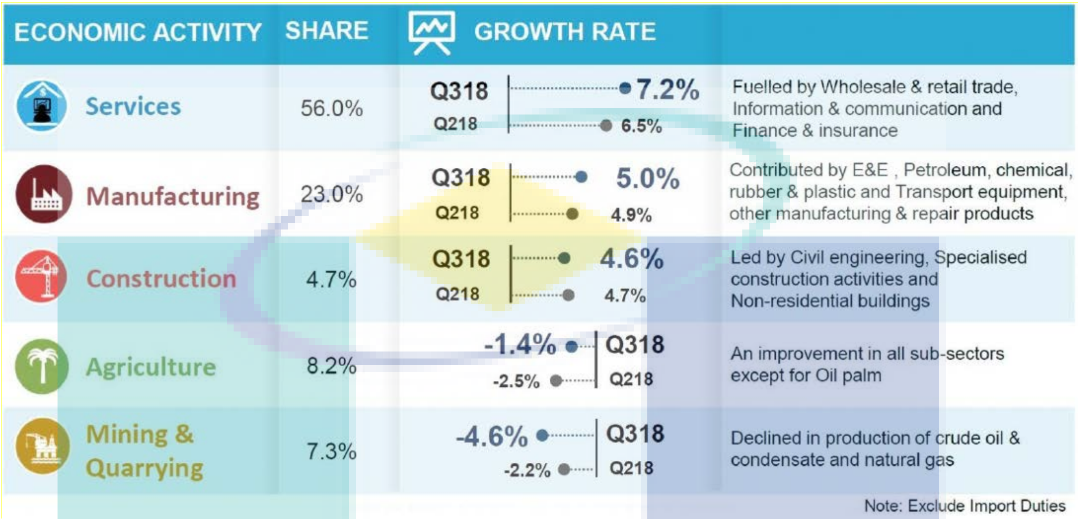


Figure 1.1 GDP by Economy Activities

Source: DOSM (2018)

Undeniably, large amounts of money need to be spent to conserve an adverse impact of the manufacturing activities on the environment. This is evidenced by the report from the Department of Statistics Malaysia (DOSM) which reported that the manufacturing sector had allocated large expenses for environmental care compared to other economic sectors (DOSM, 2011; 2012; 2013). According to the report by DOSM, the expenditure of environmental care in 2010 (i.e., evaluation and audit, waste management, environmental protection, and other environmental expenditure) is around RM 2,108.6 million, and increased to RM 2,328.9 million in 2011. Even the expenses in 2012 was not much different when allocation of RM 2,321.4 million was spent for the same purpose. Based on the economic census on environmental compliance report by DOSM (2011), the manufacturing sector has spent a total expenditure of RM 1,703.8 million or 80.8% in 2010, and remain highest in 2011 and 2012 (DOSM, 2012; 2013) as depicted in Figure 1.2.

Based on Figure 1.3, waste management activities highly contribute to environmental expenditure in 2010. It covers the management of non-hazardous solid waste (for recycle or disposal) and scheduled waste (in form of solid or liquid). In 2010, from a total of RM 1,136 million that was allocated for waste management, manufacturing sector has spent RM 920.5 million to manage non-hazardous solid waste and RM 215.5 million for scheduled waste. Meanwhile, in 2011, a total of RM 549 million from RM 799.4 million was spent, in which 59.9% was used in managing non-hazardous solid waste, and the other 40.1% was used for scheduled waste.

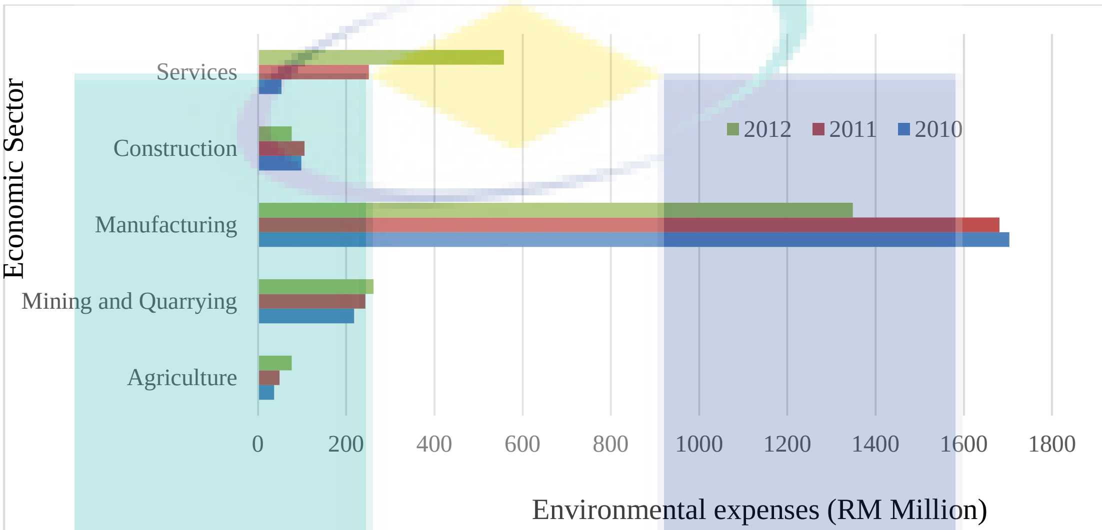


Figure 1.2 Environmental Expenses based on the Economic Sector from 2010–2012

Source: DOSM (2011; 2012; 2013)

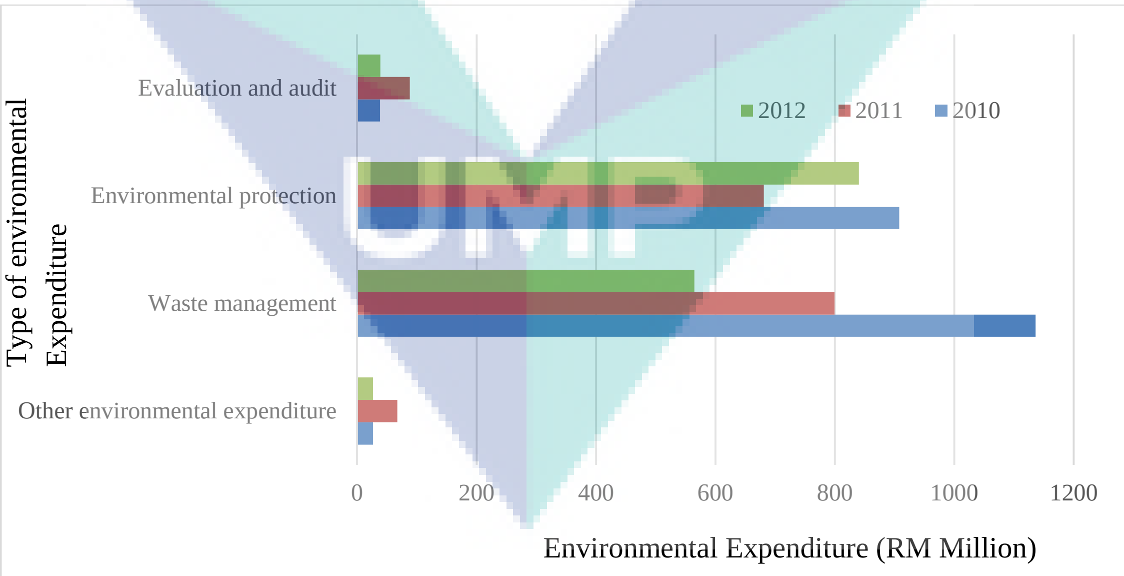


Figure 1.3 Environmental Expenses based on Types of Environmental Expenditure in All Economic Sectors from 2010–2012

Source: DOSM (2011; 2012; 2013)

Referring to the above facts, a balanced development between economic growth and environmental needs in the manufacturing sector should be emphasised. This subsequently supports the intention of Malaysian government to expand the use of lean and green technology as a preferred technology that is necessary in products and services, as well as increase the economic performance in Malaysia's economic landscape. This eventually can produce enormous benefits for Malaysian manufacturing firms, and thus help increase the sustainability of manufacturing operations, particularly to achieve the status of developed country by 2020, and become a major producer of green technology in the global market (KeTTHA, 2009). This fact makes the subject of this research very important, not just to strengthen the economic performance, but it will also be beneficial in increasing the environmental management performance towards achieving sustainable and responsive manufacturing.

1.2.1 Research Gap

The analytic hierarchy process (AHP) provides a framework to cope with multiple criteria situations involving intuitive, rational, quantitative and qualitative aspects from employees. Meanwhile, quality function deployment (QFD) gives the option to lean practitioner to identify the most appropriate lean continuous improvement strategies to meet both expectation from stakeholders and employee. In other words, any selected strategies are based on the requirement from all parties and represent the best option. Moreover, with the growing concern for manufacturing responsiveness, impact of the global industry, assessing and prioritising critical failure of the lean system based on the lean practices and lean continuous improvement strategy perspectives have drawn attention.

From the literature review, this study identified some gaps of knowledge, which are clarified as follows:

i. The extent of priority and current achievement of lean practices and lean continuous improvement strategies in the manufacturing industry have not been reported. Despite broad efforts have been shown to make the lean production system more reasonable, the status of the current achievement of lean practices and lean continuous improvement strategies by Malaysian industry has not been analysed extensively. Moreover, the significance of which lean practices and lean continuous improvement strategies that important to the Malaysian manufacturing industry has not been reported in the literature. The priority of lean practices and lean continuous improvement strategies might be different for other types of industry, which operate differently due to various combinations of the factors.

ii. The question of how lean continuous improvement strategies influence to the lean practices need to be addressed. Several researchers have identified a relationship lean continuous improvement strategies as an important part of lean practices, but still there is a lack of study to incorporate both measures with employee engagement in decision making.

iii. The AHP and QFD being deliberated as one of the utmost tools for decision making. However, there is a lack of holistic discussion on the development of lean practices and lean continuous improvement strategies especially in determining the best assembly line. Additionally, the incorporation of modelling and simulation for lean continuous improvement strategy deployment was less considered as a continuous effort for particular industries.

Therefore, there is a need to establish proper guidelines, procedures, model or frameworks of the systematic integration of lean practices and lean continuous improvement strategies to enhance the manufacturing performance.

1.3 Research Questions

Specifically, this research aims to answer the following questions:

i. What are the best lean practices and lean continuous improvement strategies for the Malaysian manufacturing industry?

ii. How much difference between the priority and current achievement of lean performance?

iii. How developed deployment model is able to improve assembly line system?

iv. What are the needs and the existence of any possible gap in lean continuous improvement strategies to optimise assembly line system?

This study aims to contribute to this growing area of research by exploring the best lean strategies. Different industries create different style of quality improvement practices, which mainly based on different cultures, infrastructure, and policies, etc. Therefore, it totally deserves serious research attention to meet the best manufacturing practices, through new insight of lean assembly line system and provides greater insights from the Malaysia context.

1.4 Research Objectives

The objectives of the research are:

i. To determine how importance, the current lean practices and lean continuous improvement strategies to the Malaysian manufacturing industry.

ii. To measure the difference between the priority and current achievement of lean performance.

iii. To develop a lean hierarchical function deployment model for assembly line performance improvement to meet the needs and existence of any possible gap in lean continuous improvement strategies.

iv. To examine the impact of lean production systems using simulation analysis.

1.6 Scope of the Research

The research focuses on lean practices and lean continuous improvement strategies, and how both factors can be integrated or implemented simultaneously in enhancing the performance of mass semi automation operation assembly line. It encompasses of 28 items for lean practices while 7 items for lean continuous improvement strategies that were only measured. The authenticity and accuracy of the research were only based on the answers given by the respondents through the distributed questionnaire, and based on the data collected from a case study company in verifying the validated model that was developed from AHP and QFD. One manufacturing company was selected. Due to confidential issue, the company was named as ABC company. It was established on 21st December 1990 and the first audio and video company in South East Asia outside Japan. The findings in the research may only be corrected at the time when this study was conducted, and was limited based on information from the samples of the population under studied.

1.7 Significance of Research

The research is considered as the first of its kind of study that integrate the lean performance criteria which consist of shortening process time, man and machine use, inventory and storage control and workspace optimisation in assembly lines using the analytic hierarchy process and quality function deployment with simulation in the Malaysian context, and can be considered as filling the gap in the body of knowledge. Moreover, this research was intended to support the fundamental in improving and enhancing lean practices among Malaysian industry to mitigate the adverse effects of unstable or uncertainty in manufacturing environment especially in the development an assembly line system. The knowledge generated and the model developed could be referred to or used by both policy maker and industrial practitioner within the Malaysia manufacturing industries in achieving sustainable economic practices that aligned with a national roadmap for lean practices.

1.8 Terminologies and Definitions

Table 1.1 shows main terminologies and definitions used in the research study.

Table 1.1 Terminologies and definitions

Terminologies		Definitions
Analytic Hierarchy Process (AHP)	:	As a decision-making method for prioritizing alternatives when multiple criteria or complex criteria must be considered.
Assembly Line	:	A structured process flow in a production line
HOW	:	Represent lean continuous improvement strategy (LS) in QFD analysis.

Table 1.1 Continued

Terminologies		Definitions
Inventory and Storage Control (ISC)	:	Lean practice for inventory management and storage control system.
Lean Assembly line	:	An efficient assembly line with no waste
Lean Continuous Improvement Strategy (LS)	:	A specific approach to enhance the implementation of lean practices.
Lean Hierarchical Function Deployment Model	:	An integrated model that consists of lean production system practices and strategy by using AHP and QFD methodology for productivity improvement especially in an assembly line.
Lean performance	:	A lean practice or strategy seen in terms of how successful it is performed.
Lean Practice (LP)	:	The adoption of the lean production system philosophy.
Lean Production System	:	A preferred approach for continuous improvement activities, mainly to improve operational efficiency and eliminate wastes.
Man and Machine Use (MMU)	:	Lean practice for man and machine deployment.
Modelling and Simulation	:	ARENA modelling and simulation for data validation in lean deployment strategy.
Quality Function Deployment (QFD)	:	An integrated WHAT and HOW of lean production tools and technique to provide industry-driven lean continuous improvement strategy.
Shortening Process Time (SPT)	:	Lean practice for processing time reduction.
Takt Time	:	Available working hour for production.
WHAT	:	Represent lean practices (LP) in QFD analysis.
Workspace Optimization (WO)	:	Lean practice for workspace consumption

1.9 Organisation of the Thesis

This thesis consists of six chapters. The first chapter introduces the context of the present research, consisting of the background of the research, problem statement, research questions, research objectives, research conceptual framework, scope of the research, significance of research and operational definition. Reviews of literature related to the topic of research is presented in Chapter 2. It starts with the overview of assembly operations, followed by facility planning and production layout. Besides, lean production system, lean practices for assembly line, lean continuous improvement strategies, quality function deployment, analytic hierarchy process and computer simulation modelling.

In Chapter 3, a specific step-by-step approach of research method in the present research is explained. The method of data collection involving the research design and administration of the research is explained in detail. The result of the analysis of questionnaire surveys is presented and discussed in Chapter 4. The analysis comprises the descriptive analysis, reliability analysis, and correlation analysis for all the datasets that were obtained from the survey respondents. Moreover, it explains how the findings from a survey are finalized in Analytic Hierarchy Process (AHP) and the development of the Quality Function Deployment (QFD) model for lean assembly line.

Chapter 5 explains three forms of case study analysis in ABC company for model validation. Finally, Chapter 6 concludes and summarises the findings of this research. The recommendations for future research were also highlighted in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews related studies of the scholars in the event to compare their findings, to see the similarities, the differences and whether or not it supports the current study. Overall, this chapter discusses the assembly operation, lean assembly line and specific criteria of each significant literature review. It also covers some information about quality function deployment, analytic hierarchy process and simulation modelling.

2.2 Assembly Operation

Manufacturing operation required specific production line to ensure the manufacturing or job flow as smooth as planned. The production line is an arrangement in a factory in which a thing being manufactured passes through a set linear sequence of mechanical or manual operations and the basic part of production system, which represents its production capability (Eyers & Potter, 2017). In fact, production process should be organised rationally in place and time, and operated continuously and rhythmically to increase productivity; to shorten the production period; to lessen the number of works in process; to speed up capital turnover; and to reduce costs. An assembly operation is typically an extremely complex system to design, plan and manage (Akpinar & Bayhan, 2011; Giannetti & Ransing, 2016). This is because, the assembly processes consist of many component parts for product realisation (Hu et al., 2011) especially in a semi-automated system which has a product moves (Whitfield, 2004). The operation requires both employee and machinery coordination along the line from start to finish to increase factory productivity and efficiency (Baumers et al., 2016).

Assembly lines are created for tools or machines, parts as well as the sequential organisation of workers. The motion of workers is reduced to the extent possible. They are handled either by motorised vehicles or conveyors like fork lifts, or gravity, with no manual tracing. Machines such as overhead cranes or fork lifts are used for lifting heavy loads. Typically, each worker performs one simple procedure. Shahanagi and Yavarian (2010) stated that each component part must travel the least possible distance while in the process of finishing and for that, the tools and men must be placed in the sequence. Next, to the parts to be assembled are delivered at convenient distances by using sliding assembly lines.

2.3 Facility Planning

The facility is defined as a building or place that provides a particular service or is used for a particular industry (Davies et al., 2013). In fact, the facility is one of the most central and strategic subjects in many manufacturing industries (Sedgewick, 1992). An efficient facility can reduce operational cost and contribute to the overall production efficiency (Tompkins, 2003). In a discrete facility location problem, the site selection where new facilities are to be established is restricted to a finite set of available candidate locations. Planning is defined as the process of making plans for anything (Amaratunga & Baldry, 2001). Strategic planning is a backbone support to strategic management and it is a major process in the conduct of strategic management (Tapinos et al., 2005). Raman et al. (2009) has reported that there is a gap between planning process, including implementation and the extent to which organisational context supports or distracts from the planning process. Evolution of an assembly line development requires a well organised facilities planning. In fact, the arrangement of the facilities gave major influenced in the overall production performance. Hebert and Chaney (2011) proved that new organisation always facing difficulty in determining best practice facilities planning while Pathirage et al. (2008) stated that the facilities must flexible and able to adopt any revolution in the industry including knowledge management, technology and demand pattern. This issue is gaining critical attention for organisations to find solution to remain competitive. For the research, the author has interrelated the development of the facilities plan towards lean assembly line.

2.4 Production Layout

A production layout may have positive correlation with an assembly line. Zijlstra and Mobach (2011) found that a well-structured production layout had influenced productivity. This is because, the better production layout provides a great place of working environment while easily to identify production problems for productivity improvement. Nevertheless, more recent attention has concentrated on the provision of lean production integration adaptable to dynamic conditions (Stålberg & Fundin, 2018). A large and growing body of literature has investigated manufacturing firms had difficulty in preparing production layout towards lean production. The organisations are not able to find the optimum way to reduce lean waste. There is a relatively small body of literature that is concerned with reducing production cost while improve production rate (Aghazadeh et al., 2011; Gonçalves & Salonitis, 2017).

In the definition, production layout is described as an arrangement or a plan, especially a schematic arrangement of parts or areas like the layout of a factory (Aqlan et al., 2014). In manufacturing systems, the two main types of layout are processed layout and product layout, which being categorized into flow line, cell, and centre. Zhang et al. (2008) has reported that the distinction between these types of layout is made based on system characteristics such as production volume and product variety. Taha and Tahriri (2008) have stated that the product layout (flow shop) is associated with high volume production and low product variety, while process layout (job shop) is associated with low-volume production and high product variety.

Several lines of evidence suggest that organisations must understand the types production layout while flexibility readiness in preparing a production layout, especially in managing manufacturing complexity (Wei et al., 2017; Sáenz et al., 2018). Previous research has established that the lean production system is also encouraged organisation to become more proactive and competent to understand the market needs that require the use of new technology and multi-tasking operation system (Frank et al., 2013; Katayama, 2017). For the research, the author had considered in production layout because is being reported as a significant factor in lean assembly line.

2.5 Lean Production System

The lean production system originally was a management approach that inspired from Toyota Production System (Holweg, 2007; Wilson, 2010). Before the term 'Lean' introduced, there are many names, terminology and ideas used to express the approach just in time, well-organised manufacturing system, pull manufacturing approach and world class manufacturing (King, 2009; Doolen and Hacker, 2005; Wilson, 2010; Rahani & al-Ashraf, 2012). However, the main objective all of the term includes lean production system aims to reduce the costs and increase the productivity by eliminating non-value added activities or so called production wastes (Yang et al., 2011; Hosseini Nasab et al., 2012). This will motivate the firms to remain competitive in global competition.

Successful implementation of lean production system has provided more potential for continual improvement. This was proved by eliminating major production wastes such as waiting, over processing, over production, ineffective transportation, poor production line movement, poor arrangement of inventory, and defective parts, the lean production system significantly can enhance productivity improvement (Abdulmalek & Rajgopal, 2007; Aguado et al., 2013). Besides, lean production system allows the firms to identify new continual improvement strategies of practice and eventually reduce the production of defective products (Womack & Jones, 2003). Then, this further increase the firm' potential to shorten the production time in the production line for on-time delivery (Cuatrecasas-Arbos et al., 2011; Sundin et al., 2011). Therefore, the firms will be more responsive and eventually able to adopt the uncertain demand requirement performance (Yang, 2013).

Lean production system has five basic principles: (1) identification of the value of the process, (2) process value stream (3) process flow establishment, (4) pulls factor classification and (5) process perfection (Doolen & Hacker, 2005; Wilson, 2010; Rahani & al-Ashraf, 2012). By having this principle, the firms can effectively strategies production activities and enhance the performance of variability in the supply, processing time or demand (Shah & Ward, 2007). Moreover, the Lean Production System also proved valuable trust for encouraging continuous improvement programmes (Aguado et al., 2013; Powell et al., 2013). It has motivated workers to contribute proactively in improving the production system and performance (McKone et al., 1999). This consequently can improve the ownership of the work, strengthen the team work and thus improve worker self-esteem (Linderman et al., 2006; Holweg, 2007; Holden, 2011).

However, some literatures had proved that the lean production system remains ineffective to the firms, although has been practised especially in the small and medium industry sectors (Demeter & Matyusz, 2011). This is because, the firms were failed to understand the actual concept of lean production system. The firms require a significant framework that helped them to identify the best result of the implementation especially in determining the lean production system tools, techniques, methods and strategies that aligned with operational performance (Vais et al., 2006; Yang, 2013).

2.6 Lean Practices for Assembly Line

The section specifically discusses how each of the prompt indicators identified can motivate the manufacturers to adapt the lean production system or the lean practices in an assembly line.

2.6.1 Shortening Process Time

Shortening process time is a major prompt indicator that drive manufacturers to adapt lean production system. Through literatures, Table 2.1 shows specific parameters for shortening process time. The table illustrates some of the main characteristics of the factor that influence the successfulness of a lean production system. The summary is also based on most preferable terminologies that used in other research work in line with Yusup (2017). There are eight lean practices had been considered in order to improve the lean production system for time based competency. Based on León et al. (2017), the research found that the researcher requires to prepare common terminology which able to understand by all respondents. By using standard terminology, the discussion will become easier and more focused.

Based on Table 2.1, most previous research found that adaptation of new technology is the most popular approach in reducing the processing time. Katayama (2017) expressed that recently firms invested a great deal of capital to buy in technology. The technology may involve material handlings technology, enterprise resource planning, full-automated production system and many more (Khanchanapong, et al., 2014; Sartal et al., 2017). Beside, technology enhances real time data collection while sensor technology able to detect error and defect product as well as Industry 4.0 Technologies (Kolberg & Zühlke, 2015; Mayr et al., 2018).

However, technology requires a high commitment from employee to ensure input or work in progress product is in-place during the production process (Ufua et al., 2018). Technology has the limitation if the firm does not have a proper maintenance system on the particular machine or system (Mostafa et al., 2015; Möldner et al., 2018). Frank et al., (2013) mentioned that there are several types of process depending on manual operation system which sometimes cannot be replaced by technology.

Secondly, decrease customer lead time is determined as one of the main stream for the lean production system (Frank et al., 2013). Kumar et al. (2018) has mentioned that lead time is most preferable measure. This is because; firms had limited space for material storage and strongly encourage just in time supplies parts. Besides, decreasing customer lead time shows the commitment of a manufacturer to promise the delivery time will give more space for other improvement through lean waste elimination. However, firms difficult to define the product value stream in measuring customer lead time (Toivonen & Siitonen, 2016; Romero & Arce, 2017). This happens in a job based operation system (Land et al., 2015). The work in progress products needs to pass through a specific process with a few types of products in a same time due to limitation of the machine or equipment especially for huge manufacturing parts.

Table 2.1 Summary Of The Shortening Process Time Parameters

Researchers	Adaptation of New Technology LP1	Decrease Customer Lead Time LP2	Decrease Throughput Time LP3	Enhanced Product Variety LP4	High Capacity of Innovation LP5	Minimise Setup Time LP6	On Time Delivery LP7	Speed Up Changeover Time LP8
Almomani & Aladeemy (2013)		x	x			x	x	x
Brad et al. (2016)	x	x		x	x			
Browning & Sanders (2012)	x	x		x	x			
Frank et al. (2013)	x	x	x			x		x
Karam et al. 2018)			x			x		
Katayama (2017)	x			x	x	x		
Khanchanapong, et al. (2014)	x			x	x	x		
Kolberg & Zühlke (2015)	x				x			
Koltai & Kalló (2017)			x			x		x
Koltai et al. (2015			x			x		x
Kumar et al. (2018)		x					x	
Land et al. 2015)		x					x	x
León et at. (2017)	x			x	x			
Mashitah Mohamed Esa et al. (2015)						x	x	x
Mayr et al. (2018)	x							
Möldner et al. 2018)	x				x			
Mostafa et al. 2015	x							
Romero & Arce (2017)		x						
Salonitis & Tsinopoulos (2016)				x	x			
Sartal et al. (2017)	x							x
Strandhagen et al. (2018)							x	
Synnes & Welo (2016)				x	x			
Teran-Somohano & Smith (2013)						x		
Toivonen & Siitonen (2016)		x						
Tönissen et al. (2012)			x					
Ufua, et al. (2018)	x							x
Welo & Ringen (2016)				x				
Westkämper (2014)					x			
Wlazlak, et al. (2018)				x				
Yan & Azadegan (2017)				x	x			

Next, decrease throughput time was determined as a third measure for lean production system. The parameter consists of all measurable times, including cycle time (processing time), allow time (break, toilet time), cleaning, set up time, preparation time, rework time, routine maintenance time, and all determined times that's have been declared by the firms (Womack & Jones, 2003).

The difference between decrease customer lead time and throughput time is the number of products. Throughput measures all products involves in the daily process while customer lead time is a specific measure (Koltai & Kalló, 2017). Failure to measure the throughput time will affect most customers and give bad influence on the firm track records. However, Koltai et al. (2015) summarised that not all firms had difficulty to measure the throughput time due to manufacturing complexity, especially involving many type product varieties in daily operation. Although, Tönissen et al. (2012) suggested that if the firms are required to define the throughput time if they wanted to expand the industry.

Yan and Azadegan (2017) stated that firms required new product development strategies to enhance product variety. Product variety refers to the increasing number of products that able to enhance the demand of existing product or product replacement. Firms will receive positive influence by customer by having product variety. On the other hand, it will be able to develop the firm reputation. Welo and Ringen (2016) proved that many new product variety developments had been implemented when firms are successful eliminating the lean waste. This is because, the cost saving from the lean production system implementation improve product variety strategies, including OEM products (Synnes & Welo, 2016; Wlazlak et al., 2018). However, Salonitis and Tsinopoulos (2016) mentioned that not all firms prefer to enhance product variety due to poor management, lack of necessary resources, resistance to change etc.

Lean production system is also empowering the High Capacity of Innovation for both product and process improvement (Brad et al., 2016). Indeed, lean comes from the fact that the design process is structured to reduce ineffectiveness and maximize value. The competitiveness has accelerated the pace of technological developments, increasing the importance of the dynamic production system (Westkämper, 2014).

In addition to managing existing products and services, the firms must incrementally and radically innovate in technology and processes to outpace competition. Furthermore, some studies compare lean and innovation rather than investigating causal interdependencies (Browning & Sanders, 2012). Although the previous studies rather explore the relationship between lean and processes than products, none of them exclusively examines the impacts of lean practices on comprehensively measured process innovation performance (Möldner et al., 2018).

High setup time can be classified as a waste for the firms. Meanwhile, short setup time is an essential element for the effective implementation of many lean pillars, i.e., JIT, and Kanban as well as productivity improvement (Karam et al., 2018). Mashitah Mohamed Esa et al. (2015) stated that minimising setup time can reduce the manufacturing cost and time consuming in production activity.

Teran-Somohano and Smith (2013) stated that firms are preferred to introduce a few categories of working hours (so called tricky time) especially when they require longer set up time for particular machines. The firms required to propose new approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques (Almomani & Aladeemy, 2013).

On time delivery is a critical measure of shortening process time. This is an ultimate goal in implementing a lean production system because most preferable parameter for majority firms align with quality and cost which also related to customer lead time and throughput time performance measures. Strandhagen et al. (2018) stated that most firms are successful in the business when they met delivery deadline. In other research findings, Land et al. (2015) had identified that the customer very concerned about the delivery because most premise does not have enough space for storage the material and had to depend on just in time delivery material. Thus, both manufacturer and supplier must have a mutual agreement to ensure the master production schedule running as per planned.

The last parameter in shortening process time is speeding up changeover time. Changeover time is referred to time to code, change, replace, clean, adjustment and modification for machine, tooling parts, jig and fixture, mould or die exchange, and employee working shift group. Mashitah Mohamed Esa et al. (2015) determined that most of lean production system failures are due to overlooking on changeover time. Firms had spent more time on machine modification while the process interrupts customer lead time (Land et al., 2015). This is because, improper production system with no lean engagement had added waiting time and longer processing time (Yazici, 2015). Therefore, minimizing changeover time is a requirement for lean production system. However, in the different research outcomes, Almomani and Aladeemy (2013) stated that changeover time required highly competent employee to speed up the process.

2.6.2 Man – Machine Use

Table 2.2 shows the summary of man-machine use parameters. The man-machine use can be well-organised when actively adopts the lean production system philosophy in the entire processes. This further provides high opportunities and space for manufacturer to engage in innovation and continuous improvement programme (Aguado et al., 2013; Powell et al., 2013). Through the lean production system, manufacturers can increase the machine availability and extend machine lifespan. Simultaneously, machine downtime due to machine breakdown or setup and changeover can be minimised (Rahani & al-Ashraf, 2012; Teran-Somohano & Smith, 2013).

Therefore, to sum up effective machine optimization is a crucial factor to ensure lean production system success. Katayama (2017) stated that most technology relies on the machine while man is required to confirm the machine effectiveness. Tönissen et al. (2012) mentioned that firms must prepare high knowledgeable man, that is able to understand the machine and optimise the machine use without breakdown and production losses. However, firms had difficulty in determining the machine effectiveness due to the poor production system.

Table 2.2 Summary of Man – Machine Use Parameters

Researchers	Effective Machine Optimization LP9	Increasing Kaizen Activities LP10	Minimising Machine Configuration LP11	Operator Flexibility and Innovativeness LP12	Optimise Poka-Yoke LP13	Proactive TPM Practice LP14	Process Line Balancing LP15
Abdulmalek & Rajgopal (2007)	x	x				x	
Aguado et al. (2013)	x			x			
Barbazza et al. (2017)			x				x
Demeter & Matyusz (2011)	x				x		
Dolgui & Gafarov (2017)	x		x				x
Dombrowski et al. (2012)					x		
Doolen & Hacker (2005)	x	x		x	x		
Ferrer (2003)		x		x			
Hajmohammad et al. (2013)					x		
Katayama (2017)	x			x			
King (2009)		x			x		x
Kojima & Kaplinsky (2004)		x				x	
Kolberg & Zühlke (2015)			x				
Lim & Zhang (2004)						x	
Linderman et al. (2006)		x					x
Losonci et al. (2011)					x		
Mayr et al. (2018)			x				
Möldner et al. (2018)			x			x	
Mura & Dini (2017)				x			x
Powell e.t al. (2013)	x		x			x	
Rahani & al-Ashraf (2012)	x				x		
Raj et al. (2016)							x
Rivera & Frank Chen (2007)						x	
Sáenz et al. (2018)				x			
Shah & Ward (2007)						x	
Stålberg & Fundin (2018)			x				x
Teran-Somohano & Smith (2013)	x			x			
Tönissen et al. (2012)	x				x		
Wei et al. (2017)				x			x
Yang et al. (2011)		x					x

More recently attention has focused on the provision of increasing Kaizen activities (Prashar, 2014). Kaizen is a Japanese word which referred to continuous improvement events. Previous research found that most recent firms are currently applying Kaizen in the most manufacturing activities especially related to man-machine use. Besides, more rewards were given to the Kaizen team when they had improved the process while reduce production cost. On the other hands, the firms provide many incentives to encourage participation of employees in Kaizen project. Successful manufacturers that adopt a lean production system in their manufacturing system also prefer to invest in improving the skill of existing workers to increase their productivity rather than increase the number of workers (Ferrer, 2003; Linderman et al., 2006). This enabled them to have multi skilled and highly competent workers (Kojima & Kaplinsky, 2004). This furthers increase the opportunities to manufacturer the get their workers engaged in Kaizen or continuous improvement in ongoing improvement of all processes (King, 2009; Yang et al., 2011).

There are relatively few historical works in the field of man-machine use. A great and developing body of literature has investigated that minimising machine configuration is currently seen as a new agenda in manufacturing industry as well as the emerging of industrial 4.0 (Kolberg & Zühlke, 2015; Mayr et al., 2018). The technology enhances the application of internet based technology, which aims to reduce the independence of man-machine use. The literature found that man, especially low skilled employee had difficulty to operate the machine (Stålberg & Fundin, 2018). Therefore, minimising machine configuration by applying high technology will bring down the machine errors (Möldner et at., 2018).

Wei et al. (2017) reported that not all firms had enough capital and expertise to invest in high technology. Besides, some of the manufacturing processes rely on manual job operation. Therefore, operators are encouraged to be more flexible, especially in adopting a multitasking job (Mirko et al., 2010). Moreover, they need to be creative and innovative in simplifying the job processing, while contributes ideas for continuous improvement actions. Sáenz et al. (2018) said that operators must have job speciality in a particular job as a survival package in the competitive manufacturing firms.

A willingness to adapt the Poka Yoke or mistake proofing technique in business with current technologies also significantly can reduce the number of workers required (Doolen & Hacker, 2005; Hajmohammad et al., 2013). By employing this strategy, only a few numbers of actors are applied primarily to monitor the overall function of poka yoke systems. This immediately contributes to a substantial decrease of monetary values. Poka yoke also allows many quality issues easily detected, thus improve the character of products produced (Demeter & Matyusz, 2011; Dombrowski et al., 2012). Through poka yoke, worker involvement in dangerous and critical process can be reduced and increase the safety level. This will attract them to engage in the full improvement process and accept the changes made in a more sustainable manner (Losonci et al., 2011).

The function of lean production system principals such as Total Productive Maintenance (TPM) will maximise machines operating time and impact on the productivity, reduction of cycle time and elimination of producing defective products (Shah and Ward, 2007; Rivera and Frank Chen, 2007). Abdulmalek and Rajgopal (2007) claimed that in integrated steel mill sectors, TPM has reduced the total production lead time from 48 to 15 days (reduction of 70 percent). This indicates that the dynamic planning, programming and maintenance of the machine will increase the manufacturing responsiveness. The ability of manufacturer to increase machine availability and reduce the congestion of machine will provide a more serious platform to evaluate the each configuration of manufacturing system (Lim & Zhang, 2004). Mostafa et al. (2015) also reported that firm must provide a lean maintenance roadmap to enhance the TPM implementation.

Process line balancing can be determined as the process to minimize the imbalance between machine and personnel while meeting a required output from the fabrication line (Das et al., 2010). Typically, the goal of this balancing problem is the minimisation of this idle time on this line through the minimization of this wide range of necessary workstations, the minimization of this cycle time, or a mixture of both (Barbazza et al., 2017). The best line balancing shows that the cycle time for each workstation is close to balancing’s line (Dolgui & Gafarov, 2017). The furtherance of the cycle time of a workstation to line balancing will trigger the waiting time in each job between stations. This will be among the issues experienced in balancing line. Well-balanced the line can be disrupted briefly as utilizing the maximum resource in work, gear to lessen the wide range of waiting time between stations for this reason lower the production cost (Raj et al., 2016). In a labour-intensive production process, the task time is uncertain since it depends on the skill of each employee, the work environment, fatigue, etc. In labour-intensive manufacturing processes, the task time is varied then, implementation the Line balancing approach to balance the time taken at each station in the production line by allocating the right number of employees to each station (Mura & Dini, 2017).

The line balancing issue is defined as the grouping regarding the jobs needed to assemble the last product towards the stations that are organized in a serial style and connected collectively by a transportation system (Dolgui & Gafarov, 2017). When the permanent production condition has been achieved, the manufacturing, product flow along the line at a continual price, and every workstation features an equivalent allocated time to complete the particular jobs.

2.6.3 Inventory and Storage Control

As a set of management techniques that well connected with the continuous improvement, the lean production system also proven to offer inventory and storage control practises (Meade et al., 2006; Losonci et al., 2011; Rahani & al-Ashraf, 2012). This involves the acquisitions of raw materials and the production of semi-finished and finished goods (Demeter & Matyusz, 2011). Most firms have a problem when they are unable to deal with the changes in demand. This vulnerability has caused them unable to manage the inventory and storage level in a more effective way when have a sudden change in demand. Sensitivity to this matter will allow to control and reduce the total costs that affect the net profit (Meade et al., 2006). Large inventories not only need to occupy a large space and increase the capital cost, but will also decrease the manufacturers' flexibility to produce products (Sundin et al., 2011). This is because, the production flexibility is important for manufacturers to quickly respond to variations in product demand in a limited market circumstances.

Table 2.3 summaries the inventory and storage control parameters. Effective pace of production based on takt time measures are a major area of interest in lean production system. The uncertainty of customer demand needs critical action by the manufacturers. This is an important signal for firms to make sure that they are able to control the inventory and storage level effectively (Ostlin & Ekholm, 2007). Thus, allow manufacturers to increase the manufacturing efficiency on the right track without bothered by the problem of excess or shortage inventory (Wong et al., 2006). The lean production system techniques such as Andon, Level Scheduling, Kanban and JIT seem can manage inventory and storage control level in each production stage (Ferrer, 2003; Melton, 2005; Cuatrecasas-Arbos et al., 2011). The use of these techniques as a real-time communication tool can bring immediate action to any difficulties faced in the production line (Losonci et al., 2011). This allows the inventory level and overproduction issues are in control (Aguado et al., 2013).

Next, efficient production levelling especially for finished goods was important to secure the firm remains strong in a competitive marketplace environment. This indicates that this trigger signal adopted important for the firm to lead off the lean production system in the manufacturing practices. Most firms that used lean production system as their improvement tools has received a positive influence on their cost saving performance through well managed inventory and storage levels (Meade et al., 2006). Moreover, internal factors such as technological change, demand pattern and new product development may influence the inventory and storage levels streamline (Hosseini Nasab et al., 2012).

Significant with limited space for inventory storage, an organized system for Just-In-Time (JIT) practices is required, particularly for raw materials (Vörös & Rappai, 2016). The organised JIT consists of an effective scheduling system, supplies readiness, temporary storage for specific demand requirement, and dependable material handling system. Cao and Schniederjans (2004) stated that an organised JIT approach required mutual commitment between both firm and suppliers. Besides, customer must recognise the JIT practices in production areas. JIT implications might receive poor feedback from customer during production visit due to limited space for inventories (Green et al., 2014).

Table 2.3 Summary of Inventory and Storage Control Parameters

Researchers	Effective Pace of Production (Takt Time) LP16	Efficient Production Levelling (Finished Goods) LP17	Organized JIT (Raw Material) LP18	Organized Kanban System (WIP) LP19	Zero Missing/Misplace Material LP20	Zero WIP (One Piece Flow) LP21
Aguado et al. (2013)	x	x				x
Cao & Schniederjans (2004)			x		x	
Cuatrecasas-Arbos et al. (2011)	x					
Deif & ElMaraghy (2014b)		x		x		x
Demeter & Matyusz (2011)					x	
Ferrer (2003)	x					
Green et al. (2014)			x			
Hopp & Spearman(2004)				x		
Hosseini Nasab et al. (2012)		x			x	
Junior & Filho (2010)				x		
Li & Rong (2009)	x					x
Lin et al. (2005)		x				x
Losonci et al. (2011)	x					
Meade et al. (2006)		x				
Melton (2005)	x					x
Ostlin & Ekholm (2007)	x	x				
Powell (2018)				x		
Solti et al. (2018)	x				x	
Tregubov & Lane (2015)				x		
Vörös & Rappai (2016)			x			
Wilson (2013)						x
Wong et al. (2006)	x					
Xanthopoulos et al. (2015)				x		
You & Grossmann (2008)		x			x	
Zhang et al. (2012)		x				x

There are many lean tools and techniques that have been applied in firms. However, the most preferable is a Kanban system for inventory management (Hopp & Spearman, 2004). A key aspect of Kanban is to deliver the right material with specific quantity and quality on time (Powell, 2018). Although, the firms have variety type of Kanban types which sometime affected misleading information (Tregubov & Lane, 2015). Xanthopoulos et al. (2015) noted that employees must attend special classes in a Kanban system to avert the above topic. Besides, the firms have to prepare a standard format of Kanban for improvement purpose. All formats, codes, and information must synchronise with manufacturing activities (Junior & Filho, 2010).

Accurate and timely provisioning of supply materials in the production line is essential to avoid missed delivery on time to customers. Cao and Schniederjans (2004) stated that most challenge in inventory and storage control is zero missing/misplace material. Many schemes had been evolved to guarantee no missing part, simply fail to maintain it. According to Demeter and Matyusz (2011), firms that widely apply lean practices have a higher inventory turnover than those that do not rely on lean production. However, there may be significant differences in inventory turnover even among lean practitioners depending on their contingencies. Thus, the factors such as production systems, order types and product types may influence the zero missing/misplace material. In the different standpoint, Solti et al. (2018) found that a problem of current detection methods for misplaced products is their reliance on up-to-date planogram information, which is often missing in practice.

Related to the missing or misplace material, zero work-in-progress (WIP) material was determined a main concern for lean production system (Deif & ElMaraghy, 2014a; 2014b). Wilson (2013) and Lin et al. (2005) identified that WIP is not exclusively the main cause of the process congestion, but shows a signboard for the inadequate production system. Besides, WIP requires more space capacity while exposed to material hazardous. Li and Rong (2009) showed that zero WIP had improved the rate of lead time, particularly in one-piece flow production line.

2.6.4 Workspace Optimisation

Workspace optimisation is determined as a general strategy for inventory flow in production system. Table 2.4 indicates the summary of workspace optimisation parameters. Effective layout configuration was designated as the most influential factor for workspace optimisation. Zijlstra and Mobach (2011) stated that firms are needed to see a production layout in operation system. The layout may consist of man and machine in a line depended on the type of product. Aghazadeh et al. (2011) noted that ineffective layout contributes many productivity issues such as product defect, WIP product, over-production and many more that also linked to lean wastes. Besides, it affected the production pace while hiding the lean waste. Mirko et al. (2010) suggested that the layout must not hide any types of waste because it covers the overhead price. Shigematsu et al. (2018) identified that layout configuration is a timeless challenge for all firms due to technological change, unpredictable demand, and complex working environment. Nevertheless, the firm must determine the best alternative to cope with latest product demand and not fix the facts to improve the layout up-to-date. The commitment of top management and the readiness of all employees to recognise the appropriate solution were the key success factor for effective layout configuration because every change may require additional cost and critical decision making.

On the other hands, an effective layout is significant with material flow and space utilisation (Kang & Chae, 2017). Asef-Vaziri and Kazemi, (2018) mentioned that the movement of material is influenced by the production layout. It consists of the types of material handling, transportation inside the factory. However, Caputo et al. (2015) stated that the material flow must consider occupational safety and health for man, machine and inventories. For space utilisation, Gerald et al. (2004) revealed that the firms are currently having limited space and require them to maximise the facility layout. Mirko et al. (2010) found that to optimise the capacity firms must utilise all work space, including the upper position of building capacity especially small medium enterprise in particular factory lot. Administration office, miscellaneous items store, or light materials were suggested to be placed at upper side while the substantial machine or equipment utilises the ground space. The configuration was a proven arrangement for material flow, including incoming and outgoing material which involved third parties.

Table 2.4 Summary of Workspace Optimisation parameters

Researchers	Effective Layout Configuration LP22	Effective Material Flow LP23	Efficient Space Utilization LP24	Minimise Number of Workstation LP25	Minimum Cost LP26	Product Quality LP27	Simplified Operation Procedure LP28
Aghazadeh et al. (2011)	x			x			x
Aouam & Kumar (2018)					x		
Asef-Vaziri & Kazemi (2018)		x	x				
Bortolotti et al. (2015)	x				x		
Caputo et al. (2015)		x	x				
Fercoq et al. (2016)						x	
Gerald et al. (2004)		x	x		x		
Houshmand & Jamshidnezhad (2006)				x			x
Kang & Chae (2017)		x	x				
Kotzur et al. (2018)					x		
Marhani et al. (2012)							x
Mirko et al. (2010)	x			x			
Mirko et al. (2010)		x	x				
Nyaga et al. (2010)							x
Pe´rez & Sa´nchez (2000)			x		x		x
Shah & Ward (2003)				x			x
Shigematsu et al. (2018)	x				x		
Sodhi & Tang (2013)					x		
Sundin et al., 2011)		x					x
Váncza et al. (2011)	x		x				x
Vörös & Rappai (2016)						x	
Wei et al. (2017)					x		
Zijlstra & Mobach (2011)	x			x	x		

Next, minimising number of workstations was acknowledged a parameter for workspace optimisation. Several methods were identified to minimise the workstation such as multitasking job by employees (Gerald et al., 2004), subcontract item from third party firms (Aouam & Kumar, 2018), the use of automation machinery (Shigematsu et al. 2018), the use of conveyor (Kotzur et al., 2018) and integrated product design (Bortolotti et al., 2015). Wei et al. (2017) mentioned that firms have no specific approach to determine the most effective workstation towards cost effective. However, Sodhi and Tang (2013) summarised that firms have no preference when producing OEM products due to specific process that asked by the customer. Although, the firms can suggest a win-win decision basis when expanding business operation with other customers.

Then, the minimum cost product quality is experienced as a crucial factor for workspace optimisation. Vörös and Rappai (2016) stated that monetary value is the basic measure for workspace utilisation especially cost product quality. As stated by Deif and ElMaraghy (2014a) cost becomes a dominant competitive advantage when there is little scope for differentiating a product. Although price is the external criterion, cost is the internal measure. Therefore, the target of the lean production system is to create a product, which meets given design specification and quality required as well as at a minimum cost. This low cost is necessary to substantiate the cost-sensitivity of the market place, therefore producing the degree of profit margin necessary to sustain the business investment involved and create opportunity for the hereafter. Seeing the product cost, quality structure is not just vital to grasping the process of estimating, but it is also significant in cost reduction efforts (Fercoq et al., 2016).

2.7 Lean Continuous Improvement Strategies

Lean continuous improvement strategy refers to a specific approach to enhance the carrying out of lean practices. The strategy is critical to secure the successful adoption of lean practice that aligned with company lean production system policy (Sanchez & Perez, 2001). The strategic deployment aims to minimise failure of lean production systems, while provides a well-structured method towards productivity improvement. Moreover, limited numbers of studies on lean production system failures are reported, mainly due to the fact that firms wish to protect and not expose their investments that went bad. However, it is an accepted fact that many implementations do fail (Salonitis & Tsinopoulos, 2016). In the few studies found about failing implementations, the common root causes are linked up to lean continuous improvement strategy.

Table 2.5 shows the summary of lean continuous improvement strategies from previous researchers. Based on the table, there are seven main strategies that can be highlighted. Numerous works have attempted to explain that method of improvement is most critical strategy that have been taken by the most lean practitioner. Soriano-Meier et al. (2011) said that the method of improvement involved physical arrangement on man and machine operating procedures. The advances were based on observation, performance records, client feedback, irregular demand pattern and technology change.

Various lines of evidence indicate that firms required to reconsider the method of improvement as the continuous action (Oliveira et al., 2017). It encourages employees to take part and contribute idea for any improvement method through their reflection or working experience. Narayanamurthy and Gurumurthy (2016) showed that by having method of improvement frequently review, the firms had reduced cost consistently. This is because, the firm capable to cultivate the lean strategy where overhead cost and the monetary value of poor quality can be identified regularly (Gonçalves and Salonitis, 2017). This research focuses on how assembly time for one particular activity in operation affects the whole production process.

Data from several studies suggest that other lean continuous improvement strategy is sharing capacity. As noted by Karim and Arif-Uz-Zaman (2013) share capacity is far more cost effective, and therefore is most preferable among lean practitioners. Due to limited man and machine availability in a manufacturing plant, the firm tried to optimise its use by encouraging capacity sharing, especially for project based product and job shop operation system.

Table 2.5 Summary of Lean Continuous Improvement Strategies

Researchers	LS1 Method of improvement	LS2 Share capacity	LS3 Add additional manpower or machine	LS4 Improve workstation layout	LS5 Better operator allocation	LS6 Work for extra hours	LS7 Production time saving tricks
Aghazadeh et al. (2011)	x			x			
Ali & Deif (2014)			x			x	
Ali & Deif (2016)		x	x				x
Aqlan et al. (2014)	x			x			
Das et al. (2010)			x				x
Deif & ElMaraghy (2014a)		x				x	
Fercoq et al. 2016)			x				
Georgiadis & Michaloudis (2012)						x	
Gonçalves & Salonitis (2017)	x			x			
Hopp & Spearman, 2004).					x		
Karim & Arif-Uz-Zaman (2013)		x					x
Koltai & Kalló (2017)				x			
Kuo & Yang, 2007).	x				x		
Li & Liu (2011)				x			
Mashitah Mohamed Esa et al. (2015)				x			
Metternich et al. 2013			x				
Mostafa et al. (2015)		x					x
Narayanamurthy & Gurumurthy (2016)	x			x		x	
Oliveira et al. (2017).	x			x			
Pakdil & Leonard (2014)				x			x
Sáenz et al. (2018)		x			x		
Sanchez & Perez (2001)						x	x
Santos et al. (2015)			x				
Şen & Çınar (2010)					x		x
Song et al. 2006).					x		
Soriano-Meier et al. (2011)	x		x				
Strandhagen et al. 2018).				x	x		
Wei et al. (2017)		x					x
Xanthopoulos et al. (2015)		x					x
Zijlstra & Mobach (2011)				x			x

Besides, there is an unambiguous relationship between share capacity and lean practices. Wei et al. (2017) proved that share capacity had improved productivity with existing equipment and machinery while enhance the cost effectiveness. However, the firms must establish maintenance management system to avoid machine breakdown which interrupted the process lead time (Xanthopoulos et al., 2015; Mostafa et al., 2015). Moreover, it requires the well organised production schedule to avoid process congestion and high volume of unnecessary inventories in the line (Sáenz et al., 2018).

Next, increasing manpower or machine was identified as one of the lean continuous improvement strategy. Previous research has established that increase manpower or machine had positive correlation with firm performance (Metternich et al. 2013). However, it requires additional cost for hiring manpower and procurement of new machines (Fercoq et al., 2016). Santos et al. (2015) said that the strategy has risk because there is no warrant to assure that new man or machine is capable to enhance lean performance. The firms must have specific measures or training to minimise the above risks and ensure the new man or machine are ready to work in standard production pace (Oliveira et al., 2017).

Furthermore, improve workstation layout is also required in lean continuous improvement strategy. Zijlstra and Mobach (2011) stated that the improvement of workstation layout is significant with effective layout. The focus of improvement are to minimise the imbalance between man and machine while meeting a required output from the production line. Aghazadeh et al. (2011) mentioned that improve workstation layout is being one of the important strategies as steps for cost reduction and standardization. Many firms started to re-organise about the production layout to reduce the cost and time, hence growth the number of outputs (Gonçalves & Salonitis, 2017). There are a few things that need to take into consideration such as the number of product, model, the line balance, the automation used in the line, the flow of work piece throughout every station, the complexity of the production environment (Aqlan et al., 2014; Mashitah Mohamed Esa et al., 2015; Koltai & Kalló, 2017). Hence, improving workstation layout is hardly one of the method to make sure that the manufacturing procedure can make the item inside the approximately estimation period time (Liu & Li, 2011).

In the competitive business environment, firms should strive more earnestly to improve productivity (Hopp & Spearman, 2004). Firms supposed to use their resources efficiently. The firms' resources are operators, tools, machines, materials and etc. Hence, managing resources in an effective manner is extremely worthy. More specifically, in labour-intensive manufacturing systems, one of the important tasks in determining the success of the production system's performance is managing operators (Strandhagen et al., 2018). The operator's participation will affect the production systems' performance. The management of the firm needs to make determinations related to operators, in planning, monitoring and controlling the production system (Kuo & Yang, 2007). Operator allocation is related to who and where the operators will be apportioned in the production system (Şen & Çınar, 2010). Operator allocation in a production organization is determined as the allocation of the best operator to each procedure. Therefore, better operator allocation is important for lean continuous improvement strategy (Song et al., 2006).

Working for extra hour or work performed by an employee in excess of a basic work day is a common alternative for lean continuous improvement strategy (Georgiadis & Michaloudis, 2012). The irony comes when an employee is required to figure out additional hours because of some important work (Sanchez & Perez, 2001). In addition to regular work hours, it is not uncommon for employees of some firms to work overtime in order to get all of the work done required for the day. Ideally, both firm and employees do not prefer to opt for extra hours (Deif & ElMaraghy, 2014a). One should also not that there are employees who willingly exceed their limits by pushing the walls of working hours and delivering desired results. There has been some improvement, merely it is minor. The reduction in production costs comes from a reduction in overtime worked by the employees (Ali & Deif, 2014).

Production time saving tricks, offers flexibility in operation working system for lean continuous improvement strategy. It is found along the concept of reducing waste, decreasing costs and improving quality. Sanchez and Perez (2001) stated that when lean methodologies and principles are followed, wasted effort, time and materials are all focused upon and eliminated. In fact, identifying non-productive actions and placing an emphasis on actions that create value is at the essence of lean methodology and lean production system (Karim & Arif-Uz-Zaman, 2013; Pakdil & Leonard, 2014). Therefore, the production time saving trick had considered a required action to enhance lean performance (Ali & Deif, 2016). Besides, it offers flexible trick where there is no specific operation required to perform the job. However, it requires multiskilling employee to ensure the flexible trick in lean strategy (Şen & Çınar, 2010).

2.8 The Critical Issue of Lean Continuous Improvement Strategy for Lean Practices

Oliveira et al. (2017) said that it was necessary to modify the production system of the firms to a new production system based on the detection and elimination of waste. Unfortunately, many firms continued to resist the adoption of this new paradigm of production system, since it was sufficient to look at the high stocks that existed in the firms for raw material, WIP and finished product. The resistance to change was no more than a psychological issue, since the adoption of lean production systems allowed organisations in the short term to improve the resources and eliminate existing change, thereby enabling them to produce the same quantities but with fewer resources. This situation posed a challenge to the top management that could choose to lay off employees or else bet on innovation and create / launch new products / services to the market and keep all existing workforce (Dombrowski et al., 2012; Dolgui et al., 2017).

Shah and Ward (2007) advocated the idea that top management should instill the spirit of teamwork in its employees through a clear focus on lean continuous improvement strategy, in order to create the firm holistic structure for lean practices. On the other hands, the firms should reinforce to employees the importance of identifying the problems and their causes, without this being a reason for delayed accomplishment, but a moment of congratulation because the employee of the company opportunity for improvement in the firms (Womack & Jones, 2003).

From literature, several authors defined lean continuous improvement strategies to help firms to enhance productivity. Among them, the author highlight the work developed by most previous researchers with the presentation of lean practices (LP), which aimed to design the flow of value of a product. The use of LP as a tool for the detection of waste as a support for the implementation of the lean philosophy has reached the most diverse sectors of activity and has contributed to eliminate some outdated concepts. The purpose of this research is to explore the relationship between lean continuous improvement strategy and lean practices. In addition to the productivity improvement, this research intends to show several lean strategies that can be applied in different situations, as well as the wastes that each can eliminate, and the benefits that are obtained from each one.

Moreover, the extent of priority and current achievement of lean practices and lean continuous improvement strategies in the manufacturing industry have not been reported. Despite the extensive efforts that have been established to create the lean production system more reasonable, however, the position of the current achievement of lean practices and lean continuous improvement strategies by Malaysian industry has not been analysed extensively. Moreover, the significance of which lean practices and lean continuous improvement strategies that are important to the Malaysian manufacturing industry has not been reported in the literature. The priority of lean practices and lean continuous improvement strategies might be different for other types of industry, which operate differently due to various combinations of the elements.

2.9 Quality Function Deployment

Quality Function Deployment (QFD) in general can be defined as advanced quality system made up of an integrated set of quality tools and technique to provide customer-driven products and service. QFD was developed in Japan in the late 1960s and early 1970s (Chan & Wu, 2002). QFD is translating customer requirements into the appropriate technical requirements for every stage in product development starting from product design and engineering until marketing strategies and sales. The processes also call the listening to the “voice of the customers” throughout the process of product development for improving the customer satisfaction by developing products/services that deliver more value.

The QFD was first introduced by Akao in 1972 at Mitsubishi’s Kobe shipyard site, and then Toyota and its suppliers developed it further for a rust prevention study. It became increasingly popular in the Western world in the 1980s. Later the concept of QFD was introduced in the US through auto manufacturers and components suppliers, many US firms, such as Procter and Gamble, Raychem, Digital Equipment, Hewlett-Packard, AT&T, GM, and Ford, applied QFD to improving communication, merchandise development, and measurement of processes and systems (Halog et al., 2001).

The QFD process can be summarised, when the customer's requirement was captured; the qualitative customer data will be read and deployed into quantitative technical requirement or quality characteristic in the House of Quality (HOQ) matrix. This method is to match customer requirements to a product's engineering characteristics. The customer requirement will be separated and analysed to measure every stage of the production process in order to ensure that the product satisfies with the need.

Many variations of QFD has been extensively studied recently. It is reviewed in terms of application areas and methodological issues (Leman et al., 2010). According to Akao and Mazur (2003), the functional field of QFD can be grouped in 3 classes, which are: (1) Primary functional field, including QFD usage in product development, customer requirement analysis and quality management system. (2) Secondary functional field, including QFD usage in concurrent engineering, management sciences, preparation, operation research, education, software and expert systems (including artificial intelligence, artificial neural network and fuzzy logic). (3) Tertiary functional field, including QFD's functions such as construction, cost, food, the environment and decision making.

The QFD has originally been developed for product design and manufacturing process enhancement, it can be employed to address virtually any business situation requiring a decision making involving a multitude of criteria, requires or demands (Akao & Mazur, 2003). It has been shown to have significantly more extensive applications such as strategic planning decision, research and evolution planning, vendor and software choice, total quality management action decisions and technical concept selection, software evolution, market expansion analysis, the aim of engineering curricula, and wellness maintenance services. QFD as a well-known method has a large application area within the operational research framework, such as improvement analysis and design process (Killen et al., 2005).

2.9.1 The House of Quality for Lean Production System

In QFD there are tools to define the quality requirement; which is the Planning Matrix, also called 'the House of Quality' (HOQ) refer to the shape house-like (Hauser & Clausing, 1988; Akao & Mazur, 2003). Its aim is to translate important quality requirements regarding product into important end-product control characteristics. The HOQ comprises several different sections or 'Rooms' that are sequentially filled in order to attain an active translation from requirements into features. Figure 2.1 presents an example of a HOQ.

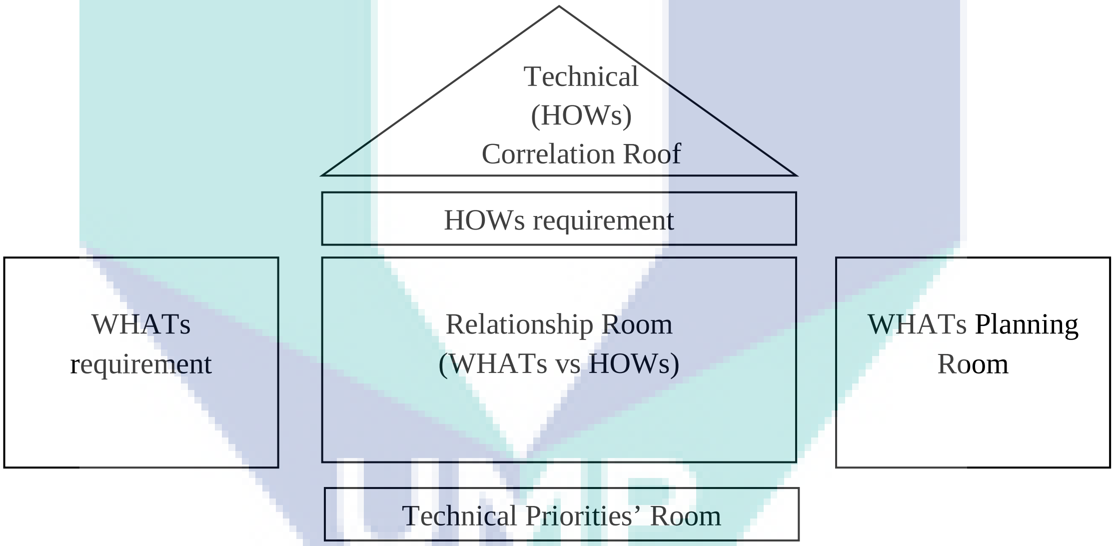


Figure 2.1 The House of Quality Concept
Source: Akao & Mazur (2003)

The first room in HOQ's is about the WHATs requirement. This room contains the structured list of requirements regarding the attributes of the lean practices as the firm describe them (also can be defined as "lean practice requirements", "want" or "what"). This room also contains a measure of the importance requirement that attached by the firm. The WHATs requirements are vague qualitative statements in the firm's own words and loose, such as 'easy to use' (Kumar et al., 2006). The firm had indicated with expected benefit that will be fulfilled by the well-defined lean practices. There were many sources to WHATs requirement such as Kaizen activities, production yields, literature study, market research data, customer complaints, sales data, retailer, opinion surveys, in-depth interview and others.

After the identification of the WHATs requirements, the data were structured and compiled using the appropriate lean practices. The firm can attach the relative importance weightage to each firm requirement based on lean practices this can be defined as the WHATs important rating. In the research, AHP was used to measure the WHATs important rating. The data can help establish priorities in the lean development process and to allocate the necessary resources.

Killen et al. (2005) stated that QFD provides an extended understanding of the improvement strategy to firm. WHATs Planning Room contained the data based on qualitative and quantitative research, what the perception of the customers of the firm leans performance or concept that satisfies on the demand of the customers itself with comparison to other quality practices. Shen et al. (2000) noted that the data was used for benchmarking analysis. WHATs Planning Room also can contain the data on customer complaint, competitor's performance, the firm's performance, the goal and objective of the firm that will not be achieved, improvement ratio (will be calculated based on the firm's current and planned levels), sales target and also weightage of each WHATs requirement. The lean team should receive a readable image of WHAT the customers or firms want from the manufacturing operation, product or concept and how this can be connected to the other lean practices. The team has now to decide how these prerequisites can be integrated into the manufacturing operation so that the customer is satisfied. This is exemplified in the HOQ by the WHAT Room.

Next, the HOWs technical characteristics directly related to the WHATs requirements are listed, that is, the "lean requirements", "quality functions" or "HOWs". They must be measurable parameters that will be used to evaluate objectively the lean practices, since their outputs are going to be controlled and compared with the target values to ensure overall lean continuous improvement strategy (HOWs) requirements are being met. Often these parameters are correlated in a manufacturing operation or product, therefore in the HOWs Correlation Roof; the lean team has to specify their degree of interdependence. This step helps to determine the effects of changing one lean practices (WHATS requirement) on the others attributes, enabling the team to identify and react to synergistic (positive interdependence) or trade-off (negative interdependence) situations. Trade-off situations often point out R&D needs and should always be solved in the way that most favours the customer.

The lean team must now fill the core of the HOQ (the Relationship Room) where the relationships between each WHATs requirement (lean practices) and the HOWs characteristics (lean continuous improvement strategy), as well as their intensity, are depicted. Eleftheriadis et al. (2018) state that a HOQ must able to encourage more firm members to participate. The team seeks consensus on how much each manufacturing operation or product characteristic affects each customer requirement based on their own expertise, customer views or data from statistical surveys and controlled experiments. This widely recognised complex task is another critical phase in the HOQ building process. On one hand, it indicates whether or not the society is adequately addressing the client requirements from a technological point of opinion. On the other hand, it is an important project checkpoint. An empty column indicates either a waste of resources, by showing that there is a HOWs characteristic not satisfying any of the listed WHATs requirements, or missing customer requirements.

The last task in building the HOQ is filling the Technical Priorities Room. It starts with a Technical Competitive Assessment of the WHATs characteristics (lean practices) in currently the manufacturing operations. In this way, the QFD team can view the other approaches achievement and their own lean strategy (HOWs) performance level regarding manufacturing operation characteristics directly affecting lean requirements. Pilot project testing usually provides the information necessary for this assessment, which again should be expressed in measurable terms. For each WHATs characteristic, the comparison between the lean and the other technical performance level is described in a graph. A row indicating the level of organisational difficulty related to realising each WHATs characteristic can also be added.

The Technical Competitive Assessment is then compared with the WHATs Competitive Assessment (WHATs Planning Room). This is practiced to find inconsistencies between how the lean and the other method are evaluating the existing manufacturing operation (Shen et al., 2000). The WHATs and HOWs Competitive Assessments, the Relationship Room and the Firm Importance Ratings all contribute to determine the Target Values or HOW. The Target Values represent, in measurable terms, the level of performance for each WHATs characteristic the firm has to provide in order to maximise customer satisfaction. These performance levels are critical control points to be assessed at each phase of the lean evolution processes. Therefore, the Target Values provide not only an objective means of assessing requirements compliance, but also specific goals for further R&D.

A final Technical Importance Rating for each WHATs characteristic can also be estimated based on the Firm Importance Rating for each requirement and the intensity of the relationships between that character and each WHATs requirement (Relationship Room). These evaluations indicate the comparative importance of each WHATs characteristic in achieving the collective lean requirements. As the absolute values are meaningless, they are often expressed as a percentage. The values are important for the analyser to plan their productivity improvement (Shen et al., 2000).

2.10 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) can be defined as a decision-making method for prioritizing alternatives when multiple criteria or complex criteria must be considered (Hill & Nydick, 1992). AHP has been given to a wide diversity of decisions areas and numerous practical problems (Ramanathan, 2001). The AHP method allows the decision maker to structure complex problems in the form of a hierarchy, or a set of integrated levels. The basic hierarchy contains at least three levels; which is the goals or objectives, the criteria, and the alternatives. Based on the decision maker's judgement the AHP offers a methodology to rank alternative courses of action, relating to the importance of the criteria and the degree to which they are met by each alternative. The problem hierarchy lends itself to an analysis grounded on the impact of a five level on the next higher degree. The process begins by defining the relative importance of the criteria in meeting the goals. The next step is to focus then shifts to measuring the extent to which the alternatives achieve each of the criteria. Finally, the results of the two analyses are synthesized to compute the relative importance of the alternatives in meeting the goal.

An AHP approach is driven by using the managerial judgment (Saaty, 2001). These judgments are expressed in terms of pairwise comparisons of items at a given level of the hierarchy with respect to their impact on the next higher level. In satisfying a goal or a criterion the pairwise comparisons, express the comparative importance of one item versus another item. Each of the pairwise comparisons represent an estimate of the ratio of the weights of the two criteria being compared. The ratio scale for processing, human judgments have been applied to a variety of decision-making problems in other areas, and it has been validated in situations where standard measures already exist. The ratio scale for human judgments will be utilised using AHP. The alternative weights reflect the relative importance of the criteria in achieving the goal of the hierarchy. The flow of AHP step-by-step is summarised in Figure 2.2.

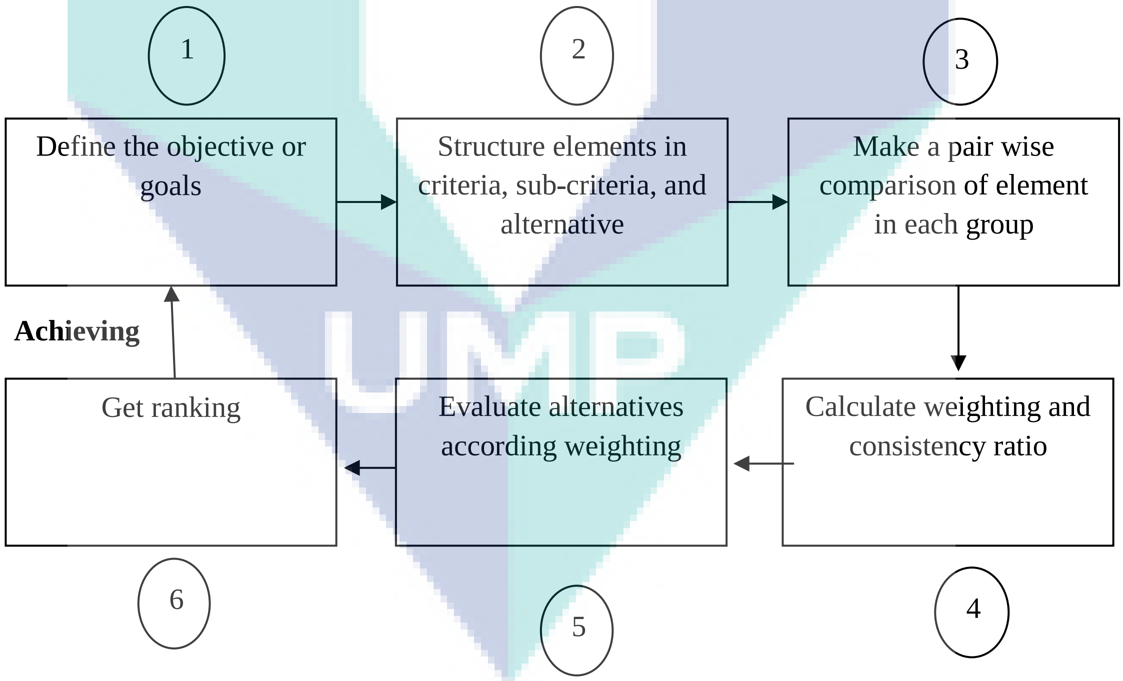


Figure 2.2 The Flow of AHP step-by-step

Source: Saaty (2001)

Hence, to quantify the managerial judgments the standard scale is used for AHP analysis as referred in Table 2.6. For example, if the firm believe that low cost is moderately more important than Takt time, then this judgment is represented by a 3. All criterion comparisons and the alternative comparisons for each criterion need to be judgments.

Table 2.6 Standard scale of AHP analysis

Verbal Judgment or Preference	Numerical Rating
Extremely Preferred	9
Very Strongly Preferred	7
Strongly Preferred	5
Moderately Preferred	3
Equally Preferred	1
The intermediate values of 2, 4, 6, and 8 provide additional levels of discrimination	

Source: Saaty (2001)

The *pairwise comparison matrix* will be representing the pairwise comparison information for each component of the problem. If there are ***n*** items that need to be compared for given matrix, then a total of ***n* (*n*-1)/2** judgements are needed. If n = 4, only six judgements is needed, whereas there are n^2 = 16 cells in the complete matrix. There are two reasons for this apparent savings in the required number of judgments; 1) since any alternative is equally preferred to itself, 1's is placed along the diagonal of the matrix. 2) The corresponding positions below the diagonals are the reciprocals of the judgments already entered. For example, assuming as before that the pairwise comparison between low cost to man machine utilisation is 3, or equivalently a three to one ratio, it follows the pairwise comparison of man machine utilisation of low cost is a one -third or 1/3. Figure 2.3 shows the example of the simple AHP model.

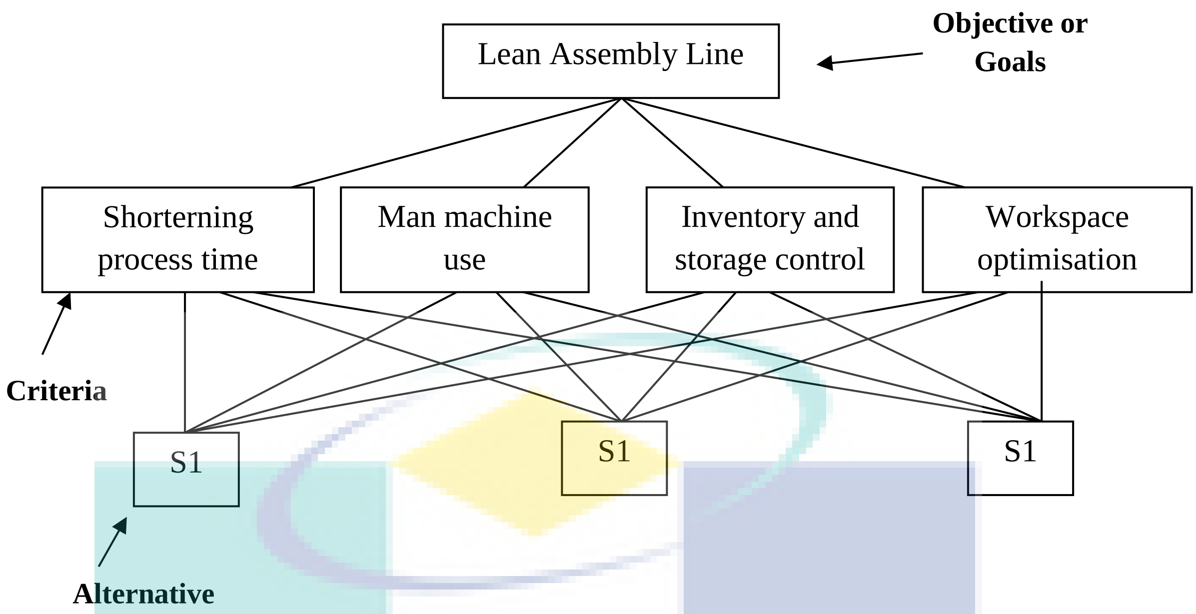


Figure 2.3 Example of Simple AHP Model

2.11 The Significance Application of AHP and QFD for Lean Production System

Because of its multiple factors of the lean practices and lean continuous improvement strategies, the weightage and prioritising of the lean production system are considered as a Multi-Criteria Decision-Making (MCDM) problem, whose AHP is one of its most popular tools (Hadidi & Khater, 2015; Wang et al., 2007). AHP allows decision makers to model complex problem based on mathematics and human psychology that involves structuring criteria into a hierarchy structure similar to a family tree (Gupta et al., 2015; Zaim et al., 2012). It assumes that humans are more capable of making relative rather than absolute judgments, but at the same time allows room for the application of heuristic human reasoning and expertise (Fan et al., 2010).

The AHP decomposes a decision problem into components of different levels. Decomposition is significant in decision analysis as it provides a depth, comprehensive and organised decision-making process. Decision-makers elicit pairwise comparisons, based from their value judgments, of the elements in the same level with respect to an element in higher immediate level (Ocampo & Clark, 2015). The approach is employed for ranking a set of alternatives or for the selection of the best in a set of alternatives. The ranking/selection is done with respect to an overall goal, which is broken down into a set of criteria (Erensal & Albayrak, 2008).

The adoption of AHP helps in structuring the complexity, measurement and synthesis of rankings. These features make it suitable for a wide variety of applications, proven as a theoretically sound and market tested and accepted methodology (Azadeh et al., 2017). It is almost universal adoption as a new paradigm for decision-making coupled with its ease of implementation and understanding constitute its success. More than that, it has proved to be a methodology capable of producing results that agree with perceptions and expectations. In the AHP approach, the decision problem is structured hierarchically in different levels with each level consisting of a finite number of decision elements (Zaim et al., 2012). The upper level of the hierarchy represents the overall goal, while the lower level consists of all possible alternatives. One or more intermediate level embodies the decision criteria and sub-criteria as shown in Figure 2.3.

The application of hybrid AHP and QFD has been reported by other researchers. Abdel-Basset et al. (2018) had performed the AHP for QFD to deal with vague and inconsistent information effectively. Rajesh and Malliga, (2013) integrate AHP and QFD to select suppliers strategically. QFD provides the importance weightings of evaluating criterion, which are derived by the importance ratings of stakeholder requirements together with the relationship weightings between stakeholder requirements and evaluating criterion. Based on the ranked criteria, alternative suppliers are evaluated and compared with each other using AHP again to make an optimal selection in Precision Machined High Pressure Die Casting components firm. Meanwhile, Ho et al. (2012) combines the AHP and QFD approach, to evaluate and select the optimal third-party logistics service providers. In the approach, multiple evaluating criteria are derived from the requirements of company stakeholders using a series of house of quality (HOQ). The importance of evaluating criteria is prioritized with respect to the degree of achieving the stakeholder requirements using fuzzy AHP. The effectiveness of the proposed approach is demonstrated by applying it to a Hong Kong based enterprise that supplies hard disk components. Chadawada et al. (2015) had applied the (AHP)-QFD model to select the best location from a firm point of view which picks the site with the best opportunity requirements. Integration of AHP-QFD process gives us a new approach to assist firms through observing various factors and selecting the best location among different alternatives.

Ho et al. (2012) in his suggestions for future work stated that although the popular approaches can deal with multiple and conflicting criteria, they have not taken into consideration the impact of business objectives and requirements of company stakeholders on the evaluating criteria. In reality, the weightings of “the parameter” evaluating criteria depend a lot on business priorities and strategies. In cases where the weightings are assigned arbitrarily and subjectively without considering the ‘‘voice” of firm stakeholders, the lean practices selected may not provide what the company exactly wants. To enable the ‘‘voice” of firm stakeholders is considered, an integrated analytical approach, combining AHP and QFD, should be developed to select best practices in lean production system strategically (Vinodh et al., 2011; Rajesh & Malliga, 2013).

Definitely, multiple evaluating criteria are derived from the requirements of firm stakeholders using a series of house of quality. The importance of evaluating criteria is prioritised with respect to the degree of achieving the stakeholder requirements using AHP. Based on the ranked criteria, alternative lean practice or lean strategies are evaluated and compared with each other using AHP again to make an optimal selection. Nevertheless, there is a lack of holistic discussion on the development of lean practices and lean continuous improvement strategies especially in determining the best assembly line. So, in this research Lean Hierarchical Function Deployment framework, which integrates the AHP and QFD, is developed.

2.12 Significance of Modelling Simulation for Lean Assembly Line

Many researchers and practitioners had explored the effectiveness as well as the utility of production system to enhance the production productivity through strengthen the assembly line. There are a lot of issues had been rising and until today, redevelopment of the production system is still having a space to improve due to the need and significant role in the industry.

The author had identified that most researchers used to study on demand uncertainty in production line. The researchers used simulation to predict demand uncertainty based on fluctuated order from customers and increasing number of competitors that offer similar products and services. Ashayeri and Lemmes (2006) proved that the value of system dynamic simulation in a real-life setting as an indispensable tool. Reiner and Trcka (2004) initiated that the improvement and simulation model developed to allow further research on the analysis of supply chains and suggest that universally valid statements based on the behaviour of specific supply chains can be quite doubtful. Er and MacCarthy (2006) identified that increasing the level of product variety has a detrimental impact on production line performance. In the presence of supply lead-time and demand uncertainty, high levels of variety result in much longer flow time and much higher system inventory relative to more stable conditions. The impact is greatest when variety involves critical materials which are required early in the production process and entail long set-up times. Krajewski and Ritzman (1999) stated that demand is used as a main key element in calculating the economic order quantity (EOQ) to minimise the total of inventory and ordering costs.

For Wader (2005), managing inventory is one of the essential concerns in the lean production system implementation. The issue of inventory management fascinated some researchers to use simulation in operation research. It is said that the ultimate goal of any effective production system is to reduce inventory (with the assumption that products are available when needed) (Nahmias, 2001). Petrovic (2001) found that uncertainty in customer demand, external supplier reliability and lead times to inventories in a serial production, supply chain (SC) can be effectively described by fuzzy sets. In contrast, the results of Fleisch and Tellkamp (2005) indicate that eliminating inventory inaccuracy can reduce supply chain cost as well as reduce the level of out-of-stock, even if the level of process quality, stolen and unsaleable items remains unchanged. Tannock et al. (2007) suggest that data-driven simulation can be useful to support the design and improvement of supply chains especially in managing inventory.

On the other hand, the researchers used to study the optimizing lead time in operation lines using simulation. Persson and Olhager (2002), identified an alternative supply chain design with respect to quality, lead-times and costs, meanwhile O’kane (2004) studied the impact of adding new machines to the existing layout in optimising lead time. Moreover, the results of the simulation show that the revised process, sheeting by combining paper of all grades with same size to cut at a sheet cutter, gives a better outcome in terms of productivity, cost saving and efficiency, than that of the original process (Kumar & Phrommathed, 2006). The process improvement can be effectively accomplished with an integrated approach of using proposed computer based tools. Nevertheless, Ozbayrak et al. (2007) found that the modelling effort has focused on measuring the production system performance in terms of key metrics such as inventory, WIP levels, backlogged order, and customer satisfaction.

Subsequently, the simulation is able to allocate the operator's assembly operations into a parallel machine-scheduling problem with precedence constraints using the objective of minimizing the workflow among the operators (Rajakumar *et al.*, 2005). It allowed the management to predict if line-balancing strategies such as set-up reduction and parts sequencing would be sufficient, or if more fundamental changes such as the addition of lines or the replacement of machines was required (Greasley, 2004). However, the enlargement of the domain of application and consequently, enrichment of the simulation model by incorporating other types of resources and by considering resource reliability and routing flexibility (Wassim Masmoudi et al., 2006). In addition, the enrichment of the reasoning mechanism by incorporating new knowledge acquired from sets of planning simulations and investigation of the approach robustness and applicability in various scenarios.

2.13 Theoretical Framework

Based on extensive review of the prior research related to Lean Practices (LP) and Lean Continuous Improvement Strategy (LS), the implementation of LP and LS were seen offers a wide range of benefits for achieving long-term organisational in improving an assembly line. Thus, in this research, as shown in the Figure 2.4, the research was anchored on two parameters, namely looking at the LP and LS. The parameters were measured by descriptive analysis for priority and current achievement (as suggested by Abdullah 2018) among lean companies. Then, the analysis was carried out using gap analysis and correlation test. The results from empirical study were used for hybrid analysis using AHP and QFD. For validation analysis, both observation and modelling simulation were considered. The detail explanation for this validation can be seen in Chapter 3.

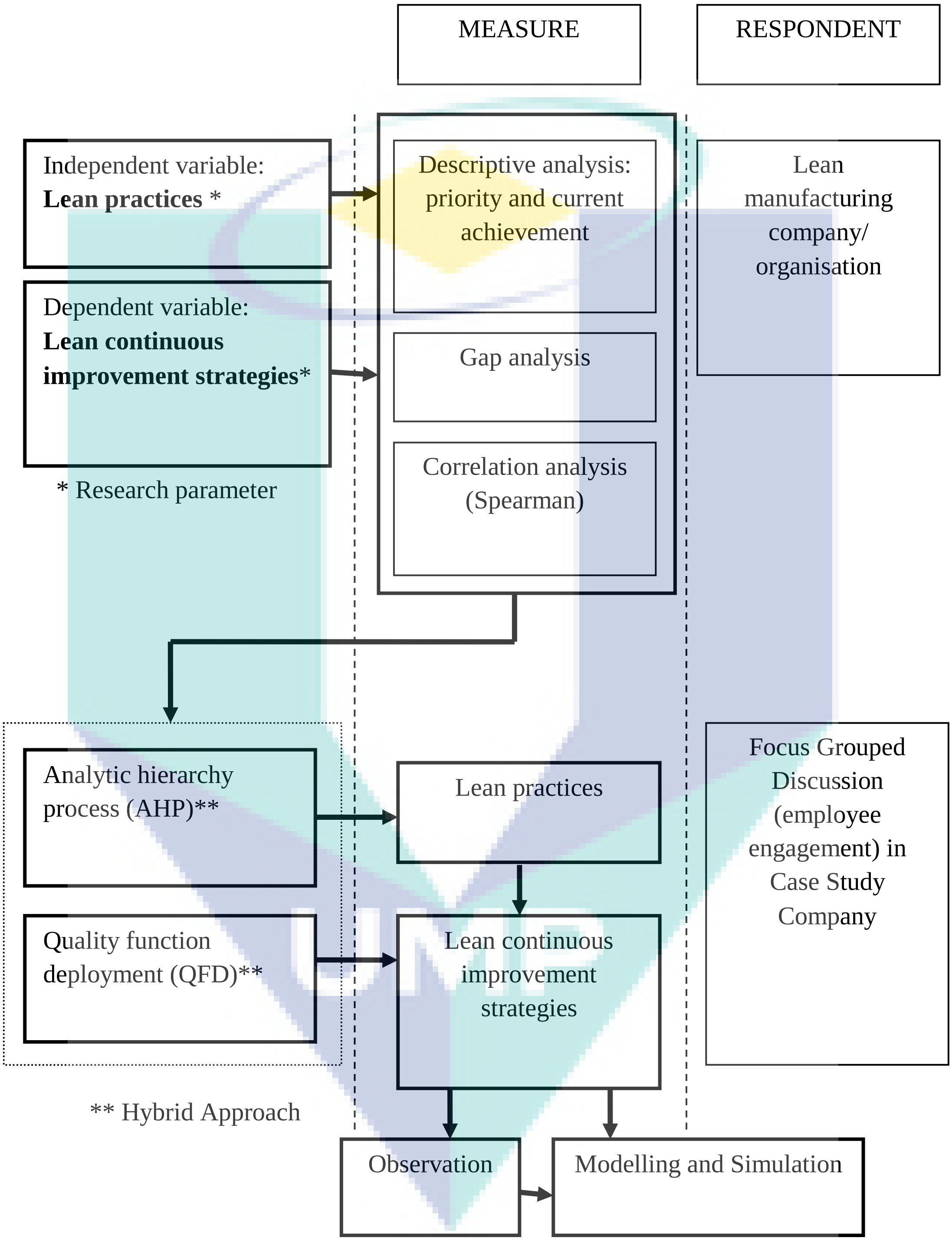


Figure 2.4 Research Theoretical Framework

2.14 Development of Conceptual framework for Lean Hierarchical Function Deployment

The Lean Hierarchical Function Deployment framework was based on AHP and QFD; where AHP was originally developed for making the decision making for the complex problem; while QFD was developed for the design of process and development. This lean hierarchical function deployment methodology was focused and elaborates more on the extended AHP and QFD used for finding the relation between lean assembly line and lean continuous improvement strategies. One manufacturing company was selected. Due to confidential issue, the company was named as ABC company. It was established on 21st December 1990 and the first audio and video company in South East Asia outside Japan. Continuous improvement and emphasis on quality has resulted in realising the company vision to establish their very own research and development (R&D) or also known as Asia Pasific Development Center, APDC (M) on 3rd April 1997. This established marks a new era of technology development and innovation in Malaysia's Audio Visual Industry, showing company commitment towards realising the Malaysia's vision of becoming a fully industrialised nation by the year 2020.

Figure 2.5 shows the conceptual model for lean hierarchical function deployment. The processes start with the findings the correlation of the main element of lean assembly specific criteria in ABC company and summarise it into the sub - element base on literature review related to the main element. Besides, the conceptual model had been referred to expert panels whose identify as in APPENDIX C. The weighting of criteria and sub-criteria for lean assembly line and sub-element of lean continuous improvement strategies is determined using AHP analysis. The AHP analysis was combined with QFD analysis; where the sub-criteria of lean practices are the WHATs requirement while sub-element of lean continuous improvement strategies represent as HOWs requirement. The result was compiled as a lean assembly line checklist for a guide and reference to other companies. The result was then validated and modelling simulation with ARENA was performed to provide better insight of the deployment.

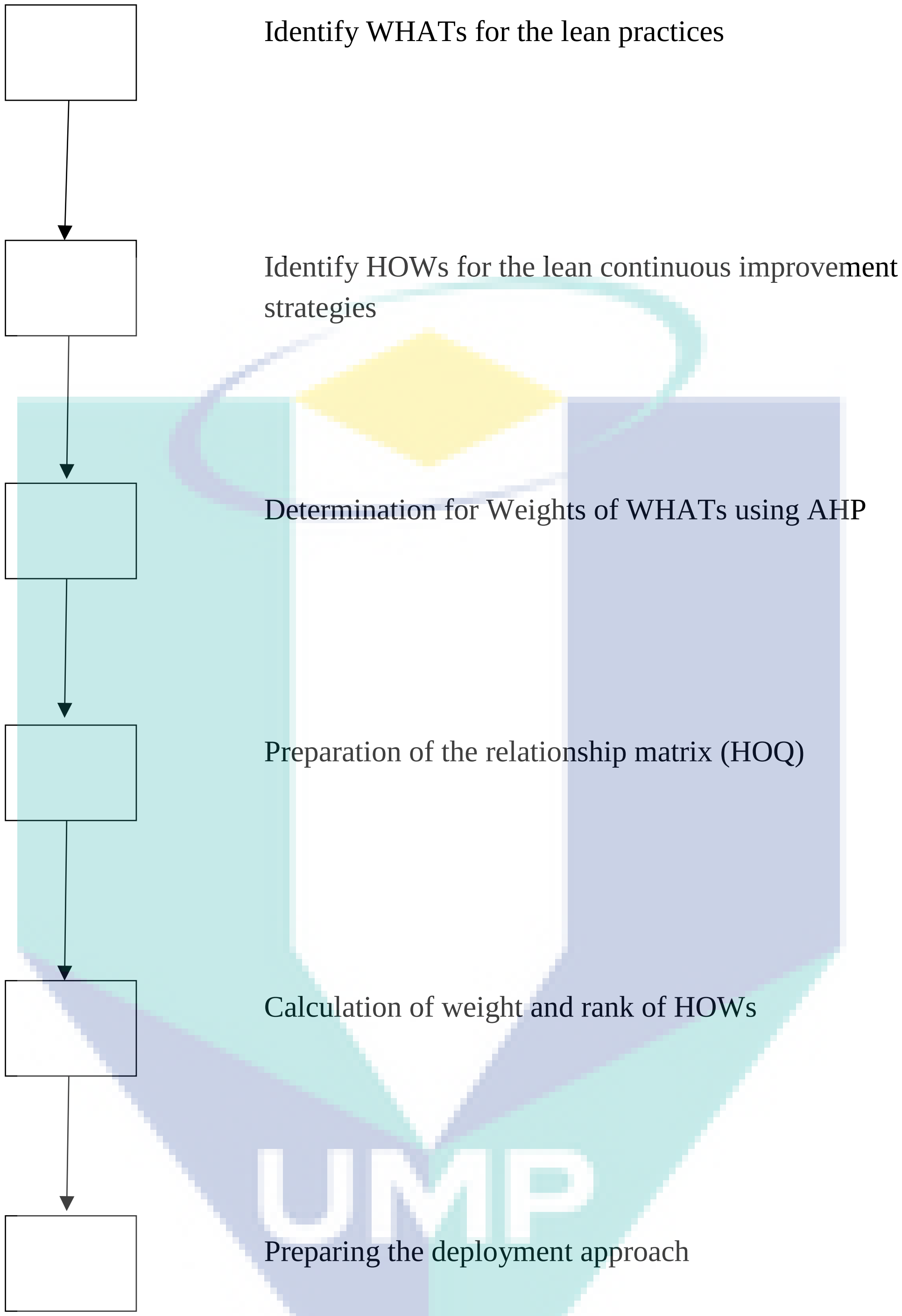


Figure 2.5 Conceptual Model for Lean Hierarchical Function Deployment

2.14.1 Identify WHATs for the Lean Practices

The starting phase involved preparing the sited visit (*Gemba*) and observation the targeted assembly line in ABC company. Based on a literature review about lean practices from previous journal, the observation, discussion and semi-structured interview has been done over a period of half months for collecting the data that related to manufacturing activities. The researchers gain the knowledge, especially in assembling process and activities that conclude the overall process starting from receiving material, material preparation, material handling, transportation, workstation design, buffer, man-machine use, work study, assembly operation, inspection and packaging.

The main criteria for lean practices were divided into four categories; shortening process time, man and machine use, inventory and storage control and workspace optimisation with contain the sub-criteria for each category. The lean assembly line criteria were adopted from lean practices in survey results analysis will be represented as customers' requirement (WHAT matrix) in QFD analysis. All 28 items in lean practices were considered because the mean score of the current achievement is over than 3.0 to show that most of the respondents were agreed with the list of the lean practices.

The data obtained were analysed using a combination of AHP and QFD. The process began with identifying the decision making using AHP. For execution phase, small focus group discussion was formed (as Mahmood, 2012; Yusup, 2017) which consists of a production assistant manager, lean manager, production executive, project leader and two operators. This small group was represented the assembly line for a consensus decision of data in AHP and QFD. Besides, they were involved in time observation, company standard time calculation and idea for improvement which encompasses specific production procedures. Each weightage of criteria and sub criteria in lean assembly line was calculated using matrix concepts.

2.14.2 Identify HOWs for the Lean Continuous Improvement Strategies

The process to identify the HOWs for the lean continuous improvement strategies was similar to WHATs requirement. These two data; criteria and elements of an assembly line is important to identify the correlation in the QFD analysis with representing WHAT and HOW matrix. All seven parameters were derived from the literature review and semi-structured interview. The survey analysis was shown that all the parameters were significantly correlated. There were seven elements of lean continuous improvement strategies that related to lean assembly line, namely the method of improvement, share capacity, add additional manpower or machine, improve workstation layout, better operator allocation, work for extra hours and use them for saving tricks.

2.14.3 Determination for Weights of WHATs using AHP

The process began by defining the relative importance of the criteria in meeting the goals. The next step was to focus then shifts to measuring the extent to which the alternatives achieve each of the criteria. Finally, the results of the two analyses were synthesized to compute the relative importance of the alternatives in meeting the goal (see Figure 2.4 for AHP process).

AHP analysis was used in making a decision for prioritising alternatives in considering the complex criteria. Therefore, the objective of this analysis was to define the weightage of lean assembly line criteria to identify the priority of each criteria and alternatives.

The structural elements of lean assembly line were based on criteria for lean practices. A total of four main criteria was categorised for lean practices in the development of the model: Shortening Process Time (SPT), Man and Machine Use (MMU), Inventory and Storage Control (ISC) and Workspace Optimisation (WO). Each of the sub-criteria that was defined and been categorising based on three main criteria as shown in Table 2.7. Figure 2.6 shows the AHP of this research starting from objective, criteria, sub- criteria and alternative.

Table 2.7 The list of criteria and sub criteria of lean assembly line

Abbreviation	Criteria
SPT	**Shortening Process Time**
LP1	Adaptation of New Technology
LP2	Decrease Customer Lead Time
LP3	Decrease Throughput Time
LP4	Enhanced Product Variety
LP5	High Capacity of Innovation
LP6	Minimise Setup Time
LP7	On Time Delivery
LP8	Speed Up Changeover Time
MMU	**Man and Machine Use**
LP9	Effective Machine Optimization
LP10	Increasing Kaizen Activities
LP11	Minimise Machine Configuration
LP12	Operator Flexibility and Innovativeness
LP13	Optimise Poka-Yoke
LP14	Proactive TPM Practice
LP15	Process Line Balancing
ISC	**Inventory and Storage Control**
LP16	Effective Pace of Production(Takt Time)
LP17	Efficient Production Levelling (Finished Goods)
LP18	Organized JIT (Raw Material)
LP19	Organized Kanban System (WIP)
LP20	Zero Missing/Misplace Material
LP21	Zero WIP (One Piece Flow)
WO	**Workspace Optimisation**
LP22	Effective Layout Configuration
LP23	Effective Material Flow
LP24	Efficient Space Utilization
LP25	Minimise Number Of Workstation
LP26	Minimum Cost
LP27	Product Quality
LP28	Simplified Operation Procedure

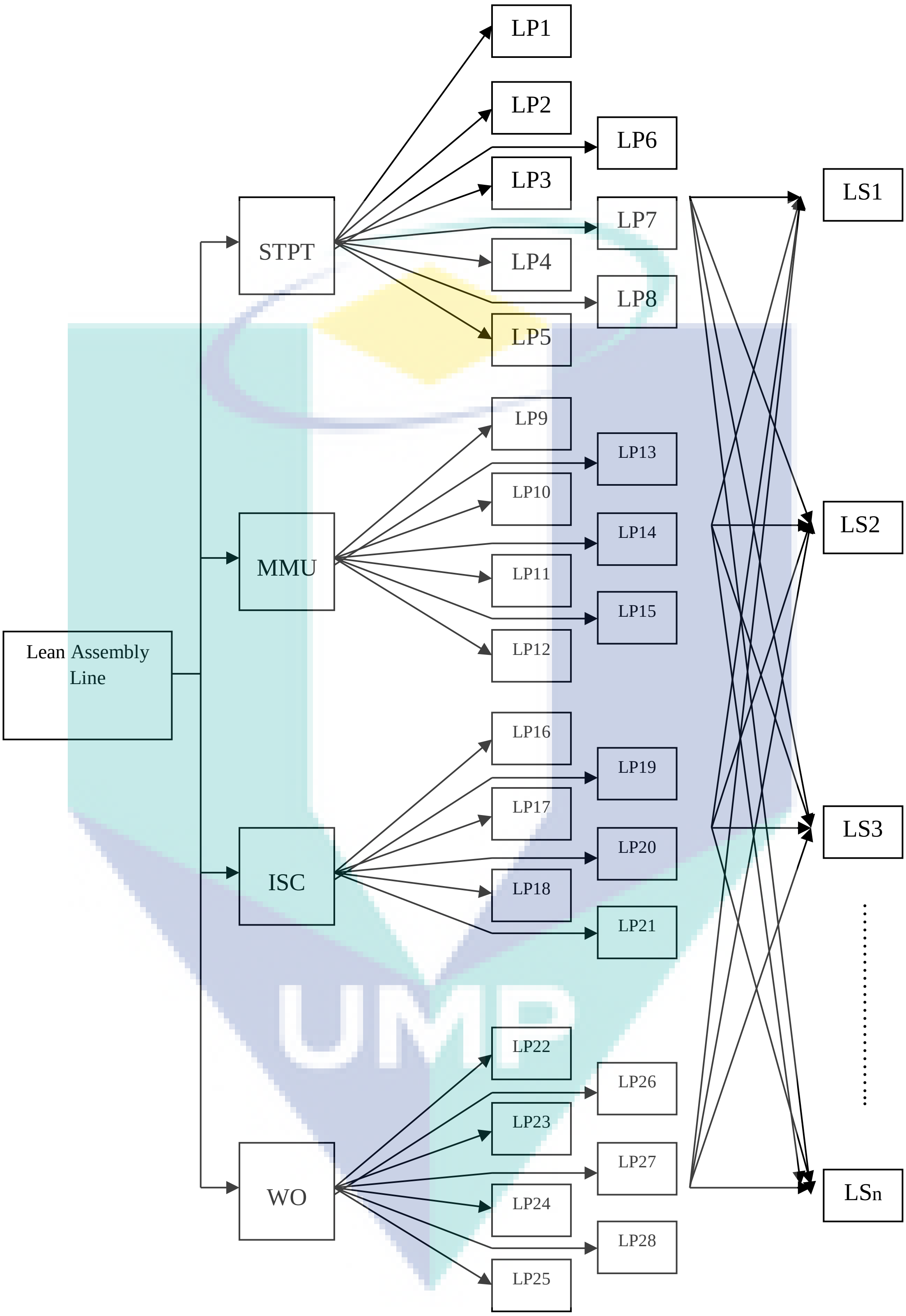


Figure 2.6 Category of each criteria, sub-criteria and alternative in AHP

In order to define the weightage of each element the pairwise comparison was used in AHP analysis. The main aim of the pairwise comparison method in the AHP was to make a ranking of the given factors or alternatives. To compare the factors often a scale {1/9,1/8,…,1/2,1,2,…,8,9} was used. The criteria and dimension with the highest priority value was construed as having the greatest degree of importance in influencing the strategic objectives and vice-versa. The example of calculation and step was shown in a pairwise comparison matrix for main criteria of lean assembly line.

<u>Step 1</u>

i. Pairwise comparison for main criteria of lean assembly line using scale {1/9,1/8,…,1/2,1,2,…,8,9} as shown in Table 2.8.

Table 2.8 Scale for Pairwise Comparison

Degree of Preference	Definition
1	Equally preferred
3	Moderately preferred
5	Strongly preferred
7	Very strongly preferred
9	Extremely preferred
2,4,6,8	Intermediate preferences between the two adjacent judgements

ii. So, the data were converted into a pair wise comparison matrix as shown in Table 2.9. The concept of pairwise comparison; if A is x times more preferred that B, then B is $1/x$.

Table 2.9 Pairwise comparison matrix for each main criteria of lean assembly line

	SPT	MMU	ISC	WO
SPT	1.00	1.00	1.00	1.00
MMU	1.00	1.00	1.00	2.00
ISC	1.00	1.00	1.00	1.00
WO	1.00	0.50	1.00	1.00
SUM	4.00	3.50	4.00	5.00

Step 2

i. The next step was to calculate the Eigenvector (weightage, W_i) for each main criteria of the Lean Assembly Line. In order to calculate the weight value (W_i), each of the matrixes in *j*, *row* must divide by no. of T_j. In this example: 1/2 = 0.50.

ii. Then calculate the value of T_i

$$T_i = \sum_{j=1}^{n} a_{ij} \qquad 2.1$$

iii. Then calculate the value of W_i

$$W_i = T_i/n \qquad 2.2$$

The Value of T_i and W_i will be show in Table 3.8.

Table 2.10 The Value of T_i and W_i for Lean Assembly Line

A_{ij} / T_j	SPT	MMU	ISC	WO
SPT	0.250	0.286	0.250	0.200
MMU	0.250	0.286	0.250	0.400
ISC	0.250	0.286	0.250	0.200
WO	0.250	0.143	0.250	0.200

	T	W	AW	AW/T	λ_{max}	RI	CI	CR
SPT	0.986	0.246	0.986	1.000	4.125	0.900	0.042	4.630
MMU	1.186	0.296	1.482	1.250				
ISC	0.986	0.246	0.986	1.000				
WO	0.843	0.211	0.738	0.875				

Step 3

i. In step 3, the Eigenvalue (lambda max, λ_{max}) based on Equation 2.3 was calculated.

$$\lambda_{max} = \sum_{i}^{n} \frac{(AW)_i}{n \times W_i} \qquad 2.3$$

$$AW_i = \overbrace{\begin{bmatrix} 1.00 & 1.00 & 1.00 & 1.00 \\ 1.00 & 1.00 & 1.00 & 2.00 \\ 1.00 & 1.00 & 1.00 & 1.00 \\ 1.00 & 0.50 & 1.00 & 1.00 \end{bmatrix}}^{A} \overbrace{\begin{bmatrix} 0.246 \\ 0.296 \\ 0.246 \\ 0.211 \end{bmatrix}}^{W_i} = \begin{bmatrix} 0.986 \\ 1.482 \\ 0.986 \\ 0.738 \end{bmatrix}$$

$$n \times W_i = 4 \times \begin{bmatrix} 0.246 \\ 0.296 \\ 0.246 \\ 0.211 \end{bmatrix} = \begin{bmatrix} 0.986 \\ 1.186 \\ 0.986 \\ 0.843 \end{bmatrix}$$

So,

$$\lambda_{max} = \frac{0.986}{0.986} + \frac{1.482}{1.186} + \frac{0.986}{0.986} + \frac{0.738}{0.843} = 4.630$$

Step 4

For checking the Consistency of Judgments Decision makers are rarely consistent in their judgments with respect to qualitative issues. A consistency ratio (CR) is driven from the ratio of the consistency of the results being tested to the consistency of the same problem evaluated with random numbers. The formula to define the CR as stated below:

$$CR = \frac{CI}{RI} \times 100 \qquad 2.4$$

Where, CI is consistency index and RI is random index. CI and RI can be defined as:

$$CI = (\lambda\ max - n) / (n - 1) \qquad 2.5$$

For RI:

Table 2.11 Values of RI for different matrix sizes, n

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty (2001)

Where, n represents the dimension of the matrix and for acceptable results; example pairwise comparison is consistent; CR should be less than 0.10 (10%).

$$CI = (4.13 - 4) / (4 - 1)$$
$$CI = 0.04$$
$$CR = 0.04 / 0.90$$
$$CR = 4.63\ \%$$

Since CR is less than 10%, the judgments have been consistent.

In order to measure overall weightage, each of the sub-criteria weight must be multiplied by the weight of the main criteria for each category. Refer to overall weightage; each of sub-criteria was given a ranking. The calculation was as per equation 2.5. Saaty (2001) stated that the ranking system was the final step in AHP. Saedin (2017) mentioned that the rank helped the author to make a decision. In line with Abdullah (2018), the higher three were considered main criteria for each parameter subset. Meanwhile, Hasan (2015) stated that the parameter could be based on specific limit. Thus, the research was used both highest three as the considerations in the ranking system. This is because, only the best items are chosen for further discussion in QFD analysis (Saedin, 2017).

$$\text{Overall } W_i \text{ for each category} = W_i \text{ of Main criteria} \times W_i \text{ of each sub-criteria} \qquad 2.6$$

Sample of calculation for Overall W_i for LP1

Overall $W_i = 0.25 \times 0.16 = 0.04$

2.14.4 Preparation of the Relationship Matrix

The objective of the methodology to be developed in the present work was to adapt the approach of QFD in the definition and specification of a class of advanced production system (Besterfield, 2009). The QFD approach was developed as an advance quality system made up of an integrated set of quality tools and techniques to provide customer-driven product and service (Akao & Mazur, 2003). For this research, the two principal aspects in QFD focused on:

i. WHAT was required to satisfy the lean production system (the lean practices requirements), and
ii. HOW important were things to the firms (the relative importance for Lean continuous improvement strategies)

QFD applies its tools and techniques in improving the product, and to the process of product development (and services). The procedures inherent in the approach allow trade-offs to be made on parameters that affect the objective of meeting the lean production system requirements.

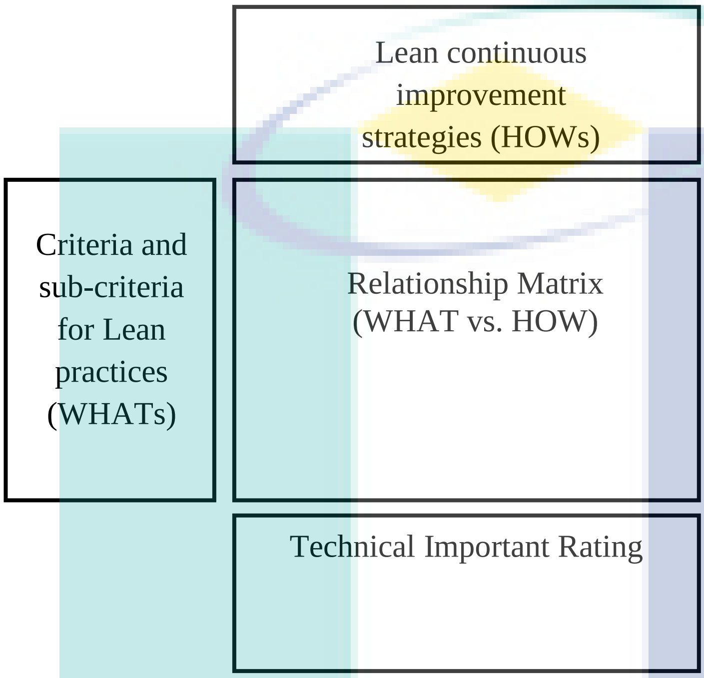


Figure 2.7 Four Rooms in Development of House of Quality (HOQ)
Source: Akao & Mazur (2003)

The relationship between WHATs and HOWs was determined in relationship matrix box with the intersection of the WHATs row and the HOWs column. Depending on the degree of contribution for the element of Lean continuous improvement strategies towards achieving the criteria of lean practices; the relationship between WHATs and a HOWs is being categorized as “strong”, “medium”, “weak or no” relationship value to each specific WHATs and HOWs pairing (as suggested by Akao and Mazur, 2003; Killen et al. 2005). For this an appropriate scale is three (9-3-1); which mean 9 represent strong relationship, 3 represent medium relationship and 1 represent the weak relationship was applied.

This stage was one of the key elements of the QFD method because it was the one which permits the transition to be made between what the criteria of lean practices and element of lean continuous improvement strategies. In determining the strength of the relationships between HOWs and WHATs, the judgment has to be based on the extent to which the element of lean continuous improvement strategies can impact the criteria of lean practices.

2.14.5 Calculation of Weight and Rank of HOWs

The technical important rating room was used to evaluate the HOWs ratings. These were the combination of the degree of priority for the firm requirement (HOWs room) and the strength of the relationship between the criteria of lean practices and lean continuous improvement strategies. The technical important ratings were expressed in two ways in the planning matrix; which was Actual value and Relative value (Besterfield, 2009).

The actual value of importance rating =

∑ [(Weightage of WHAT's) × (Strength of WHAT' vs. HOW's)] 2.7

Relative value of importance rating =

(Actual value of importance rating / Total value of importance rating) ×100 2.8

The actual value was the numerical value calculated using the formula and it did not have any significance in so far as indicating the degree or importance of the HOWs. Thus the relative values were used in determining what degree of importance each of the HOWs had. The HOWs element was ranked after getting the value of relative importance of HOWs.

The rank scale of 5-4-3-2-1 was used, where 5 represent the most importance option and 1 the least important. The need to introduce the rank at this stage was that not all of the HOWs were deployed, whereas the value of the Actual values and the relative important were calculated for all the options. Rank value was used as it gave a more meaningful degree of relative importance of the HOWs, as compared to the percentage of the relative importance. The formula to determine the Rank was suggested by Besterfield (2009) as;

Rank =

(Value of relative importance × 5) / maximum value of relative importance 2.9

The sample of calculation LS3 for Actual importance, relative importance and rank:

Actual importance =	$\sum$ [(0.038 ×3) + (0.068 × 3) + (0.033 × 3)]
	= *0.417*
Relative importance	= (*0.417* / 11.056) × 100
	= *0.038 × 100*
	= *3.8 ~ 4.0*
Rank	= *(4 × 5)/30*
	= *0.67 OR Approximately 1 #*

2.14.6 Preparing the Deployment Approach

In this research, the deployment approach was based on modelling and simulation analysis. The reason why simulation in industry growth rapidly because of the improvement of simulation based software has reduced the model developed time. It was used many times in doing analyses of a production line or a value stream operation line (Mat Tahar, 1999; Mahmood, 2012; Razik, 2015; Yusup, 2017). The easy guidance on simulation software provides benefit to the designer to model the production line. The simulator also supports a unique, easy-to-learn modelling language, methods, algorithm in models. For the research, ARENA software was chosen for modelling simulation analysis. ARENA software represents the advancement of technology in modelling and simulation. It is an interactive yet comprehensive system that enables an input data to be analysed. Arena is a one-step, graphical modelling and animation system that's according to ideas from object-oriented development and hierarchical modelling.

ARENA is an interactive visual simulation program, which sees the world of manufacturing component and element in different ways (Kelton et al., 2007). The ARENA provides an integrated framework for building simulation models in a wide variety of applications. An entire simulation project may be completed within the Arena system. The basic concept of Arena system was use of blocks and these are the different types of blocks represent each the process used during simulation: create, queue, seize, delay, release, count dispose, group, splits assign, branch. There was flowed in making the analysis using the Arena software system which is an input data analysis, model building, interactive execution, animation, execution tracing, model verification and output analysis. All those things were the main element and necessary item need to complete the simulation system (Mat Tahar, 1999).

Model windows are where all the editing of blocks before the simulation process takes place. A new model was created, existing model was modified here, animation was developed and the model was executed, all the process were done in the model window. A model was developed in model window by attaching the entire template and selects required blocks and place in the model window. All of the form in the model window were then interconnected with each other to form a flow of process and a modelling was constructed and created and the existing model was modified.

The study involved observation, group discussion, real-time study and action research on the selected countermeasure was performed in fastest way. Figure 2.8 shows the layout of the selected assembly line. The assembly line performed the assembly in two different types of products where both products were assembled at different assembly line at the inspection station. Both of the products were paired together, Product X going through nine workstations (WS1 – WS9), five inspection stations (WS10 – WS14) and adopted by another four sub-assembly workstations (WS15 – WS18) meanwhile Product Y was going through of three workstations (WS 19 –WS21) and one inspection station (WS22). Both products were paired (WS23) and inspected for final checking (WS24 – WS25) before entering the packaging station (WS26).

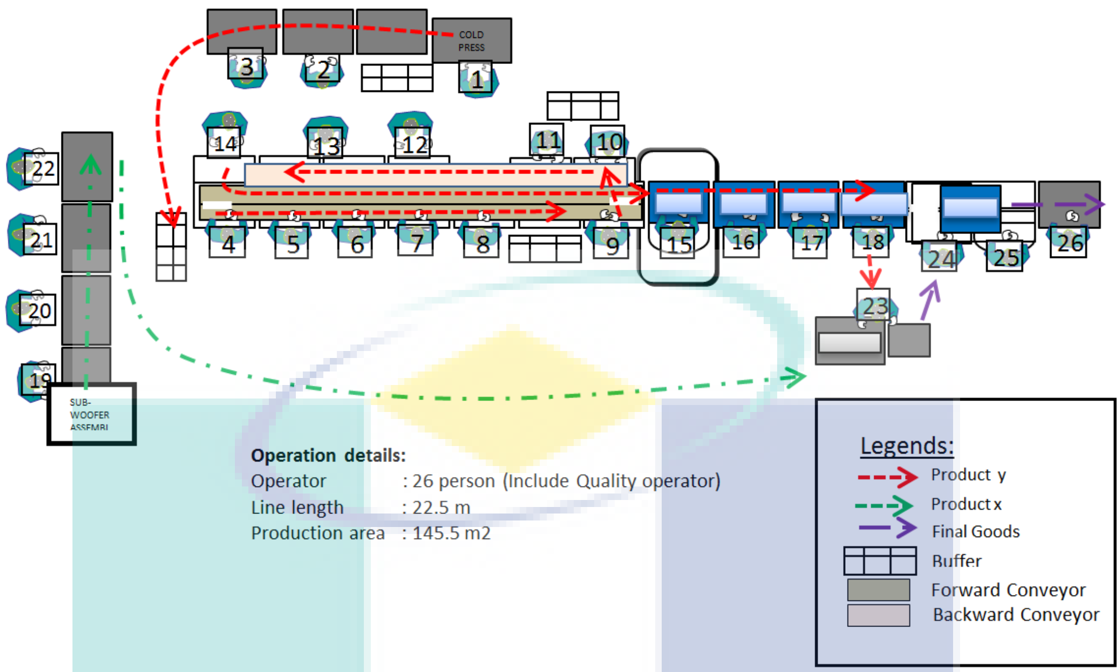


Figure 2.8 General Layout of an Assembly Line

Source: ABC Company (2017)

Table 2.12 shows the mean cycle time (from time study) and the distribution coefficient, which had been analysed by Input Analyser. The Input Analyser is a standard component provided in the ARENA software. The function of the input analyser itself is to identify the quality of fits of the distribution function of the input data station. The data shows the results from the histogram function analysis that allows the comparison of the histogram distribution and show the effect of the changes in parameter on the same distribution (see APPENDIX E).

Based on the trials data of each station, the input analyser was made to show the changes of the parameter in each of the stations between the distributions, the statistic test of the chart. Trial of data was important to the input analyser, because the more the trials, the better distribution would be.

Total lead time for the single fairing product was 2218.1 seconds and required 443,620 seconds or 7393.67 minutes to complete 200 unit daily demands.

Table 2.12 Cycle Time Distribution Analysis

Workstation	Mean (in second)	CT Distribution*	Square Errors
WS1	75.8	75.1 + 1.45 * BETA(1.43, 1.63)	0.018
WS2	85.7	84 + 2.96 * BETA(1.17, 0.951)	0.019
WS3	176.0	TRIA(173, 176, 177)	0.101
WS4	146.0	143 + 5.72 * BETA(1.07, 0.9)	0.056
WS5	88.5	85 + 6 * BETA(0.991, 0.708)	0.008
WS6	83.8	82.1 + LOGN(1.75, 1.44)	0.012
WS7	112.0	110 + LOGN(1.93, 1.3)	0.019
WS8	113.0	109 + 7 * BETA(0.893, 0.848)	0.057
WS9	86.3	TRIA(83.1, 87.1, 88.8)	0.013
WS10	69.1	66 + 5 * BETA(0.835, 0.525)	0.044
WS11	71.8	TRIA(70.3, 70.6, 74.5)	0.005
WS12	88.6	85 + 6 * BETA(1.1, 0.777)	0.023
WS13	75.5	UNIF(73, 78)	0.020
WS14	85.1	NORM(85.1, 1.39)	0.028
WS15	73.1	71 + GAMM(0.989, 2.11)	0.047
WS16	82.2	UNIF(80, 84)	0.080
WS17	86.7	TRIA(83.2, 88, 89)	0.051
WS18	58.6	56.3 + LOGN(2.45, 1.83)	0.062
WS19	62.4	58.1 + 6.84 * BETA(1.86, 1.18)	0.062
WS20	88.6	85 + ERLA(1.79, 2)	0.041
WS21	70.4	TRIA(68, 70.4, 73)	0.090
WS22	84.3	83.1 + 2.53 * BETA(1.3, 1.45)	0.007
WS23	80.9	79.6 + ERLA(0.41, 3)	0.018
WS24	62.3	NORM(62.3, 0.659)	0.014
WS25	41.7	TRIA(40.7, 41.2, 43.3)	0.030
WS26	69.7	64 + 8 * BETA(0.646, 0.347)	0.044
Lead time (per product)	2218.1		

NOTE: * The details of work study result can be seen in APPENDIX E.

2.15 Summary

This chapter discusses the fundamental approach in defining the concept for assembly line, facility planning, production layout, lean production system, lean practices for assembly line, lean continuous improvement strategies, quality function deployment, and analytic hierarchy process. Besides, all critical reasons such as the issue of lean continuous improvement strategy for lean practices, significance of modelling, simulation for lean assembly line, and the significance application of AHP and QFD for the lean production system had been discussed. From the literatures, the lean practices are perceived to be widely accepted in many industries. However, to determine the best decision in promoting the lean practices required motivation. This has been given a new impression, not only in strengthening the implementation of lean practices and lean continuous improvement strategy, but also integrating QFD, AHP and simulation modelling study for lean production system.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this research. In conducting this research, a logical order based on a systematic approach to empirical research was applied. The flow of the research activities is in a linear direction in order to achieve the objectives of this research.

3.2 Research Design

As depicted in Figure 3.1, this research began with problem identification and refinement. By studying the current contemporary industrial environment, an extensive literature review concerning assembly line, facility planning, production layout, lean production system, lean practices for assembly line, lean continuous improvement strategies, quality function deployment, and analytic hierarchy process was conducted. This is purposely to determine the parameter of lean practices (LP) and lean continuous improvement strategies (LS) in a wide area, locally and globally. The previous studies have been carefully examined to identify the loops and gaps that need to be focused on this research. The information obtained from the literature review was then defined and refined in the development of the questionnaire and case study approach.

The next stage is data collection. Survey and case study approaches were chosen in this research. In investigating the degree achieved and factors of the LP and LS, a set of questionnaire has been produced based on the criteria determined from the literature (first research objective).

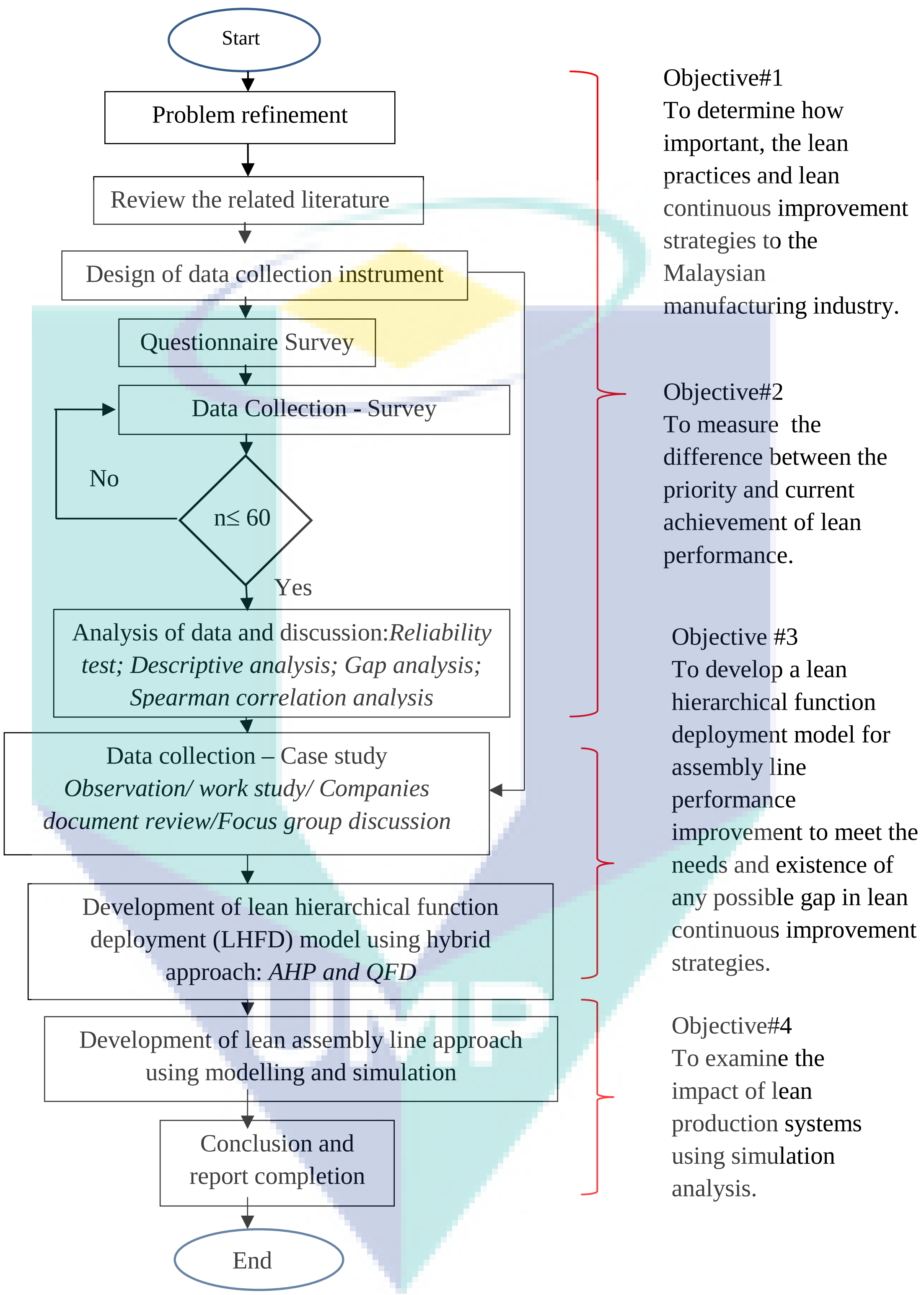


Figure 3.1 Process Flow for Research Methodology

Initially, the questionnaire was tested through a pre-study to ascertain the validity and reliability of each indicator for each research variable in the questionnaire before it was distributed to the respondents in the final survey. Meanwhile, a case study was performed to confirm the preliminary study in the literature review. Besides, in achieving second and third research objective, case study approach is more appropriate (Razik, 2015). The firm documents review, semi-structured interviews, and field observation methods were also adopted for collecting data for simulation and modelling. Mixed methods combining qualitative and quantitative approach were applied to data collection in this study. Mahmood (2012) suggested that qualitative data, such semi-structured interviews with the companies can defend the primary data.

The result from the final survey was then analysed statistically using SPSS software. The analysis comprise the descriptive analysis, and correlation analysis. Descriptive analysis focused on mean and standard deviation. Gap analysis between LP and LS achievements and priorities were based on mean value. Abdullah (2018) and Yusup (2017) suggested, Spearman correlation analysis was chosen due to ordinal type (nonparametric version) of data. Spearman's correlation coefficient, measures the strength and direction of association between two ranked variables. In the research, all items in LP and LS were analysed with the Spearman correlation test. This was used in assessing whether each indicator in each group of variable has a positive correlation, a negative correlation, or no correlation existing between indicators based on the range value of correlation coefficient from −1 to 1 (Szmidt and Kacprzyk, 2010).

For evaluation purpose, the data from case study in a company was collected through observation, document review of secondary data, interviews with a focus grouped and work study. For work study, a selected production line from a case study in a company was referred. The purpose of the case study was to develop lean assembly line performance measure. The data from analysis of the survey were used to finalise significance parameters in the case study. Analytic hierarchy process (AHP) combining with quality function deployment (QFD) was considered for data analysis to achieve the second objective of the research as suggested by Razik (2015). For the Lean Hierarchical Function Deployment, discussion with focus group was carried out. The group represents a production line team member. The focus group had helped researchers to understand completely the scenario and production performance (Abdullah, 2018; Saedin, 2017). The data was then utilised in simulation analysis to test whether the determinations in the hybrid approach were reliable, especially for lean strategies (LS) as good as a performance standard. Modelling and simulation using the ARENA software was executed utilizing the data from the case study company. The simulation analysis was intentionally selected for evaluation and testing to avoid any interruption to any physical changes on the current operations during the case study.

3.3 Survey Questionnaire Design

From literature reviews, questionnaire for the survey was developed to collect data for this research. The following explains the survey questionnaire design.

3.3.1 Questionnaire Structure

The questionnaire was organised into four sections including a combination of closed, open-ended, and rating questions. The rating questions were set up on a five-point Likert scale which aimed to measure the priority and current achievements described by each of the items (Adebanjo et al., 2016; Fargani et al., 2016; Sohi et al., 2016; Thome & Sousa, 2016; Vilkas et al., 2015). The scale of priority was ranged from 1 to 5, where 1: Unimportant, 2: Slightly important, 3: Important, 4: Very important, 5: Extremely important. The scale of current performance/achievement were rated as; 1: Very Poor, 2: Poor, 3: Fair, 4: Good, and 5: Very Good.

The questionnaire contains four parts which were developed in dual languages, namely English and *Bahasa Melayu* for respondents to be able to understand the questions easily and provide answers without any constraints. The description of each of the sections is presented in Table 3.1.

Table 3.1 Structure of Survey Questionnaire

Questionnaire Section *	Descriptions
Part 1: Company Information	To profile the company information by inquiring the company name, ownership, main business operation, status of original equipment manufacturer (OEM), industry product groups, the number of employees and the International Organisation for Standardisation (ISO) certified obtained by the company.
Part 2: Lean Practices	Questions on current manufacturing performance consist of 28 items. Rating questions were used to test the priority and the current lean practices of the Malaysia manufacturing industry.
Part 3: Lean continuous improvement Strategies	The objective of lean production practices is questioned in 7 items. The questions utilised five-point rating scale to evaluate the priority and the recent lean strategies in Malaysia manufacturing industry.
Part 4: Respondent Information	Particulars of the respondent, such as name, job title, and contact information. Requests for the company to take part in the next phase of the study.

NOTE: * Refer APPENDIX A for a sample.

3.3.2 Questionnaire Content Validity

The contents of the questionnaire were based on the literature review. At initial state, the questionnaire has undergone the content validity test including English and Malay terminologies (the assessment of questionnaire (pre-test) form as per APPENDIX B). This was to ensure that the indicators of the questionnaire adequately represent each of the variables being measured (Sekaran, 2006). To confirm the validity of the indicators in each research variables, the content in the questionnaire was discussed by a panel of experts, consisted of two senior lecturers and two industry professionals (refer APPENDIX C for background of a panel of experts). Among the comments are:

Table 3.2 Questionnaire Content Validity

Comment	Action
The statement in the questionnaire is too long.	Simplifying the wordings based on standard terminology as per use in industry
The statement in the questionnaire is too general and can cause a vague answer to be given by respondents, thus contribute to the discrepancy of data.	Listing the items by categorising the lean practices or strategies.
An appropriate scale is required in order to make an accurate judgment before and what to be achieved in lean implementation.	Add priorities and achievement sub-answer to measure the gap of achievement before and what to be achieved by respondents in the companies.

Based on the feedback, comments, and recommendation received, minor modifications were considered in improving the contents of the questionnaire. Although a few statements were found repeated in several variations, the researcher decided to keep each of the statements because, all the statements identified reflect the current scenario in lean assembly operations.

3.3.3 Questionnaire Administration

The questionnaire was sent by mail and email to the potential respondents. Each questionnaire was accompanied by a personally addressed (head of the company) and cover letter explaining the nature of the research, advising that the result would be available on request, and assured the recipients of strict confidentiality. Postage-paid and self-addressed reply envelopes were also included in the mail. A second copy of the questionnaire, cover letter and postage-paid, self-addressed reply envelope was mailed two weeks after the reminder via phone call to all non-respondents. Finally, a second reminder was done six weeks after the original mailing. To provide a broad overview of the current lean practices in Malaysia, the distribution of survey questionnaires was done across a wide geographical area of the manufacturing industries.

3.3.4 Survey Sampling Approach

The population and sample size of the previous study in lean practices survey are shown in Table 3.4. From the table, there were studies that did not consider population (Adebanjo et al., 2016; Bayo-Moriones et al., 2010; Bozarth et al., 2009; Coker & Helo, 2016; Holtskog, 2013; Manzouri et al., 2014; Welo & Ringen, 2015). The response rate was recorded in between 16.1 to 77.5 percent, while the lowest number of respondents was 23 (Bozarth et al., 2009) and the highest number of respondents was 603 (Holtskog, 2013). Sampling technique was not used because of the survey was not representing any population. Although this study received 61 completed responses that sound a minor number of questionnaire surveys nevertheless, it was considered to be reasonably representative of this industry due to its relatively small size as a whole (Huang & Mak, 1998; Mahmood, 2012). These numbers of responses were considered relevant for statistical analysis for hypothesis testing (Norman, 2010). Thus, 61 respondents or 22.4 percent of respond rate in this research was considered sufficient for basic statistical analysis. Moreover, the research was mainly not focusing on the survey method, but require some empirical support from respondents on the list of LP and LS measures (as Abdullah, 2018).

Table 3.3 Population and Sampling of Previous Research on Lean Practices

Author	Population	Number of samples	Response rate (%)
Zahraee (2016)	120	93	77.5
Kumar et al. (2013)	88	62	70.5
Randhawa and Ahuja (2017)	275	92	33.5
Rose et al. (2013)	250	61	24.4
Author (2019)	-	61	22.4
Abdullah (2018)	-	51	20.4
Vilkas et al. (2015)	208	41	19.7
Nawanir et al. (2016)	1000	161	16.1
Bozarth et al. (2009)	-	23	-
Coker and Helo (2016)	-	40	-
Manzouri et al. (2014)	-	100	-
Adebanjo et al. (2016)	-	159	-
Bayo-Moriones et al. (2010)	-	203	-
Welo and Ringen (2015)	-	297	-
Holtskog (2013)	-	603	-

3.4 Initial Model Validation

The initial model of Lean Hierarchical Function Deployment is validated its applicability and usefulness that provide an opportunity of refinement and improvement. To perform the validation of initial model, content validity is done with the assistance of experts' opinion (as suggested by Razik, 2015). The validation process is carried out by having discussion and semi-structured interviews with the panel from the academic experts and practitioners (as APPENDIX C). These panels should have at least 5 years of experience in the lean manufacturing practices. The two academicians that expert in the lean manufacturing field have been consulted which should contribute to the validity positively.

3.5 Modeling Simulation through Case Study

From the initial validation of the model, some modifications were done based on suggestions of the experts. Next the final model validation using a case study approach is done. Model validation is essential to affirm that the developed model addresses the issues, provides precise information about the system being modelled and ensures that the model is applicable in the industry (as suggested by Mahmood, 2012). The validation of the model is done in the ABC Company (under Electronic and Electrical Product Sector) in Malaysia to provide evidence of the feasibility and practicability and tests the acceptability of the model from the practitioner perspective. In the validation of the model stage, field observation, time study, document reviews, and semi-structured interviews have been applied as sources of confirmation, in order to affect the validity positively as Abdullah (2018).

3.5.1 Field Observations

Field observation was adopted in the study to gain more in depth information or knowledge on the related issues (Ngadiman, 2013) as well as to increase the internal validity (Mysen, 2012). The data collected in real-time through field observation were considered as primary data and beneficial and recommended for the study. The operational flow and the functions of the related system were studied through actual operation observations, production handbooks and operation manuals.

Observation was carried out by observing closely the activities of machines and data for operational efficiency was recorded (Bon and Ping, 2011). The study assessed the company's manufacturing and business processes by visiting the production assembly line to directly observing lean practices. Discussion and interview were carried out to contextualise the responses of the staff or operators in relation to observations made during the observations of company operations (as Thomas et al., 2012).

3.5.2 Company's Documents Review and Time Study

To have a clear understanding of the current process and problems under studied, archival records, documents and photographic evidence are reviewed. The documented data from the history records available such as production flow, working hours, number of shift, input, output and others as in the list of information in the Table 3.5. The time study was conducted to verify the information for validation purpose. The results are presented in APPENDIX E.

Table 3.4 List of Information from case study for Validation of the Model

Information	**Unit measurement**
Production flow (Layout)	-
Assembly line production area	m^2
Input per day	Quantity (Number)
Output (for normal working hours) per day	Quantity (Number)
Number of shift	Quantity (Number)
Number employee per workstation per shift	Quantity (Number)
Normal working hours	Hours
Working break hours (morning break, lunch break, hi-tea break)	Minutes
Man and machine hours for assembly process (per workstation)	Minutes

3.5.3 Semi Structured Interview

Semi-structured interview is considered in gathering information that cannot be obtained using quantitative measures. The semi-structured interview guide was developed upon a common case study protocol inferred from the review of literature done prior to the case study Nordin et al., (2014). In this study, the semi-structured interview method followed Bourne et al. (2002) approach:

i. Each interview started with a short series of open ended questions,
ii. Responses to these open ended questions were probed to ensure that the interviewer understood the points being made and to gather specific examples,
iii. Questions were asked focused on a prompt list of variables from literature study,
iv. Responses were probed to ensure understanding.

The semi-structured interview procedure was carried out based on the Figure 2.6 to establish the comprehensive assessment matrix of each indicator according to the lean practices (LP) and the priority values for AHP. Meanwhile, information on Lean continuous improvement strategies (LS) for lean practices in QFD (as Figure 2.7) are also gathered through this approach.

3.6 Summary

This chapter describes the research method that has been used in this present research, covering the data collection, method of data analysis, and other related works which aims to answer the research questions to meet the research objectives. The sources of both primary and secondary data were explained. Besides, survey questionnaire design has been explained comprising the structure, content validity and administration. A pre-analysis of work study has also been introduced as an introduction to the case study. Lastly, lean hierarchical function deployment framework has been discussed including the assembly line layout which is applicable for ARENA simulation and modelling.

CHAPTER 4

DATA ANALYSIS AND DISCUSSION

4.1 Introduction

In the research, the questionnaires were developed consists of 28 indicators on the lean practices, and 7 items for lean continuous improvement strategies in Malaysia manufacturing industry. The survey inquires the items' current achievement and the priority or target on the subjects by the 5 points Likert scale, from Low Extent (1) to a High Extent (5). A total of 250 questionnaires were posted to respondents but only 68 responses were received contributing to 27.2% response rate. After the screening process, 61 completed with useful information were accepted for further analysis (the list of respondents as APPENDIX D). The results were analysed using the Statistical Package for Social Sciences (or also known as IBM SPSS software). The questionnaires were ensured to be completed by the person who has working experience more than 2 years and has knowledge about the issues related to lean practices.

4.2 Analysis of Sample Demographics

The first aspect to be investigated was the demographic information concerning the respondents and companies such as the company ownership, percentage of main business operation, percentage of original equipment manufacturer (OEM) products, industry product group, the number of employees and the certified management certification status. For the respondents, the demographic data shows that the respondents were from the top management/administration of the company consists of CEO/Director/Senior manager (20.0%), manager/assistant manager (65.00%), and senior engineer/engineer (15.00%). The data is summarised in Figure 4.1.

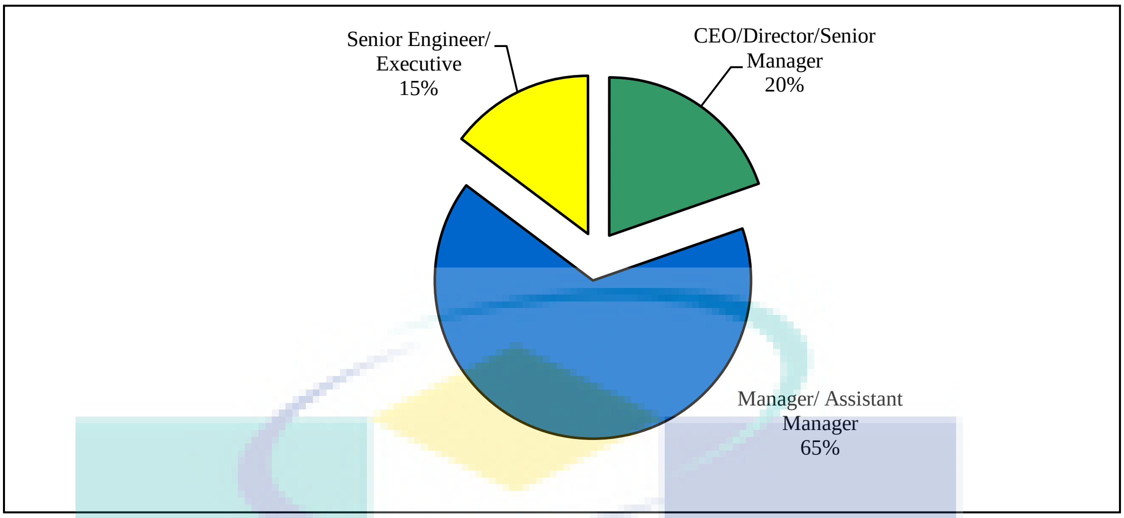


Figure 4.1 Percentage of Respondents

The demographic data show that the percentage of the local and foreign company were 26.2% and 73.8% respectively. For the product group, it shows that the largest of respondents were categorised in the electric and electronics product group (45.9%). It followed by the automotive products group (18.0%), chemical/scientific and other products group (14.8%) and mechanical engineering product group (8.20%). About 13.1 percent of the company having a mixture of product groups such as automotive, electric/electronic and mechanical product group. Majorities of companies operating with a manpower capacity in the range over than 500 employees that contributed about 75.4%, while 4.9% operate with a capacity of fewer than 100 employees. The percentage of the capacity manpower in the range of 101 to 200 and 201 to 500 employees of the companies is 9.8% each. In term of certification, 54 respondents' companies had obtained ISO 9001 certification, which contributes about 88.5%, 20 (32.8%) companies had obtained TS 16949 certification, 40 (65.6%) companies had obtained ISO 14001 and 31 (50.8%) companies had obtained OHSAS 18001 certification. The demographic information about the company is summarised in Table 4.1.

Table 4.1 Demographic Information of Company

Characteristics	**Percentage (%)**
Company ownership	
Local ownership	26.2
Foreign ownership	73.8
Main Business Operation	
Manufacturing	32.8
Assembly	60.7
Other	6.6
Major Product	
Original Equipment Manufacturer (OEM)	70.5
Non-OEM	29.5
Industry product group	
Automotive product	18.0
Electric and electronic product	45.9
Mechanical product	8.2
Chemical and scientific product	14.8
Mixture product	13.1
Number of employees	
50 to 100	4.9
101 to 200	9.8
201 to 500	9.8
More than 500	75.4
Certification	
ISO 9001	88.5
TS 16949	32.8
ISO 14001	65.6
OHSAS 18001	50.8

N=61

4.3 Lean Practices for Malaysia Manufacturing Industry

The lean practices in the Malaysian manufacturing industry were based on literature study, which was discovered 28 items. This analysis was done to identify the state of the art of the lean practices in the Malaysian manufacturing industry in terms of the priority of each practice and the achievement that have been realised. Determining priority and current achievement of current lean practices in the Malaysian manufacturing industry was essential to ascertain their impact on the manufacturing performance. By knowing both priority and achievement of lean practices, the author is able to understand what actually the main concern for a lean production system for Malaysia manufacturing industry in general.

4.3.1 Priority and Achievement of Lean Practices

The mean score of the priority and achievement of lean practices is presented in Table 4.2. In the meantime, Figure 4.2 shows the summary of the mean score while Figure 4.3 shows the achievement and priorities gap for lean practices. From Figure 4.2, the product quality (LP27) has the highest priority mean score of 4.67 in Malaysian industry. The following priority elements of current manufacturing performance that score more than 3.50 include on time delivery (LP7), minimum cost (LP26), and efficient space utilisation (LP24) at a mean score of 4.52, 4.26 and 4.05 respectively. As for LP current achievement, on time delivery (LP7) has the highest mean score value at 4.07, followed by product quality (LP27) and minimum cost (LP26) at a mean score value of 3.93 and 3.77 respectively as can be seen in Figure 4.2.

Respondents also agreed that adaptation of new technology (LP1) and this reported a mean score value of 3.67. The least important of lean practices in the Malaysian industry was a Zero WIP (One Piece Flow) (LP21) with the mean score of 3.10 and 2.93 for priority and achievement respectively. Although with this code of practice in the Malaysian production industry could provide information on the effectiveness of WIP management where every process can produce and stock as little as one piece at a time. Although the difference of mean score showed that the achievement practices are still lower than priority, the study shows product quality is positively associated with the lean performance acknowledged the importance to deliver a good product to customers in order for cost reduction.

There was considered no gap between priority and achievement in term of Enhanced Product Variety (LP4) due to the high number of diversity or build-combinations undeniably presents massive problems in the design and operation of the assembly systems. Meanwhile, as shown in Figure 4.3, minimising number of work station (LP25) has a positive impact among 28 items of lean practices because the mean score for achievement is most likely to show an impact on the priorities. As agreed by many researchers like Womack & Jones (2003), Vilkas et al. (2015) and Kumar et al. (2013), LP27 will no be the main focus in this research although the mean score shows a huge gap between the achievement and priorities. This is because, quality was considered a complex solution while lean is more concentrate on the time based performance (Stålberg & Fundin, 2018). In the most cases, to solve a quality product resolution it require effective solution while lean encourage efficient strategy (Gonçalves & Salonitis, 2017).

Table 4.2 Mean Score and achievement and priorities gap for lean practices

	Lean practices	Priorities	Achievement	Gap
LP1	Adaptation of New Technology	3.87	3.67	-0.20
LP2	Decrease Customer Lead Time	4.00	3.59	-0.41
LP3	Decrease Throughput Time	3.97	3.62	-0.34
LP4	Enhanced Product Variety	3.61	3.57	-0.03
LP5	High Capacity of Innovation	3.66	3.51	-0.15
LP6	Minimise Setup Time	3.82	3.54	-0.28
LP7	On Time Delivery	4.52	4.07	-0.46
LP8	Speed Up Changeover Time	3.82	3.39	-0.43
LP9	Effective Machine Optimisation	3.93	3.54	-0.39
LP10	Increasing Kaizen Activities	3.75	3.39	-0.36
LP11	Minimise Machine Configuration	3.46	3.36	-0.10
LP12	Operator Flexibility and Innovativeness	3.46	3.25	-0.21
LP13	Optimise Poka-Yoke	3.62	3.23	-0.39
LP14	Proactive Total Preventive Maintenance (TPM) Practice	3.77	3.34	-0.43
LP15	Process Line Balancing	3.70	3.51	-0.20
LP16	Effective Pace of Production (Takt Time)	3.69	3.46	-0.23
LP17	Efficient Production Levelling (Finished Goods)	3.84	3.54	-0.30
LP18	Organised Just-in-Time (JIT) for Raw Material	3.70	3.31	-0.39
LP19	Organised Kanban System for Work-in-Progress (WIP)	3.34	3.20	-0.15
LP20	Zero Missing/Misplace Material	3.87	3.31	-0.56
LP21	Zero WIP (One Piece Flow)	3.10	2.93	-0.16
LP22	Effective Layout Configuration	3.87	3.56	-0.31
LP23	Effective Material Flow	3.87	3.54	-0.33
LP24	Efficient Space Utilisation	4.05	3.61	-0.44
LP25	Minimise Number of Work Station	3.54	3.56	0.02
LP26	Minimum Cost	4.26	3.77	-0.49
LP27	Product Quality	4.67	3.93	-0.74
LP28	Simplified Operation Procedure	3.98	3.64	-0.34

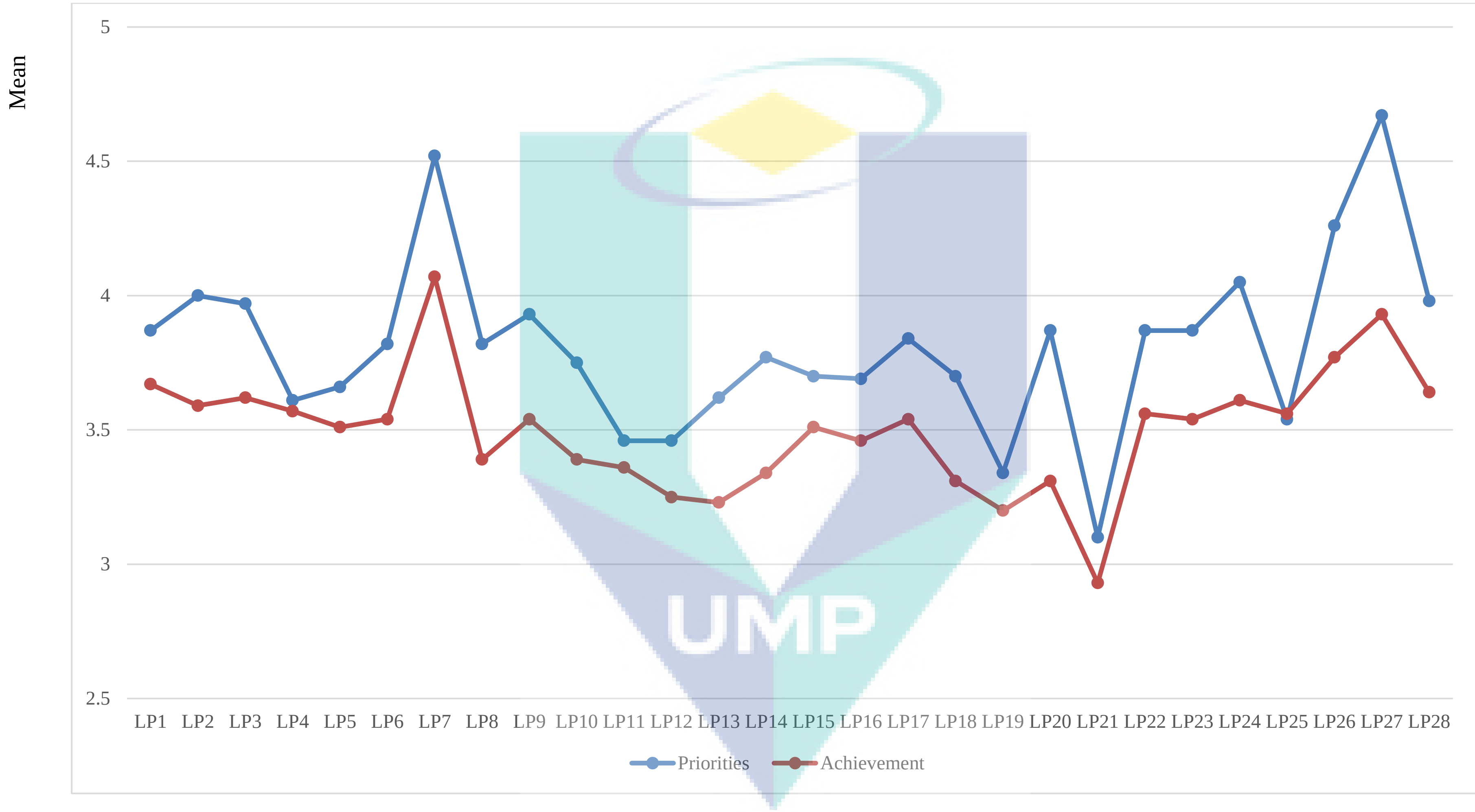


Figure 4.2 Line Graph for Lean Practices

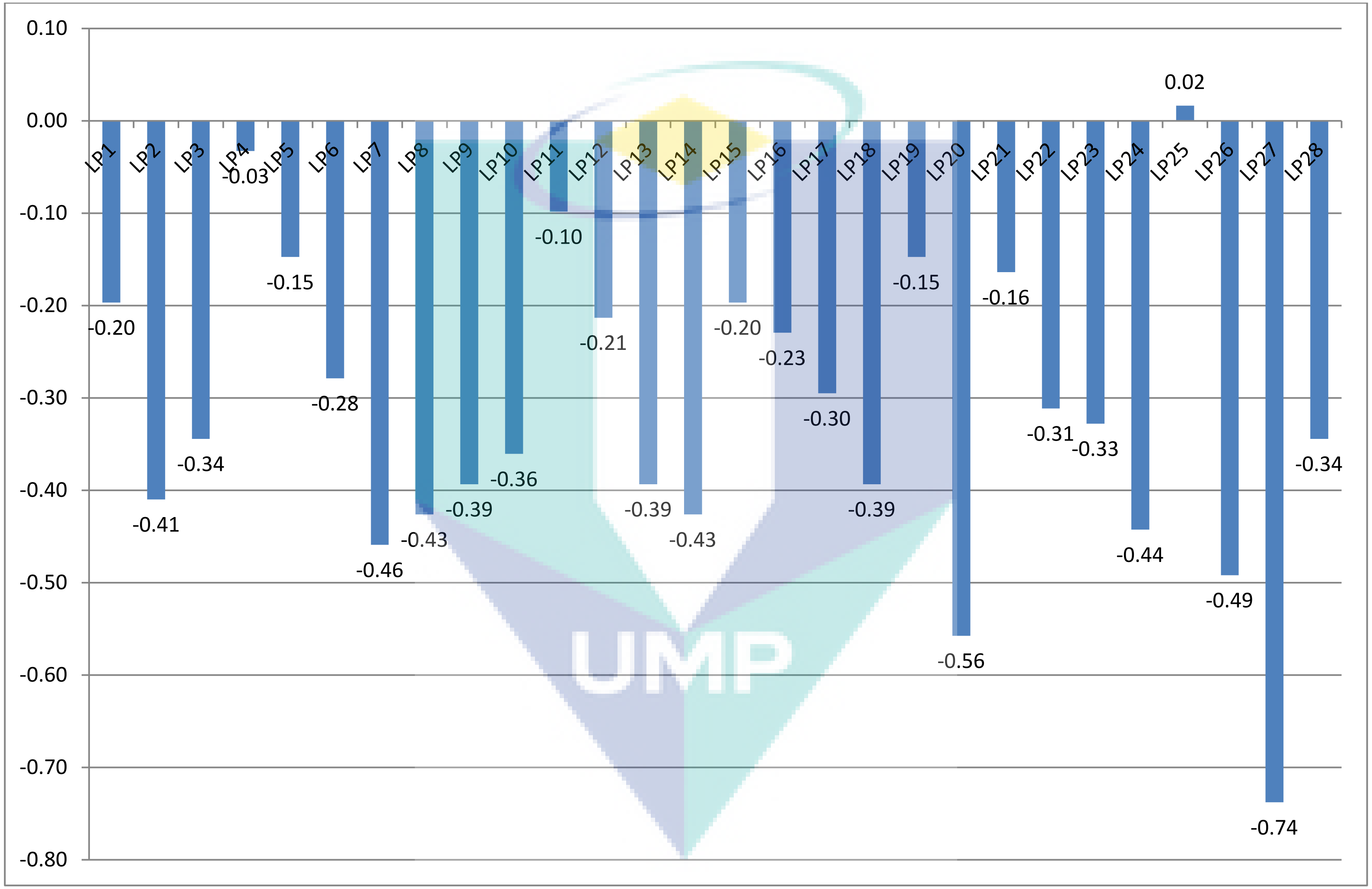


Figure 4.3 Achievement and Priorities Gap for Lean Practices

4.3.2 Correlation Analysis for Lean Practices

A Spearman correlation analysis was conducted in order to determine the strength of the relationship between current lean practices for both priority and achievement. The results are presented in Table 4.3 and Table 4.4 respectively. This test generates a total of 784 matrices of the relationship among the 28 LP indicators. The test results for priority show that the correlation coefficient ranges from 0.252 to 0.685, which prove significant at the 0.001 levels. 10 pairs of matrices were found to have a strong positive correlation ranging in value from 0.606 to 0.685 followed by 195 of matrices with moderate positive correlation relationship ranging in value from 0.403 to 0.595.

On the other hand, there are some differences between the test result for the priority and achievement. The test result for achievement shows that the correlation coefficients range from 0.252 to 0.688, which prove significant at either the 0.001 or 0.05 level. 10 pairs of matrices were found to have a strong positive relationship ranging in value from 0.601 to 0.688 followed by 347 of matrices with moderate positive correlation coefficient ranging in value from 0.400 to 0.595.

The comparison of correlation results between the level of priority and achievement clearly shown in Table 4.5. Meanwhile, Figure 4.4 shows the overall number of correlated items in lean practices. As can been seen in Figure 4.4, LP11 and LP12 have highest correlated items with other lean practices. In other words, *minimise machine configuration* and *operator flexibility and innovativeness* are considered most significant items in lean practices. The ability of manufacturer to maximise the use of a machine in an efficient manner as well as minimise the configuration will speed up the processing time (Sundin et al., 2011). Besides, the production flexibility is important for manufacturers to quickly response (Aguado et al., 2013).

For lean practices achievement, there were seven items which showed most significant with other practices. The most influence practices is LP14, Proactive Total Preventive Maintenance (TPM) Practice, followed by LP17, LP18, LP12, LP11, LP7 and LP13. Besides, LP2, LP4, LP16, LP21 and LP27 had less significant correlation with both priorities and achievement of the lean practices.

Table 4.2 Spearman correlation for lean practices (priority)

	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	LP9	LP10	LP11	LP12	LP13	LP14
LP2	0.188	1.000												
LP3	.413(**)	.395(**)	1.000											
LP4	0.129	.269(*)	0.014	1.000										
LP5	.420(**)	0.141	0.248	0.169	1.000									
LP6	.297(*)	0.249	.380(**)	0.217	0.207	1.000								
LP7	0.222	.266(*)	.490(**)	-0.013	0.122	0.175	1.000							
LP8	0.155	.252(*)	.260(*)	0.211	0.046	.595(**)	0.001	1.000						
LP9	.388(**)	0.132	.385(**)	0.066	.289(*)	.580(**)	.318(*)	.393(**)	1.000					
LP10	0.218	.261(*)	.256(*)	.388(**)	.318(*)	0.164	.374(**)	0.026	0.201	1.000				
LP11	0.216	.270(*)	.512(**)	0.104	.417(**)	.587(**)	0.161	.549(**)	.556(**)	.329(**)	1.000			
LP12	.309(*)	.290(*)	.301(*)	.502(**)	.276(*)	.332(**)	0.104	.442(**)	.433(**)	.418(**)	.426(**)	1.000		
LP13	.435(**)	.302(*)	.291(*)	0.219	.471(**)	0.249	.398(**)	0.143	.311(*)	.439(**)	.386(**)	.518(**)	1.000	
LP14	.298(*)	0.084	.289(*)	0.207	0.199	.449(**)	.336(**)	.450(**)	.528(**)	0.174	.464(**)	.434(**)	.373(**)	1.000
LP15	.264(*)	0.168	.381(**)	.383(**)	.320(*)	.559(**)	.318(*)	.408(**)	.484(**)	.337(**)	.431(**)	.520(**)	.300(*)	.667(**)
LP16	.341(**)	0.027	.257(*)	0.155	0.121	.362(**)	.272(*)	.426(**)	.362(**)	0.189	.300(*)	.361(**)	.254(*)	.646(**)
LP17	0.148	.327(*)	.434(**)	.280(*)	0.192	.475(**)	.293(*)	.396(**)	.563(**)	0.242	.532(**)	.422(**)	.270(*)	.492(**)
LP18	0.238	.339(**)	.447(**)	.272(*)	0.240	.393(**)	0.232	.456(**)	.443(**)	.267(*)	.523(**)	.491(**)	0.237	.457(**)
LP19	.306(*)	0.171	.354(**)	.290(*)	.326(*)	0.201	0.089	.284(*)	.297(*)	.374(**)	.447(**)	.599(**)	.422(**)	.367(**)
LP20	.257(*)	0.077	.315(*)	0.228	.334(**)	0.246	.331(**)	0.238	.320(*)	.341(**)	.416(**)	.342(**)	.365(**)	.388(**)
LP21	0.157	.373(**)	0.174	.481(**)	0.215	.292(*)	0.176	.298(*)	0.155	.373(**)	.289(*)	.380(**)	.349(**)	.291(*)
LP22	.321(*)	.303(*)	.283(*)	.256(*)	.338(**)	.377(**)	.263(*)	0.209	.396(**)	0.240	.397(**)	.546(**)	.514(**)	.381(**)
LP23	.306(*)	0.216	.305(*)	.262(*)	.405(**)	.394(**)	.302(*)	.303(*)	.432(**)	.393(**)	.513(**)	.507(**)	.494(**)	.366(**)
LP24	0.222	0.001	.297(*)	0.119	.315(*)	.395(**)	.385(**)	0.220	.513(**)	.290(*)	.436(**)	.421(**)	.460(**)	.368(**)
LP25	0.240	.303(*)	.331(**)	.305(*)	.500(**)	.318(*)	.309(*)	0.205	.274(*)	.601(**)	.404(**)	.439(**)	.589(**)	0.218
LP26	.306(*)	.294(*)	.457(**)	0.221	.322(*)	.329(**)	.567(**)	0.069	.425(**)	.409(**)	.442(**)	.365(**)	.332(**)	.325(*)
LP27	.426(**)	.396(**)	.481(**)	0.087	0.146	0.119	.529(**)	0.167	0.176	0.122	0.166	0.200	.349(**)	.305(*)
LP28	.385(**)	0.160	.383(**)	0.116	.265(*)	.449(**)	.480(**)	0.251	.618(**)	.403(**)	.453(**)	.425(**)	.368(**)	.396(**)

Table 4.3 Continued

	LP15	LP16	LP17	LP18	LP19	LP20	LP21	LP22	LP23	LP24	LP25	LP26	LP27
LP16	.606(**)	1.000											
LP17	.616(**)	.463(**)	1.000										
LP18	.595(**)	.359(**)	.673(**)	1.000									
LP19	.409(**)	.325(*)	.499(**)	.572(**)	1.000								
LP20	.278(*)	.309(*)	.331(**)	0.135	.431(**)	1.000							
LP21	.442(**)	0.193	.297(*)	.404(**)	.373(**)	0.003	1.000						
LP22	.474(**)	.307(*)	.446(**)	.302(*)	.363(**)	.404(**)	.382(**)	1.000					
LP23	.491(**)	.276(*)	.349(**)	.291(*)	.409(**)	.497(**)	.357(**)	.685(**)	1.000				
LP24	.485(**)	0.176	.399(**)	.361(**)	.402(**)	0.191	.350(**)	.504(**)	.602(**)	1.000			
LP25	.559(**)	0.245	.399(**)	.403(**)	.526(**)	.294(*)	.542(**)	.454(**)	.451(**)	.511(**)	1.000		
LP26	.368(**)	0.157	.326(*)	0.250	.302(*)	.506(**)	0.167	.425(**)	.486(**)	.411(**)	.465(**)	1.000	
LP27	0.202	0.166	.311(*)	.348(**)	.276(*)	.427(**)	0.004	.315(*)	0.202	0.165	.264(*)	.513(**)	1.000
LP28	.421(**)	.295(*)	.341(**)	.325(*)	.263(*)	.391(**)	0.217	.543(**)	.504(**)	.506(**)	.420(**)	.684(**)	.349(**)

NOTE:
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.001 level

Table 4.4 Spearman correlation for lean practices (achievement)

	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8	LP9	LP10	LP11	LP12	LP13	LP14
LP2	.483(**)	1.000												
LP3	.622(**)	.500(**)	1.000											
LP4	.464(**)	.456(**)	.307(*)	1.000										
LP5	.529(**)	.357(**)	.465(**)	.461(**)	1.000									
LP6	.320(*)	.424(**)	.330(**)	0.173	.287(*)	1.000								
LP7	.518(**)	.475(**)	.448(**)	.434(**)	.317(*)	.561(**)	1.000							
LP8	.499(**)	.452(**)	.375(**)	.375(**)	.477(**)	.596(**)	.497(**)	1.000						
LP9	.439(**)	.393(**)	.458(**)	0.159	0.248	.612(**)	.598(**)	.628(**)	1.000					
LP10	.475(**)	.363(**)	.390(**)	.366(**)	.307(*)	0.132	.491(**)	.365(**)	.483(**)	1.000				
LP11	.379(**)	.405(**)	.281(*)	0.242	.396(**)	.688(**)	.664(**)	.581(**)	.572(**)	.364(**)	1.000			
LP12	.597(**)	.527(**)	.524(**)	.344(**)	.383(**)	.314(*)	.518(**)	.645(**)	.497(**)	.527(**)	.522(**)	1.000		
LP13	.579(**)	.400(**)	.422(**)	.395(**)	.414(**)	0.171	.487(**)	.371(**)	0.248	.507(**)	.502(**)	.580(**)	1.000	
LP14	.621(**)	.427(**)	.452(**)	0.208	.323(*)	.387(**)	.458(**)	.499(**)	.512(**)	.479(**)	.551(**)	.611(**)	.553(**)	1.000
LP15	.623(**)	.329(**)	.535(**)	.275(*)	.391(**)	0.202	.395(**)	.358(**)	.483(**)	.584(**)	.295(*)	.505(**)	.501(**)	.591(**)
LP16	.306(*)	0.085	0.063	0.106	0.247	.393(**)	.437(**)	.319(*)	.451(**)	.361(**)	.463(**)	0.252	0.177	.370(**)
LP17	.325(*)	.489(**)	.347(**)	0.251	0.206	.517(**)	.592(**)	.460(**)	.497(**)	.439(**)	.581(**)	.531(**)	.490(**)	.426(**)
LP18	.374(**)	.448(**)	.402(**)	.296(*)	.383(**)	.479(**)	.501(**)	.585(**)	.624(**)	.430(**)	.581(**)	.541(**)	.447(**)	.585(**)
LP19	.348(**)	.354(**)	.346(**)	0.144	.404(**)	.428(**)	.458(**)	.396(**)	.460(**)	.395(**)	.614(**)	.450(**)	.475(**)	.459(**)
LP20	.316(*)	0.249	0.194	.298(*)	.370(**)	0.235	.350(**)	.374(**)	.349(**)	.468(**)	.369(**)	.363(**)	.433(**)	.427(**)
LP21	.303(*)	.368(**)	0.195	0.245	0.180	.318(*)	.374(**)	.507(**)	.383(**)	.417(**)	.619(**)	.506(**)	.468(**)	.515(**)
LP22	.380(**)	.321(*)	.431(**)	.270(*)	.453(**)	.397(**)	.520(**)	.511(**)	.363(**)	0.146	.504(**)	.450(**)	.364(**)	.385(**)
LP23	.304(*)	.420(**)	.404(**)	0.202	0.167	.348(**)	.410(**)	.411(**)	.649(**)	0.225	.431(**)	.414(**)	.262(*)	.454(**)
LP24	0.242	.276(*)	.548(**)	0.144	.341(**)	.270(*)	.383(**)	.369(**)	.330(**)	0.168	.433(**)	.400(**)	.332(**)	0.235
LP25	.365(**)	.253(*)	.517(**)	0.204	.319(*)	.277(*)	.261(*)	.438(**)	.351(**)	.345(**)	.407(**)	.539(**)	.411(**)	.339(**)
LP26	.480(**)	.369(**)	.489(**)	0.240	.492(**)	.317(*)	.338(**)	.398(**)	.404(**)	.298(*)	.480(**)	.451(**)	.489(**)	.519(**)
LP27	.467(**)	.287(*)	.285(*)	0.230	0.216	.382(**)	.386(**)	.366(**)	.376(**)	.272(*)	.372(**)	.287(*)	.533(**)	.563(**)
LP28	.383(**)	.379(**)	.357(**)	0.160	0.162	.408(**)	.396(**)	.525(**)	.528(**)	.308(*)	.419(**)	.383(**)	.298(*)	.443(**)

Table 4.4 Continued

	LP15	LP16	LP17	LP18	LP19	LP20	LP21	LP22	LP23	LP24	LP25	LP26	LP27
LP16	.456(**)	1.000											
LP17	.485(**)	.455(**)	1.000										
LP18	.350(**)	0.223	.565(**)	1.000									
LP19	0.169	.341(**)	.460(**)	.560(**)	1.000								
LP20	.254(*)	0.158	.276(*)	.377(**)	.486(**)	1.000							
LP21	0.219	0.145	.498(**)	.611(**)	.476(**)	.270(*)	1.000						
LP22	.436(**)	.434(**)	.478(**)	.428(**)	.312(*)	0.177	.303(*)	1.000					
LP23	.503(**)	.404(**)	.528(**)	.507(**)	0.196	0.060	.353(**)	.573(**)	1.000				
LP24	.386(**)	0.211	.479(**)	.370(**)	.266(*)	0.138	.256(*)	.677(**)	.475(**)	1.000			
LP25	.423(**)	0.242	.501(**)	.407(**)	0.204	0.151	.479(**)	.455(**)	.350(**)	.565(**)	1.000		
LP26	.513(**)	0.168	.371(**)	.521(**)	.373(**)	.412(**)	.395(**)	.524(**)	.387(**)	.377(**)	.396(**)	1.000	
LP27	.306(*)	0.081	.312(*)	.496(**)	.300(*)	.435(**)	.390(**)	0.117	0.187	0.153	0.240	.345(**)	1.000
LP28	0.148	0.219	.298(*)	.425(**)	0.248	0.132	.505(**)	0.242	.448(**)	0.196	.404(**)	0.175	.346(**)

NOTE:
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.001 level

Table 4.5 The summary of the correlation test for lean practices

	Priorities		Achievement	
	Moderate	**Strong**	**Moderate**	**Strong**
LP1	LP3, LP5 LP13, LP27	-	LP2, LP4, LP5, LP7, LP8, LP9, LP10, LP12, LP13, LP26, LP27	LP3, LP14, LP15
LP2	-	-	LP1, LP3, LP4, LP6, LP7, LP8, LP11, LP12, LP13, LP14, LP17, LP18, LP23	-
LP3	LP1, LP7, LP11, LP17, LP18, LP26, LP27	-	LP5, LP7, LP9, LP12, LP13, LP14, LP15, LP18, LP22, LP23, LP24, LP25, LP26	-
LP4	LP12, LP21	-	LP1, LP2, LP5, LP7	-
LP5	LP11, LP13, LP23, LP25	-	LP1, LP3, LP4, LP8, LP13, LP19, LP22, LP26	-
LP6	LP8, LP9, LP11, LP14, LP15, LP17, LP28	-	LP2, LP7, LP8, LP17, LP18, LP19, LP28	LP9, LP11
LP7	LP3, LP26, LP27, LP28	-	LP1, LP2, LP3, LP4, LP6, LP8, LP9, LP10, LP12, LP13, LP14, LP16, LP17, LP18, LP19, LP22, LP23	LP11
LP8	LP6, LP11, LP12, LP14, LP15, LP16, LP18	-	LP1, LP2, LP5, LP7, LP11, LP14, LP17, LP18, LP21, LP22, LP23, LP25, LP28	LP9, LP12
LP9	LP6, LP11, LP12, LP14, LP15, LP17, LP18, LP23, LP24, LP26	LP28	LP1, LP3, LP7, LP10, LP11, LP12, LP14, LP15, LP16, LP17, LP19, LP26	LP6, LP8, LP23
LP10	LP12, LP13, LP26, LP28	LP26	LP1, LP7, LP9, LP12, LP13, LP14, LP15, LP17, LP18, LP20, LP21	
LP11	LP3, LP5, LP5, LP8, LP9, LP12, LP14, LP15, LP17, LP18, LP19, LP20, LP23, LP24, LP25, LP26, LP28	-	LP2, LP8, LP9, LP12, LP13, LP14, LP16, LP17, LP18, LP22, LP23, LP24, LP26, LP28	LP6, LP7, LP19, LP21
LP12	LP4, LP8, LP9, LP10, LP11, LP13, LP14, LP15, LP17, LP18, LP19, LP22, LP23, LP24, LP25, LP28	-	LP1, LP2, LP3, LP7, LP9, LP10, LP11, LP15, LP17, LP18, LP19, LP21, LP22, LP23, LP24, LP25, LP26	LP8, LP14
LP13	LP1, LP5, LP10, LP12, LP19, LP22, LP23, LP24, LP25	-	LP1, LP2, LP3, LP5, LP7, LP10, LP11, LP14, LP15, LP15, LP17, ,P18, LP19, LP20, LP21, LP25, LP26, LP27	-
LP14	LP6, LP8, LP9, LP11, LP12, LP17, LP18	LP15, LP16	LP2, LP3, LP7, LP8, LP9, LP10, LP11, LP13, LP15, LP17, LP18, LP19, LP20, LP21, LP23, LP26, LP27,LP28	LP1, LP12
LP15	LP6, LP8, LP9, LP11, LP12, LP18, LP19, LP21, LP22, LP23, LP24, LP25, LP28	LP14, LP16, LP17	LP3, LP9, LP10, LP12, LP13, LP14, LP16, LP17, LP22, LP23, LP25, LP26	LP1
LP16	LP8, LP17	LP14	LP7, LP9, LP11, LP15, LP17, LP22, LP23	-
LP17	LP3, LP6, LP9, LP11, LP12, LP14, LP19, LP22	LP18	LP2, LP6, LP7, LP8, LP9, LP10, LP11, LP12, LP13, LP14, LP15, LP16, LP18, LP19, LP21, LP22, LP23, LP24, LP25	-
LP18	LP3, LP6, LP9, LP11, LP12, LP14, LP18, LP21, LP25	-	LP2, LP3, LP6, LP7, LP8, LP10, LP11, LP12, LP13, LP14, LP17, LP19, LP22, LP23, LP25, LP26, LP27, LP28	LP21
LP19	LP11, LP12, LP13, LP20, LP23, LP24, LP25	-	LP5, LP6, LP7, LP9, LP12, LP13, LP14, LP17, LP18, LP20, LP21	LP11
LP20	LP11, LP22, LP23, LP26, LP27	-	LP10, LP13, LP14, LP19	

Table 4.5 Continued

	Priorities		Achievement	
	Moderate	**Strong**	**Moderate**	**Strong**
LP21	LP4, LP25	-	LP8, LP10, LP12, LP13, LP14, LP17, LP19, LP25, LP28	LP11, LP18
LP22	LP12, LP13, LP24, LP25, LP26, LP28	LP23	LP3, LP5, LP7, LP8, LP11, LP12, LP15, LP17, LP18, LP23, LP25, LP26	LP24
LP23	LP5, LP9, LP11, LP12, LP13, LP25, LP26, LP28	LP24	LP2, LP3, LP7, LP8, LP11, LP12, LP14, LP15, LP16, LP17,LP18, LP22, LP24, LP28	LP9
LP24	LP9, LP11, LP12, LP13, LP25, LP26, LP28	-	LP3, LP11,LP12, LP17, LP23, LP25	LP22
LP25	LP5, LP11, LP12, LP26, LP28	LP10	LP3, LP8, LP11, LP12, LP13, LP15, LP17, LP18, LP21, LP22,LP24, LP28	-
LP26	LP3, LP7, LP9, LP10, LP11, LP27	LP28	LP1, LP3, LP5, LP9, LP11, LP12, LP13, LP14, LP15, LP18, LP20, LP22	-
LP27	LP1, LP3, LP7	-	LP1, LP13, LP14, LP18, LP20	-
LP28	LP6, LP7, LP10, LP11, LP12	LP9	LP6, LP8, LP11, LP14, LP18, LP21, LP23, LP25	-

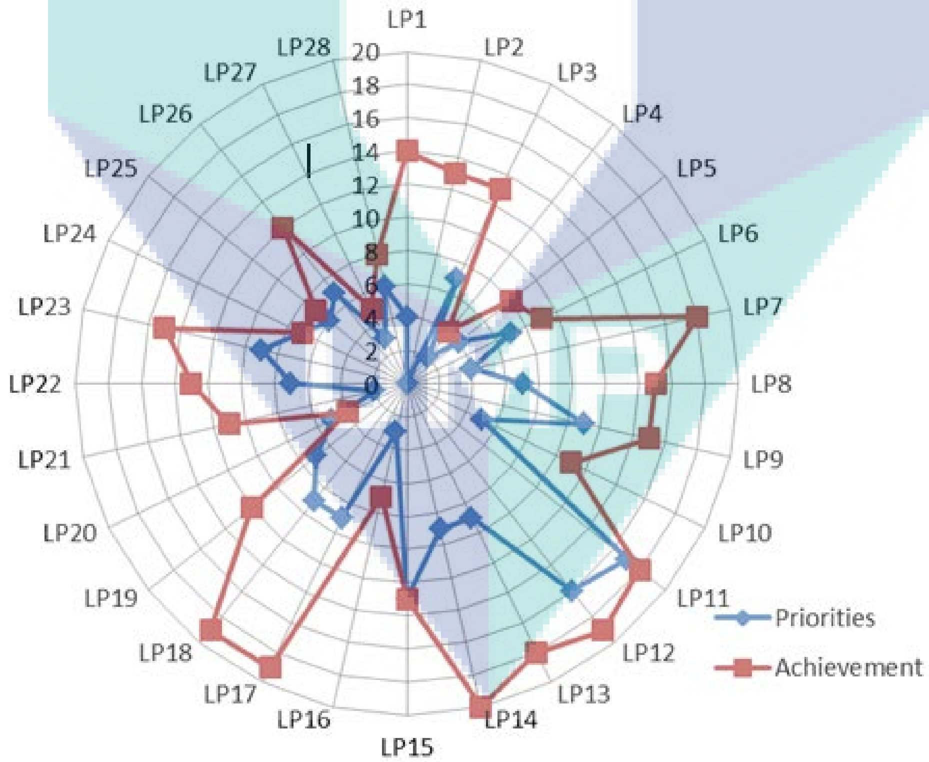


Figure 4.4 Number of Correlated Items in Lean Practices

4.4 Lean Continuous Improvement Strategies

The purpose of implementing lean strategies in production was based on 7 elements. This analysis was done to identify the state of the art of the aims of the manufacturer using lean strategies for manufacturing production in Malaysian manufacturing industry in terms of the priority of each practice and the achievement that have been achieved. Defining priority and current achievement of lean continuous improvement strategies in the Malaysian manufacturing industry was vital to make sure it benefits the production and improve manufacturing performance.

4.4.1 Priority and Achievement of Lean Continuous Improvement Strategies

The mean score for priority and current achievement of LS are presented in Table 4.6 and Figure 4.5. The respondents agreed that all seven items fulfilled the priority where most of the manufacturers are prioritised method of improvement (LS1) which has the highest mean score of 4.00. This followed by the better operator allocation (LS5) and improve workstation layout (LS4) at a mean score of 3.87 and 3.74 respectively. However, work for extra hours (LS6) was still less preferable as this item ranked the lowest score with a mean score of 3.03 as it might increase the cost for extra working hours.

Better operator allocation (LS5) has the highest mean score for LS current achievement value at 3.67, followed by method of improvement (LS1) and add additional manpower or machine (LS3) at a mean score value of 3.62 and 3.62 respectively. In contrast, share capacity (LS2) has less influence as the respondents appraised this with the lowest mean score value of 3.18.

Figure 4.6 shows a bar chart for achievement and priorities gap for lean continuous improvement strategies. Based on Figure 4.6, LS6 and LS3 have contributed a positive impact on the current LS achievement. This result was indicated that work for extra hours and add additional manpower or machine were less focus in lean strategies for most of manufacturing companies to achieve the production target.

In fact, LS1 required more attention for lean strategies. Method of improvement is required due to technology change, design change, product change, employee turnover and system change. The manufacturing industry may not be able to fix the issues and different scenarios will contribute a divergent problem statement. From Figure 4.6, share capacity and better operator allocation have same issues with method of improvement. Most respondents felt that both lean strategies have some difficulty to achieve. Both strategies are associated to flexibility systems that have to allow operator to share the workstation, equipment, machinery, and space.

Table 4.6 Achievement and Priorities Gap for Lean Continuous Improvement Strategies

	Lean continuous improvement strategies	Priorities	Achievement	Gap
LS1	Method of improvement	4.00	3.62	-0.38
LS2	Share Capacity	3.43	3.23	-0.20
LS3	Add Additional Manpower or Machine	3.54	3.61	0.07
LS4	Improve Work Station Layout	3.74	3.56	-0.18
LS5	Better Operator Allocation	3.87	3.67	-0.20
LS6	Work for Extra Hours	3.03	3.54	0.51
LS7	Production time saving tricks	3.33	3.2	-0.13

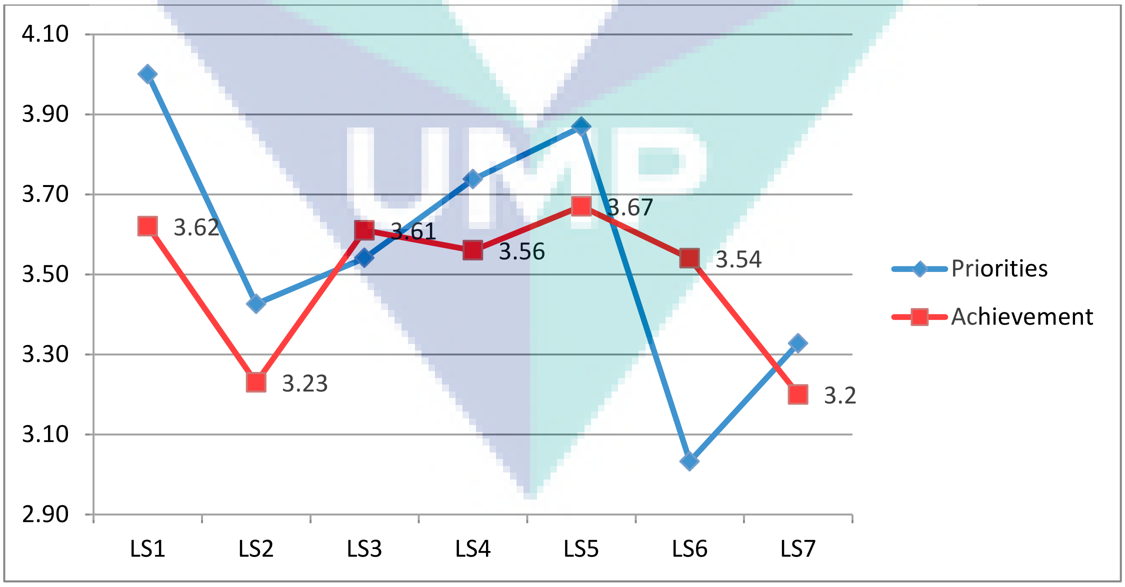


Figure 4.5 Line Chart for Lean Continuous Improvement Strategies

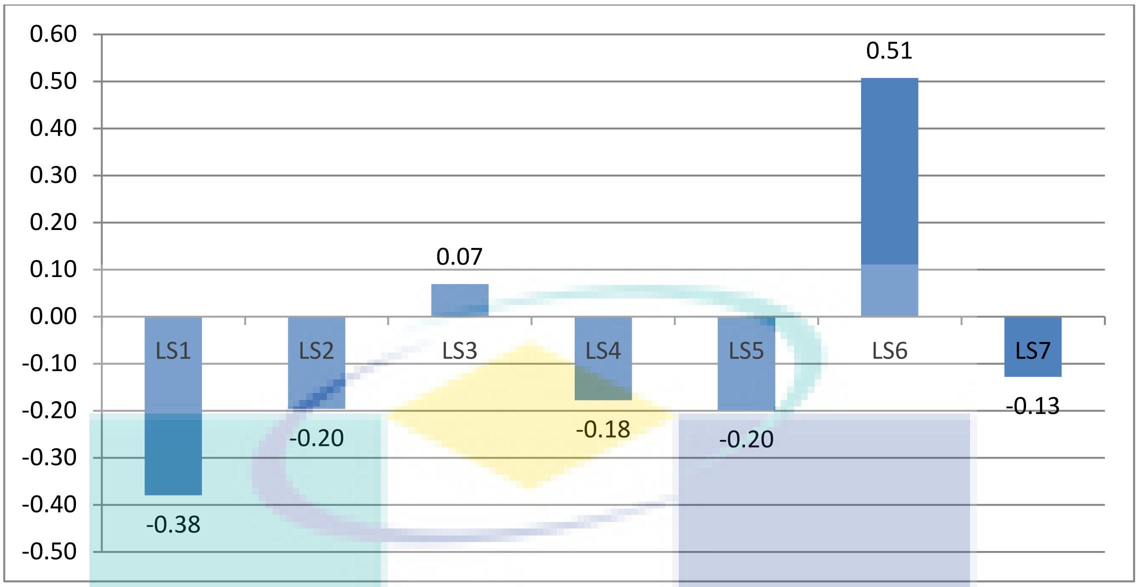


Figure 4.6 Bar Chart for Achievement and Priorities Gap for Lean Continuous Improvement Strategies

4.4.2 Correlation Analysis for Objectives of the Implementation of Lean Practices

A Spearman correlation analyses was conducted in order to determine the strength of the relationship between LS elements for both priority and achievement. The results are presented in Table 4.7. This test generates a total of 49 matrices of the relationship among the seven LS indicators. The test results for priority shows that the correlation coefficients range from 0.266 to 0.611, which prove significant at either the 0.001 or 0.05 levels. A pair of matric was found to have a strong positive correlation in value 0.611 followed by five pairs of matrices with moderate positive correlation coefficient ranging in value from 0.430 to 0.528.

However, there were some differences between the test result for the priority and achievement. The test result for achievement showed that the correlation coefficients range from 0.261 to 0.604, which prove significant at either the 0.001 or 0.05 levels. Six pairs of matrices were found to have moderate correlation coefficient ranging in value from 0.424 to 0.581. A pair of matrices show a strong correlation relationship for achievement.

Table 4.7 shows that both LS1 and LS5 have significant influence on other lean strategies. In other words, method of improvement and better operator allocation have impacted in the priorities lean strategies. Conversely, the achievement result shows that share capacity (LS2) and improve work station layout (LS4) were significantly affected other lean strategies.

Table 4.8 and Table 4.9 show Spearman Correlation test for LP and LS priorities and achievement respectively. This test generates a total of 196 matrices of the relationship. 46 significant correlated items in lean strategies priorities were identified while 44 items in lean strategies achievement had moderate significant different. Improve work station layout, LS4, had strong correlation with three lean practices.

There are operator flexibility and innovativeness (LP12), organised Kanban system for Work-in-Progress (LP19) and effective material flow (LP23). Besides, LS4 also has moderate correlation with other 12 items in lean practices for priorities. Nevertheless, LS1 has moderate significant correlated with 17 items in lean practices. In other words, only 11 items in priorities lean practices might not be influenced by the method of improvement.

From Table 4.8, add additional manpower or machine (LS3), work for extra hours (LS6), and production time saving tricks (LS7) are the three items in lean strategies priorities that have no significant correlation with all lean practices. The result also shows that as in Table 4.9, work for extra hours is considered no significant influence for lean practice achievement. Besides, LS3 only have four moderate significant correlation items with lean practices.

Table 4.7 Spearman Correlation Test For Lean Continuous Improvement Strategies (Priority And Achievement)

	Priority					
	LS1	**LS2**	**LS3**	**LS4**	**LS5**	**LS6**
LS2	.489(**)	1.000				
LS3	.266(*)	.430(**)	1.000			
LS4	.521(**)	.371(**)	0.169	1.000		
LS5	.611(**)	.332(**)	.488(**)	.528(**)	1.000	
LS6	0.170	0.117	.367(**)	0.087	.292(*)	1.000
LS7	0.076	0.124	.280(*)	.286(*)	.299(*)	0.161

	Achievement					
	LS1	**LS2**	**LS3**	**LS4**	**LS5**	**LS6**
LS2	.581(**)	1.000				
LS3	.297(*)	.441(**)	1.000			
LS4	.604(**)	.546(**)	.320(*)	1.000		
LS5	.350(**)	.324(*)	.297(*)	.451(**)	1.000	
LS6	0.120	0.233	.300(*)	-0.039	0.196	1.000
LS7	.379(**)	.385(**)	.261(*)	.271(*)	.424(**)	0.083

NOTE:
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.001 level

Table 4.8 Spearman Correlation Test for LP and LS Priorities

	LS1	LS2	LS3	LS4	LS5	LS6	LS7
LP1	.319(*)	.355(**)	-0.018	.357(**)	0.221	-.315(*)	0.096
LP2	.368(**)	.410(**)	.271(*)	0.246	.354(**)	0.189	0.076
LP3	.476(**)	.564(**)	.319(*)	.332(**)	.388(**)	0.048	0.120
LP4	0.166	.342(**)	0.125	0.181	0.211	0.105	0.121
LP5	.474(**)	0.241	0.140	.326(*)	.450(**)	0.110	0.042
LP6	.322(*)	.298(*)	.260(*)	.290(*)	0.217	-0.011	.359(**)
LP7	.342(**)	0.218	0.144	0.165	.285(*)	0.012	0.155
LP8	0.158	0.205	0.126	.256(*)	0.135	-0.218	.330(**)
LP9	.486(**)	0.202	.315(*)	.484(**)	.421(**)	-0.007	.346(**)
LP10	.348(**)	.271(*)	0.034	.401(**)	0.218	0.087	0.126
LP11	.445(**)	.337(**)	.358(**)	.446(**)	.437(**)	0.101	.325(*)
LP12	.551(**)	.339(**)	0.041	.608(**)	.320(*)	-0.010	0.187
LP13	.569(**)	.343(**)	-0.035	.477(**)	.388(**)	-0.048	0.168
LP14	.418(**)	0.160	0.154	.338(**)	0.152	-0.052	.362(**)
LP15	.440(**)	.395(**)	0.234	.429(**)	0.218	0.060	.340(**)
LP16	0.092	0.193	-0.088	.329(**)	0.029	-0.217	.424(**)
LP17	.434(**)	.534(**)	.383(**)	.533(**)	.401(**)	0.166	.277(*)
LP18	.471(**)	.404(**)	0.230	.491(**)	.371(**)	0.097	.338(**)
LP19	.383(**)	.369(**)	0.080	.620(**)	.299(*)	0.060	0.158
LP20	.325(*)	0.227	0.111	.385(**)	.319(*)	-0.085	0.146
LP21	.300(*)	.324(*)	0.156	.443(**)	0.224	0.112	0.175
LP22	.565(**)	.382(**)	.258(*)	.585(**)	.565(**)	0.052	.254(*)
LP23	.458(**)	.363(**)	0.138	.600(**)	.529(**)	-0.014	0.211
LP24	.500(**)	0.232	0.085	.455(**)	.390(**)	-0.032	0.096
LP25	.498(**)	.377(**)	0.094	.459(**)	.335(**)	0.220	0.106
LP26	.537(**)	.336(**)	.344(**)	.313(*)	.460(**)	0.133	0.065
LP27	.405(**)	.352(**)	0.114	0.217	.358(**)	-0.153	0.014
LP28	.467(**)	.282(*)	.333(**)	.462(**)	.502(**)	0.017	.382(**)

NOTE:
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.001 level

Table 4.9 Spearman Correlation test for LP and LS achievement

	LS1	LS2	LS3	LS4	LS5	LS6	LS7
LP1	.403(**)	.414(**)	0.188	.253(*)	0.212	-0.050	.482(**)
LP2	.367(**)	.452(**)	0.212	.316(*)	0.132	0.062	0.227
LP3	.479(**)	.517(**)	0.191	.298(*)	.264(*)	0.091	.329(**)
LP4	0.203	.346(**)	0.088	0.218	0.084	0.002	0.194
LP5	.319(*)	.590(**)	.317(*)	0.211	.329(**)	0.150	.364(**)
LP6	.334(**)	0.153	.281(*)	0.011	0.079	.286(*)	0.239
LP7	.492(**)	0.250	0.176	0.160	0.130	-0.031	0.207
LP8	.392(**)	.342(**)	.361(**)	.275(*)	0.059	0.073	.304(*)
LP9	.509(**)	0.225	.359(**)	.263(*)	0.158	0.054	.344(**)
LP10	.540(**)	.397(**)	0.179	.432(**)	.301(*)	-0.171	.429(**)
LP11	.478(**)	.339(**)	.498(**)	0.214	.284(*)	0.204	.352(**)
LP12	.418(**)	.438(**)	.356(**)	.349(**)	0.239	0.138	.364(**)
LP13	.487(**)	.465(**)	0.247	.443(**)	.351(**)	-0.058	.279(*)
LP14	.354(**)	.304(*)	.322(*)	.291(*)	.353(**)	-0.056	.493(**)
LP15	.495(**)	.475(**)	0.231	.386(**)	.427(**)	0.029	.491(**)
LP16	.342(**)	0.174	0.177	0.188	0.219	0.052	.491(**)
LP17	.520(**)	.410(**)	.345(**)	.450(**)	.417(**)	.305(*)	.319(*)
LP18	.515(**)	.319(*)	.462(**)	.403(**)	.302(*)	0.088	.393(**)
LP19	.370(**)	.327(*)	.349(**)	0.251	0.171	0.023	.397(**)
LP20	0.076	0.178	0.204	-0.029	0.240	-0.007	0.160
LP21	.333(**)	.347(**)	.414(**)	.413(**)	0.229	-0.007	.346(**)
LP22	.438(**)	.461(**)	.376(**)	0.237	0.213	0.193	.263(*)
LP23	.392(**)	.331(**)	.311(*)	.338(**)	.303(*)	0.168	.326(*)
LP24	.387(**)	.375(**)	.401(**)	.257(*)	.263(*)	0.230	0.212
LP25	.358(**)	.427(**)	.382(**)	.454(**)	.441(**)	0.156	.264(*)
LP26	.559(**)	.515(**)	.390(**)	.257(*)	.501(**)	0.244	.511(**)
LP27	0.251	0.186	.308(*)	.291(*)	.295(*)	-0.135	.258(*)
LP28	.380(**)	.315(*)	0.066	.380(**)	0.152	-0.097	.269(*)

NOTE:
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.001 level

4.5 Analysis of Analytic Hierarchy Process

Analysis of analytic hierarchy process or AHP is based on case study in PAVCJM. The purpose of the AHP analysis is to verify the survey findings. This step is required in the development of lean hierarchical function deployment framework as shown in Figure 3.2.

Table 4.10 until 4.17 show the results of pair wise comparison and CR for each of the sub-criteria. The result was obtained from generated formula as discussed in sub section 2.14.3.3 (page 58) for a pairwise comparison, weighting and consistency ratio. As mentioned earlier, the main aim of the pairwise comparison method in the AHP is to make a ranking of *n* given factors or alternatives. To compare the factors the scale {1/9,1/8,…,1/2,1,2,…,8,9} were used. The criteria and dimension with the highest priority value was constructed as having the greatest degree of importance in influencing the strategic objectives and vice-versa. The consensus from focus group discussion was taken into account to determine the value of the rating point in each criterion for lean practices.

The majority of those who responded to this item felt that most of the listed criteria were important and sometimes had difficulty in determining the rating. The sub group of the lean practice helped the focus group discussion to categorise the value more reasonably. Various perspectives were expressed in the discussion also required the rating process performed in a longer time regarding to lean practices to be more accurate (Hasan, 2015).

These results suggest that the process on data collection may be significant when the focus group discussion is the process owner or expert in the discussion of the subject matter. Together these results provide important insights into the WHATs requirement critical analysis. The result also revealed the actual priorities of lean practices requirements to the firm for further research analysis.

Table 4.10 Pair Wise Comparison Matrix for SPT Sub-Criteria

	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8
LP1	1.00	0.33	0.50	1.00	1.00	1.00	0.50	1.00
LP2	3.03	1.00	1.00	2.00	2.00	1.00	2.00	2.00
LP3	2.00	1.00	1.00	1.00	2.00	1.00	2.00	1.00
LP4	1.00	0.50	1.00	1.00	0.50	1.00	1.00	1.00
LP5	1.00	0.50	0.50	2.00	1.00	0.50	0.50	1.00
LP6	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00
LP7	2.00	0.50	0.50	1.00	2.00	1.00	1.00	2.00
LP8	1.00	0.50	1.00	1.00	1.00	1.00	0.50	1.00
	12.03	5.33	6.50	10.00	11.50	7.50	8.50	10.00

Table 4.11 Standardized Matrix for SPT Sub-Criteria

	LP1	LP2	LP3	LP4	LP5	LP6	LP7	LP8
LP1	0.083	0.062	0.077	0.100	0.087	0.133	0.059	0.100
LP2	0.252	0.188	0.154	0.200	0.174	0.133	0.235	0.200
LP3	0.166	0.188	0.154	0.100	0.174	0.133	0.235	0.100
LP4	0.083	0.094	0.154	0.100	0.043	0.133	0.118	0.100
LP5	0.083	0.094	0.077	0.200	0.087	0.067	0.059	0.100
LP6	0.083	0.188	0.154	0.100	0.174	0.133	0.118	0.100
LP7	0.166	0.094	0.077	0.100	0.174	0.133	0.118	0.200
LP8	0.083	0.094	0.154	0.100	0.087	0.133	0.059	0.100

	T	W	AW	AW/T	λ_{max}	RI	CI	CR
LP1	0.701	0.088	0.555	0.791	8.920	1.410	0.131	9.322
LP2	1.536	0.192	2.694	1.754				
LP3	1.250	0.156	1.719	1.375				
LP4	0.825	0.103	0.722	0.875				
LP5	0.766	0.096	0.671	0.875				
LP6	1.049	0.131	1.181	1.125				
LP7	1.062	0.133	1.327	1.250				
LP8	0.810	0.101	0.709	0.875				

Table 4.12 Pair Wise Comparison Matrix for MMU Sub-Criteria

	LP9	LP10	LP11	LP12	LP13	LP14	LP15
LP9	1.00	1.00	1.00	0.50	2.00	1.00	0.50
LP10	1.00	1.00	1.00	1.00	0.50	1.50	1.00
LP11	1.00	1.00	1.00	0.67	1.00	0.50	0.50
LP12	2.00	1.00	1.49	1.00	1.00	1.00	0.50
LP13	0.50	2.00	1.00	1.00	1.00	1.00	0.50
LP14	1.00	0.67	2.00	1.00	1.00	1.00	0.40
LP15	2.00	1.00	2.00	2.00	2.00	2.50	1.00
	8.50	7.67	9.49	7.17	8.50	8.50	4.40

Table 4.13 Standardized Matrix MMU Sub-Criteria

	LP9	LP10	LP11	LP12	LP13	LP14	LP15
LP9	0.118	0.130	0.105	0.070	0.235	0.118	0.114
LP10	0.118	0.130	0.105	0.139	0.059	0.176	0.227
LP11	0.118	0.130	0.105	0.093	0.118	0.059	0.114
LP12	0.235	0.130	0.157	0.139	0.118	0.118	0.114
LP13	0.059	0.261	0.105	0.139	0.118	0.118	0.114
LP14	0.118	0.087	0.211	0.139	0.118	0.118	0.091
LP15	0.235	0.130	0.211	0.279	0.235	0.294	0.227

	T	W	AW	AW/T	λ_{max}	RI	CI	CR
LP9	0.890	0.127	0.890	1.000	7.747	1.320	0.125	9.432
LP10	0.955	0.136	0.955	1.000				
LP11	0.737	0.105	0.597	0.810				
LP12	1.011	0.144	1.155	1.142				
LP13	0.913	0.130	0.913	1.000				
LP14	0.881	0.126	0.889	1.010				
LP15	1.612	0.230	2.879	1.786				

Table 4.14 Pair wise comparison matrix for ISC sub-criteria

	LP16	**LP17**	**LP18**	**LP19**	**LP20**	**LP21**
LP16	1.00	1.00	2.00	2.00	1.00	2.00
LP17	1.00	1.00	2.00	2.00	1.00	1.00
LP18	0.50	0.50	1.00	2.00	0.67	1.00
LP19	0.50	0.50	0.50	1.00	0.67	0.67
LP20	1.00	1.00	1.49	1.49	1.00	1.00
LP21	0.50	1.00	1.00	1.49	1.00	1.00
	4.50	5.00	7.99	9.99	5.34	6.67

Table 4.15 Standardized Matrix for ISC sub-criteria

	LP16	**LP17**	**LP18**	**LP19**	**LP20**	**LP21**
LP16	0.222	0.200	0.250	0.200	0.187	0.300
LP17	0.222	0.200	0.250	0.200	0.187	0.150
LP18	0.111	0.100	0.125	0.200	0.125	0.150
LP19	0.111	0.100	0.063	0.100	0.125	0.100
LP20	0.222	0.200	0.187	0.149	0.187	0.150
LP21	0.111	0.200	0.125	0.149	0.187	0.150

	T	**W**	**AW**	**AW/T**	**λ_{max}**	**RI**	**CI**	**CR**
LP16	1.360	0.227	2.040	1.500	6.581	1.240	0.116	9.375
LP17	1.210	0.202	1.613	1.333				
LP18	0.812	0.135	0.767	0.945				
LP19	0.600	0.100	0.384	0.640				
LP20	1.096	0.183	1.276	1.164				
LP21	0.923	0.154	0.922	0.999				

Table 4.16 Pair wise comparison matrix for WO sub-criteria

	LP22	LP23	LP24	LP25	LP26	LP27	LP28
LP22	1.00	1.00	1.00	2.00	1.00	1.00	1.00
LP23	1.00	1.00	1.00	2.00	1.50	1.00	1.00
LP24	1.00	1.00	1.00	1.00	1.00	1.50	1.50
LP25	0.50	0.50	1.00	1.00	2.00	1.00	1.00
LP26	1.00	0.67	1.00	0.50	1.00	1.00	1.00
LP27	1.00	1.00	0.67	1.00	1.00	1.00	1.00
LP28	1.00	1.00	0.67	1.00	1.00	1.00	1.00
	6.50	6.17	6.33	8.50	8.50	7.50	7.50

Table 4.17 Standardized Matrix for WO sub-criteria

	LP22	LP23	LP24	LP25	LP26	LP27	LP28
LP22	0.154	0.162	0.158	0.235	0.118	0.133	0.133
LP23	0.154	0.162	0.158	0.235	0.176	0.133	0.133
LP24	0.154	0.162	0.158	0.118	0.118	0.200	0.200
LP25	0.077	0.081	0.158	0.118	0.235	0.133	0.133
LP26	0.154	0.108	0.158	0.059	0.118	0.133	0.133
LP27	0.154	0.162	0.105	0.118	0.118	0.133	0.133
LP28	0.154	0.162	0.105	0.118	0.118	0.133	0.133

	T	W	AW	AW/T	λ_{max}	RI	CI	CR
LP22	1.094	0.156	1.250	1.143	7.286	1.320	0.048	3.608
LP23	1.152	0.165	1.399	1.214				
LP24	1.109	0.158	1.268	1.143				
LP25	0.936	0.134	0.936	1.000				
LP26	0.863	0.123	0.760	0.881				
LP27	0.923	0.132	0.879	0.952				
LP28	0.923	0.132	0.879	0.952				

4.5.1 AHP Ranking

Based on the results from pairwise comparison and weightage calculation, it can be summarised and ranked each of the main criteria and sub-criteria as in Table 4.18. Each of the sub-criteria weight must be multiplied by weight of main criteria for each category to measure overall weightage. In overall weightage, each of sub-criteria is given a ranking.

Table 4.18 The overall weightage and ranking for each sub-criterion

NO.	CRITERIA	W*i*	Overall W	Rank
	Shortening process time (0.25)			
LP2	Decrease Customer Lead Time	0.192	0.047	1
LP3	Decrease Throughput Time	0.156	0.038	2
LP7	On Time Delivery	0.133	0.033	3
LP6	Minimise Setup Time	0.131	0.032	4
LP4	Enhanced Product Variety	0.103	0.025	5
LP8	Speed Up Changeover Time	0.101	0.025	6
LP5	High Capacity Of Innovation	0.096	0.024	7
LP1	Adaptation Of New Technology	0.088	0.022	8
	Man And Machine Use (0.30)			
LP15	Process Line Balancing	0.230	0.068	1
LP12	Operator Flexibility and Innovativeness	0.144	0.043	2
LP10	Increasing Kaizen Activities	0.136	0.040	3
LP13	Optimise Poka-Yoke	0.130	0.039	4
LP9	Effective Machine Optimization	0.127	0.038	5
LP14	Proactive TPM Practice	0.126	0.037	6
LP11	Minimise Machine Configuration	0.105	0.031	7
	Inventory And Storage Control (0.25)			
LP16	Effective Pace Of Production(Takt Time)	0.227	0.056	1
LP17	Efficient Production Levelling (Finished Goods)	0.202	0.050	2
LP20	Zero Missing/Misplace Material	0.183	0.045	3
LP21	Zero WIP (One Piece Flow)	0.154	0.038	4
LP18	Organized Jit (Raw Material)	0.135	0.033	5
LP19	Organized Kanban System (WIP)	0.100	0.025	6
	Workspace Optimisation (0.21)			
LP23	Effective Material Flow	0.165	0.035	1
LP24	Efficient Space Utilization	0.158	0.033	2
LP22	Effective Layout Configuration	0.156	0.033	3
LP25	Minimise Number Of Workstation	0.134	0.028	4
LP27	Product Quality	0.132	0.028	5
LP28	Simplified Operation Procedure	0.132	0.028	6
LP26	Minimum Cost	0.123	0.026	7

4.6 Analysis of Quality Function Deployment

The list is often referred as the WHATs that a customer needs or expect in a particular product or improvement. This list of primary (main criteria) is very general in nature. The secondary (sub-criteria) is explained in greater detail than those on the list of primary customer requirements. There are four groups of main criteria and 12 preferable sub-criteria in lean production system. The main criteria consist of shortening process time (SPT), man and machine use (MMU), inventory and storage control (ISC) and workspace optimisation (WO). Table 4.19 shows the list of customer requirement for lean assembly line (WHATs room).

Table 4.19 The list of customer requirement for lean assembly line (WHATs room)

Primary (main criteria)	Secondary (sub-criteria)	Abbreviations
Shortening process time (SPT)	Decrease Customer Lead Time	LP2
	Decrease Throughput Time	LP3
	On Time Delivery	LP7
Man and Machine Use (MMU)	Process Line Balancing	LP15
	Operator Flexibility and Innovativeness	LP12
	Increasing Kaizen Activities	LP10
Inventory and Storage Control (ISC)	Effective Pace Of Production (Takt Time)	LP16
	Efficient Production Levelling (Finished Goods)	LP17
	Zero Missing/Misplace Material	LP20
Workspace Optimisation (WO)	Effective Material Flow	LP23
	Efficient Space Utilization	LP24
	Effective Layout Configuration	LP22

4.6.1 Lean Continuous Improvement Strategies (HOWs)

The second room in HOQ represents the company requirements (technical requirement or also called as measurable requirements), which mean HOWs company take part in order to achieve the implementation of Lean continuous improvement strategies (Table 4.20).

Table 4.20 The List of Lean Continuous Improvement Strategies

Lean continuous improvement strategies	Abbreviations
Method of improvement	LS1
Share capacity	LS2
Add additional manpower or machine	LS3
Improve workstation layout	LS4
Better operator allocation	LS5
Work for extra hours	LS6
Production time saving tricks	LS7

4.6.2 Relationship between WHATs and HOWs

Tables 4.21 until Table 4.24 show the relationship between WHATs and HOWs, based on three categories of the main criteria. From Table 4.21, the analysis shows the strong relationships between LP2 with LS7. In the other words, customer lead time has a positive impact by using time saving tricks. Besides, production time saving trick can enhance all three main criteria in shortening process time. The appropriate method of improvement is believed able to shorten the process time. For decrease throughput time, add manpower or machine, or production time saving tricks were considered the most significant effort. However, this kind of strategy could increase the operational cost while increasing the input.

Table 4.21 Relationship Matrix Between Shortening process time and Lean Continuous Improvement Strategies

LPs (WHATs) \ LSs (HOWs)			LS1	LS2	LS3	LS4	LS5	LS6	LS7
SPT (0.25)	LP2	0.047	■			■	▲		●
	LP3	0.038	▲		●			▲	■
	LP7	0.033	▲				■		■

Legends:

- ● Strong Relationship (9)
- ■ Medium Relationship
- ▲ Weak Relationship (1)

Meanwhile, Table 4.22 shows that process line balancing (LP15) has significant influence to five lean continuous improvement strategies. This result was expected because previous researchers also agreed that LP15 been considered the most preferable approach to enhance productivity in lean production system (see Yilmaz and Yilmaz, 2015). This is because, for ABC Company the list of the HOWs is most related to process line balancing while work for extra hours becomes the last option in productivity improvement. Besides, operator flexibility and innovativeness, LP17 is considerable with share capacity, operator allocation and production time saving trick. Additional manpower and work for extra hours are not significant for operator flexibility and innovativeness, and increasing Kaizen activities. This results support the findings of Mohd Ghazali Maarof & Fatimah Mahmud (2016), who had found that Kaizen is influenced by process owner which experienced in the workstation on normal working hour. In fact, many industries are currently do not prefer to work for extra hours due to cost saving and green policy (Verrier et al. 2016; Reyes et al. 2018).

Table 4.22 Relationship Matrix between Man and Machine Use and Lean Continuous Improvement Strategies

LPs (WHATs) \ LSs (HOWs)			LS1	LS2	LS3	LS4	LS5	LS6	LS7
MMU (0.30)	LP15	0.068	●	●	■	●	●	▲	●
	LP12	0.043	■	●		■	●		●
	LP10	0.040	■	■		▲	■		●

Legends:

- ● Strong Relationship (9)
- ■ Medium Relationship
- ▲ Weak Relationship (1)

Table 4.23 shows the relationship between inventory and storage control and lean continuous improvement strategies. Based on QFD analysis, LS1 has significant impact on all three variables: effective pace of production (LP16), efficient production levelling (LP17) and zero missing or misplace material (LP18). In contrast, LS3, LS5 and LS6 have no relationship with the WHATs criteria.

Table 4.23 Relationship between Inventory and Storage Control and Lean Continuous Improvement Strategies

LPs (WHATs) \ LSs (HOWs)			LS1	LS2	LS3	LS4	LS5	LS6	LS7
ILA (0.25)	LP16	0.056	●			■			■
	LP17	0.050	●	▲		▲			■
	LP20	0.045	●						

Legends:

- ● Strong Relationship (9)
- ■ Medium Relationship
- ▲ Weak Relationship (1)

For workspace optimisation, LS1 or method of improvement was identified the most significant with lean strategies (see Table 4.24). In other words, the selection method of the lean tool is very crucial for workspace optimisation. This finding is also supported by Yazici (2005) in the previous research whereby method of improvement must be rely on the organisation problem statement and lean strategies. Besides, efficient space utilisation, LP24 has strong correlation with another two strategies: share capacity and improve workstation layout as stated in Padrón et al. (2009).

Table 4.24 Relationship between Workspace Optimisation and Lean Continuous Improvement Strategies

LPs (WHATs) \ LSs (HOWs)			LS1	LS2	LS3	LS4	LS5	LS6	LS7
WO (0.21)	LP23	0.035	●			■	■		■
	LP24	0.033	●	●		●			
	LP22	0.033	●	■	■	●			

Legends:

- ● Strong Relationship (9)
- ■ Medium Relationship
- ▲ Weak Relationship (1)

4.6.3 Technical Important Rating

The result for all calculation of actual importance, relative importance and rank are shown in Table 4.25. The bar graphs in Figure 4.7 and Figure 4.8 show the resulting of relative importance and ranks on the requirements at each level of the lean continuous improvement strategies.

Table 4.25 The technical importance rating between WHATs and HOWs

LPs (WHATs) \ LSs (HOWs)			LS1	LS2	LS3	LS4	LS5	LS6	LS7
SPT (0.25)	**LP2**	0.047	■			■	▲		●
	LP3	0.038	▲		■			▲	■
	LP7	0.033	▲				■		■
MMU (0.30)	**LP15**	0.068	●	●	■	●	●	▲	●
	LP12	0.043	■	●		■	●		●
	LP10	0.040	■	■		▲	■		●
ILA (0.25)	**LP16**	0.056	●			■			■
	LP17	0.050	●	▲		▲			■
	LP20	0.045	●						
WO (0.21)	**LP23**	0.035	●			■	■		■
	LP24	0.033	●	●		●			
	LP22	0.033	●	■	■	●			
Actual importance			3.341	1.565	0.417	1.839	1.37	0.106	2.418
Relative importance			30	14	4	17	12	1	22
Rank			5	2	1	3	2	0	4

<u>Legends:</u>

● Strong Relationship (9)

■ Medium Relationship

▲ Weak Relationship (1)

Based on the figures, there are three main HOWs to improve the WHATs. In other words, LS1, LS4 and LS7 have higher possibility to enhance the implementation of lean practices. The findings were similar to Oliveira et al. (2017) and Narayanamurthy and Gurumurthy (2016) which found that the method of improvement (LS1) is the most influential parameter of lean success story. Moreover, the findings showed that work for extra hours (LS6) was not preferable by PAVCJM which denying the findings in Georgiadis and Michaloudis (2012). This is because, work for extra hours is obviously add cost while discourage employees to work effectively in production line.

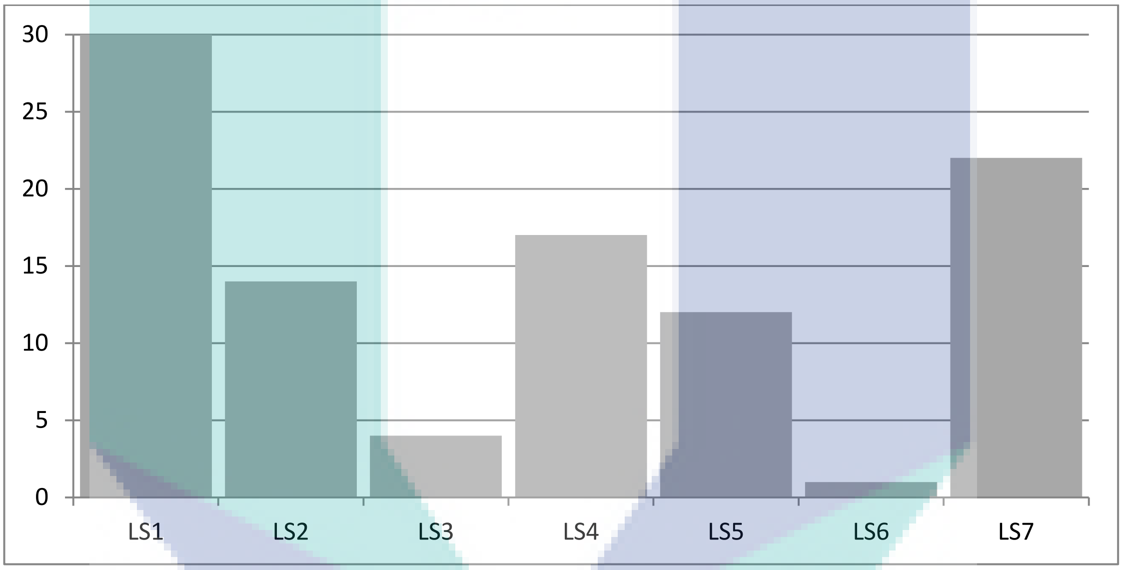


Figure 4.7 Relative importance for Lean Continuous Improvement Strategies

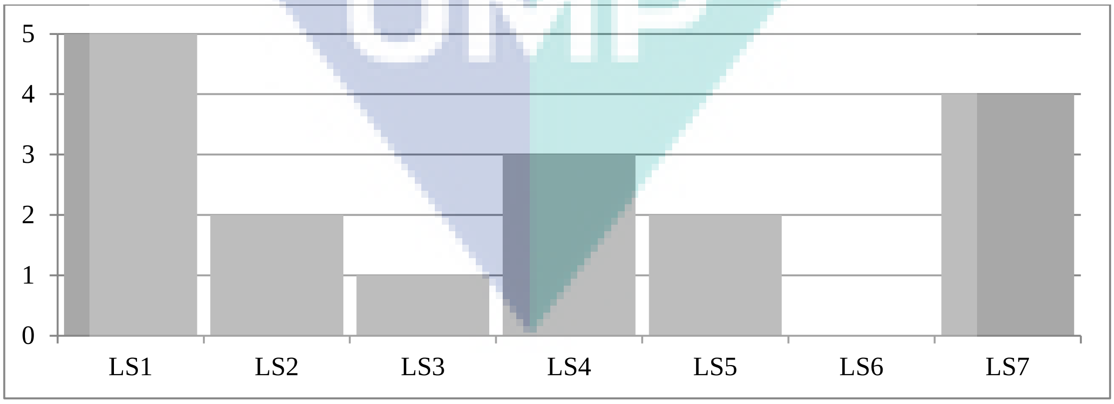


Figure 4.8 Ranking for Lean Continuous Improvement Strategies

The analysis also proved that by having structured lean hierarchical function deployment framework, the firm can find out easily on what should be done to prioritise the action for assembly line performance improvement. As suggested by Salonitis and Tsinopoulos (2016), a few of the lean practices parameters were influenced by lean continuous improvement strategies. Similarly, focusing on the specific lean continuous improvement strategies may indirectly beneficial most lean practices. However, the firm requires to plan the deployment strategy to realise the implementation. Abdullah (2018) mentioned that the deployment plan is important to ensure the effectiveness of the developed framework.

4.8 Summary

This chapter effectively discusses the development of the AHP – QFD model in the research based on the data obtained from surveys and case study. By using the datasets in each variable that has been grouped into several factors in this chapter, all important factors have gone through re-analysis of particular case study. This is to ensure that each group of factors in each variable are relevant and significant in developing the model of the research using AHP and QFD. Finally, an integration model of AHP and QFD towards better performance for lean assembly line was developed. Next chapter is modelling and simulation analysis. It explains the model deployment.

CHAPTER 5

MODELLING AND SIMULATION ANALYSIS

5.1 Introduction

This chapter discusses three forms of case studies in ABC company. The case studies were based on three Lean Continuous Improvement Strategies that have been defined as most potential for lean assembly model in QFD analysis. They are production time saving tricks, method of improvement and improve workstation layout. The data for simulation was provided by the industrial engineering department and personal time observation in the assembly line for model validation and academic purpose only. An assembly line was permitted to be considered due to unmentioned reason. All suggestions for the improvement were based on semi- structured interview, group discussion and observation.

5.2 Case Study 1: Production Time Saving Tricks

The first case study was executed based on production time saving tricks, LS7. Established in the result of QFD analysis, production time saving tricks are able to provide more significant impact for lean practices including production line. The case study aimed to simulate production line improvement using computerise simulation software. The model was developed based on current state operation system and was found imbalanced performance between 18 workstations.

5.2.1 Development of Simulation Model

Flow system was the first of many steps to make a simulation system. The importance of the process flow chart to the system was to give the guidance to the system where it was a medium to propose a good production layout. Figure 5.1 shows the flow of the processes where it contains 18 steps which were divided into three main sections: assembly preparation; main assembly line; and inspection line. Each workstation (WS) required at least one operator to do the assembly job. All of the operators work daily from 8:00 a.m. to 5:30 p.m. with an hour break between 9:30 a.m. and 10:00 a.m., one hour lunch break from 1:00 p.m. to 2:00 p.m., and 30 minute tea break after 3:30 p.m. The overtime was allowed but not more than two hours.

The processes were as follows: the assembly kit was served by the operator in assembly, prep section which involved three workstations (WS1 to WS3) where the number of workstations was determined based on machine and special product jig and fixture on the particular process. Section two was the main assembly line which distributed into two groups. Group A consist of WS4 to WS9 while group B involve WS10 until WS14. In this section, conveyor was used for material handling where each of the group had a different flow of product movement. The last section is inspection line. Four operators were required where WS16 to WS18 involve almost similar testing instrument.

The daily quantity required was 180. Table 5.1 shows the cycle time distribution that was generated by the input analyser (one of the ARENA simulation tool) to determine the best data which least square error in the model development whilst Figure 5.2 shows the ARENA simulation model.

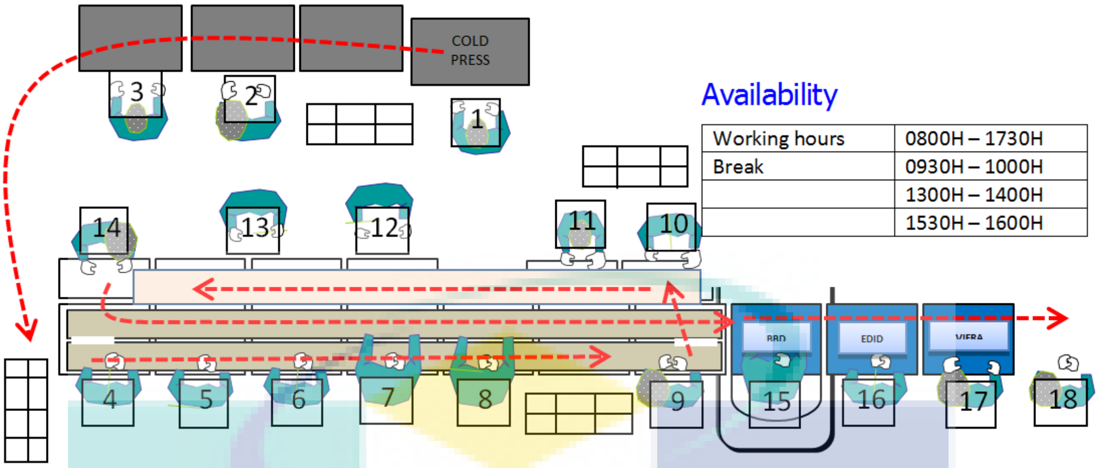


Figure 5.1 The Flow of the Current Production Line

Table 5.1 Cycle Time Distribution Analysis

WS	Mean (in second)	CT Distribution	Square Errors
WS1	75.8	75.1 + 1.45 * BETA(1.43, 1.63)	0.018456
WS2	85.7	84 + 2.96 * BETA(1.17, 0.951)	0.018570
WS3	176.0	TRIA(173, 176, 177)	0.100998
WS4	146.0	143 + 5.72 * BETA(1.07, 0.9)	0.056070
WS5	88.5	85 + 6 * BETA(0.991, 0.708)	0.008087
WS6	83.8	82.1 + LOGN(1.75, 1.44)	0.011701
WS7	112.0	110 + LOGN(1.93, 1.3)	0.019281
WS8	113.0	109 + 7 * BETA(0.893, 0.848)	0.057365
WS9	86.3	TRIA(83.1, 87.1, 88.8)	0.013379
WS10	69.1	66 + 5 * BETA(0.835, 0.525)	0.044335
WS11	71.8	TRIA(70.3, 70.6, 74.5)	0.004522
WS12	88.6	85 + 6 * BETA(1.1, 0.777)	0.022879
WS13	75.5	UNIF(73, 78)	0.020000
WS14	85.1	NORM(85.1, 1.39)	0.027741
WS15	73.1	71 + GAMM(0.989, 2.11)	0.047108
WS16	82.2	UNIF(80, 84)	0.080000
WS17	86.7	TRIA(83.2, 88, 89)	0.050658
WS18	58.6	56.3 + LOGN(2.45, 1.83)	0.061772

Source: ABC Company (2017)

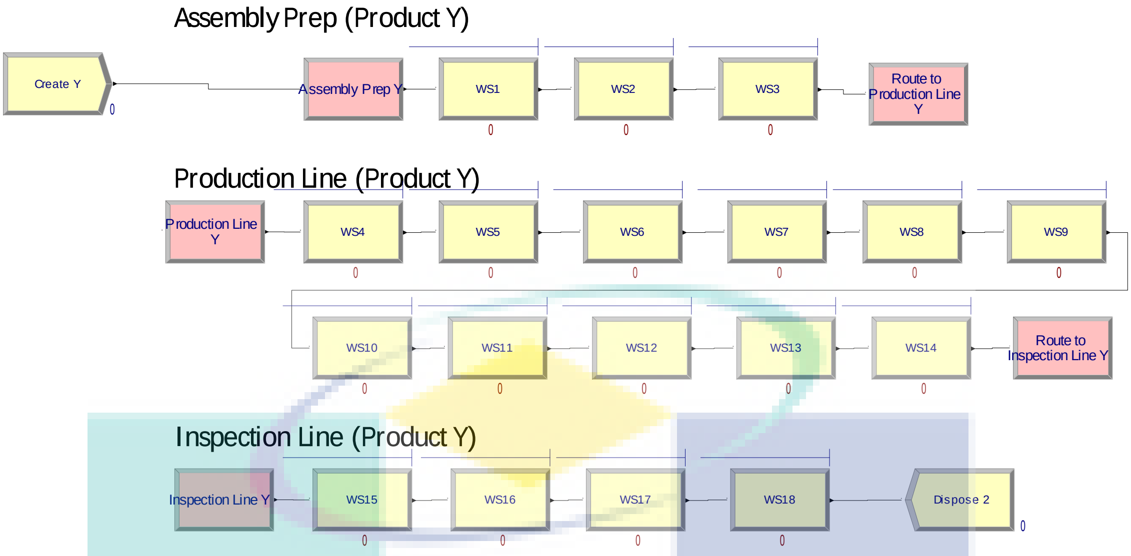


Figure 5.2 ARENA Simulation Model

5.2.2 Verification of Simulation Model

Verification was a medium to identify the simulation either the simulation was good enough to implement or not. Verification of simulation model could be done by counting the number of outputs and compare the similarities of the production of the actual production line with the simulation model. The reason verification method was made to identify the confident level of the simulation model. Table 5.2 shows the verification of the simulation model by using the data from the study.

Table 5.2 The Verification Process of the Simulation System

Content	Actual Production line	Simulation model
Input	180	180
Output	148	145
Different	3	-
Level verification	100 – (3/148 * 100)	97.97%

The input of the line was 180 and it was similar to the simulation, but the difference was the number of the output produced. The total output of the actual production line was 148 sets compare to the output produce by the simulation model which was 145 sets. Both the actual and the simulation model were based on the same data of time study. The verification of calculation was based on the differences of number of output produced.

The results showed the difference of the output was 3 sets, the simple calculation and the total calculation showed that the confidence level of the simulation model is about 97.97%. In other words, the simulation model and actual production line have 97.97% similarities. There was standard verification that the simulation should follow in order to achieve a good simulation with higher similarities between both the actual line and the simulation model, the simulation with a total verification of 95% and above, the simulation had a complete similarity with the actual production line but if it was below 95%, the simulation confident level was considered low.

The similarities of both actual production line and simulation model was important because as both of the lines have high similarities, the problem caused by the actual production line now can be easily monitored by the simulation model.

5.2.3 Analysis of Takt Time

Figure 5.3 shows the analysis of takt time. From the figure, cycle time at WS3 was the highest. The analysis also showed that some processes have the potential to be merged, but it was limited to, process or job design in the particular workstation including special machinery or equipment or jig and fixture. The WS1, WS2, WS5, WS6, WS10 to WS18 were the most potential workstation to be combined if the company required to reduce the number of workstations. Besides, they also can optimise the manpower utilization through job rotation or job enlargement as suggested by previous researchers (Mossa et al., 2016; Bortolotti et al., 2015).

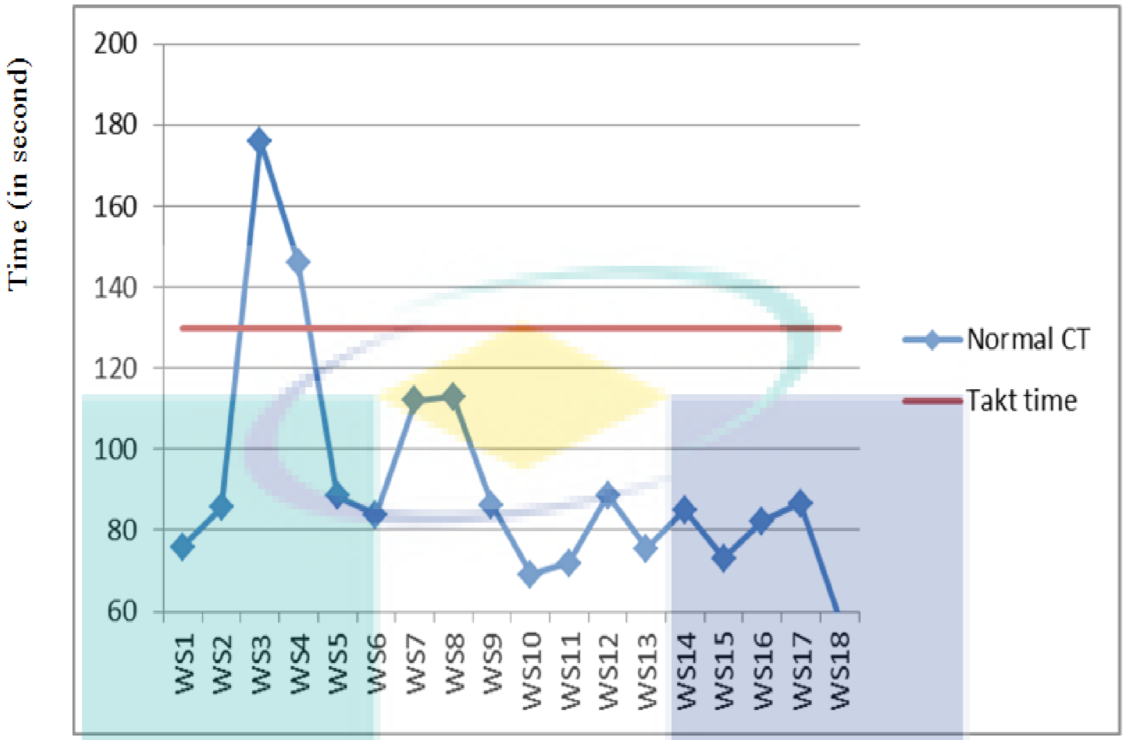


Figure 5.3 Analysis of Takt time

Alnahhal and Noche (2013) mentioned that mixed model assembly lines was influenced the material flow effectiveness. Thus, there were four alternatives of working hour had been considered: normal working hour (9.5 hours); normal working hour with 1-hour overtime job (10.5 hours); 1.5 hours (11 hours) and 2 hours (11.5 hours).

The considerations of all four alternatives were due to the takt time limitation. If any process is equal to or more than the takt time value, the overtime is not applicable. This constraint was the first consideration in the production line balancing.

Figure 5.4 shows the new takt time comparison. As can be seen in Figure 5.4, at least 1.5 hours overtime job was able to make sure the production meets the daily quantity demand.

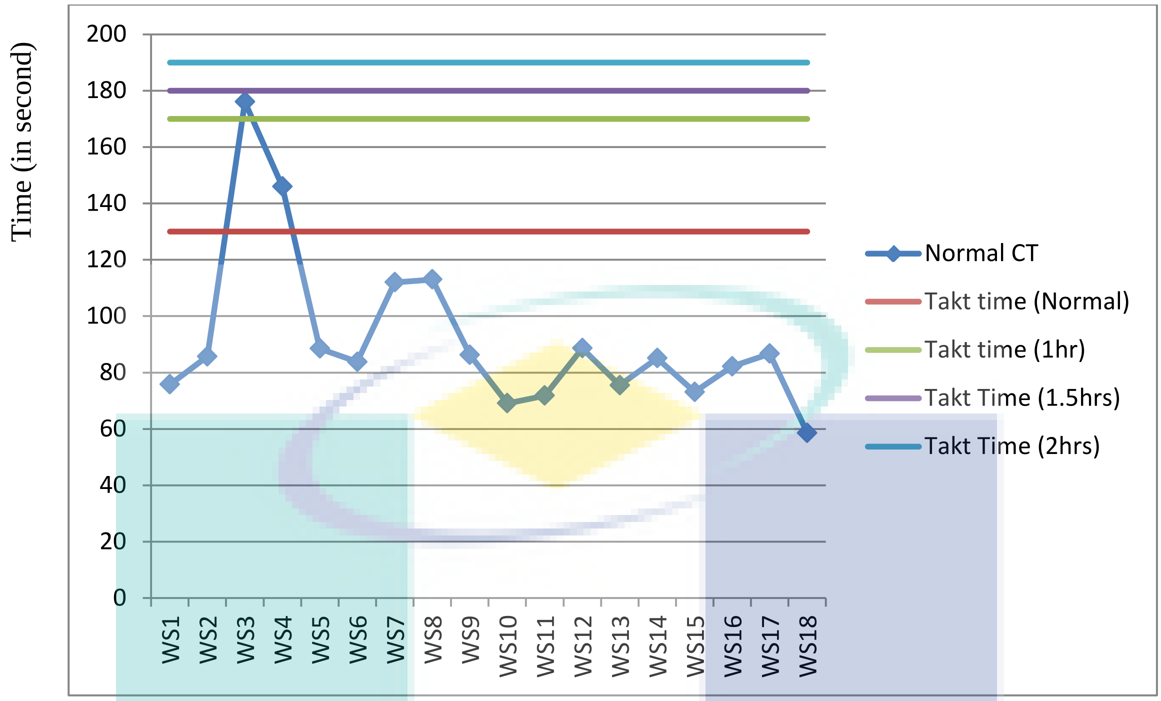


Figure 5.4 Comparison of Takt time

The calculation of takt time was as follows:

Given information:

Normal working hours: 9.5 hrs

Normal break time: 2 hrs

Available Working Hours per Day = 9.5 – 2 = 6.5 hrs ~ 23400 seconds

Daily Quantity Required = 180 units

$\therefore$ Takt Time = 23400 ÷ 180 = 130 seconds

If the overtime job is allowed (for example WS1) the new cycle time will be considered as follows:

WS1 normal cycle time = 75.8s

With 1 hour overtime job will give additional 20 seconds to operator to meet daily quantity demand, 180 units of finish goods. In other words, the new specific standard cycle time will increase while the operator has a chance to complete at least 47 unit additional product in WS1.

Given information:

Additional working hours: 1 hour ~ 3600 seconds

Daily Quantity Required = 180 units

Normal cycle time for WS1 = 75.8 s

Additional time for WS1= 75.8 + (3600/180) = 95.8 seconds, OR

Additional WIP product completion = 3600 ÷ 75.8 = 47.49 ~ 47 units

5.2.4 Analysis of WIP and Manpower Utilisation

Based on the four types of working hours, six ARENA model configurations were performed. This idea was inspired by Battini et al. (2009) in introducing optimal policy in an assembly line. Table 6.3 shows the result of the analysis which represented by A (current performance with normal working hour), B (extended 1 hour working hour), C (with 1.5 hours overtime job), D (with 2 hours overtime job), E (with 1.5 hours overtime job into two types working hour: WS1 – WS9: 800H – 1730H; WS10 – WS18: 830H – 1800H), and F (Standard working hour (with additional 1 manpower at WS3), flexibility job in WS16, WS17 and WS18 and two type of working hours: WS1 – WS9: 800H – 1730H; WS10 – WS18: 830H – 1800H).

The configurations were based on potential generated output, WIP and manpower utilisation (MU). The settings also consider the low cost impact and work balance for dynamic and innovative approach (as suggested by Behrouzi & Wong, 2011). From Table 5.3, it can be seen that the configuration on A, B and C was not meeting the daily quantity required – 180. The A has 35 WIP where B and C are 14 and 4 respectively. WS3 was the most critical workstation when A and B was nominated. For D, E and F, the result show that no WIP was generated, but the costs involve were varied. Meanwhile, D and E offer additional six products if required.

Table 5.3 WIP and Manpower Utilisation

WS	A	B	C	D	E	F
	WIP	WIP	WIP	MU	MU	MU
WS1	-	-	-	32.96%	32.95%	37.89%
WS2	-	-	-	37.24%	37.22%	42.82%
WS3	27	7	-	76.20%	76.25%	43.95%
WS4	1	1	-	63.61%	63.60%	72.95%
WS5	1	-	-	38.44%	38.50%	44.14%
WS6	-	1	-	36.44%	36.44%	41.83%
WS7	1	-	-	48.68%	48.61%	56.03%
WS8	-	1	-	48.98%	49.01%	56.21%
WS9	1	-	-	37.59%	37.52%	43.15%
WS10	-	1	1	29.99%	29.99%	34.50%
WS11	1	-	-	31.17%	31.18%	35.91%
WS12	-	1	1	38.41%	38.41%	44.10%
WS13	1	-	-	32.76%	32.77%	37.75%
WS14	-	1	-	37.00%	37.05%	42.57%
WS15	1	-	1	31.73%	31.78%	36.57%
WS16	-	1	-	35.63%	35.64%	40.97%
WS17	1	-	1	37.74%	37.67%	43.35%
WS18	-	-	-	25.64%	25.63%	29.33%
Total WIP	35	14	4	-	-	-
Max Output	145	166	176	186	186	180

Figure 5.5 shows the manpower utilisation graph. From Figure 5.5, the F was greater than D or E because it can improve the utilisation of several workstations and consider more balance. For F, the range of manpower utilisation was 43.62 percent, while D and E were 50.56 and 50.62 percent respectively.

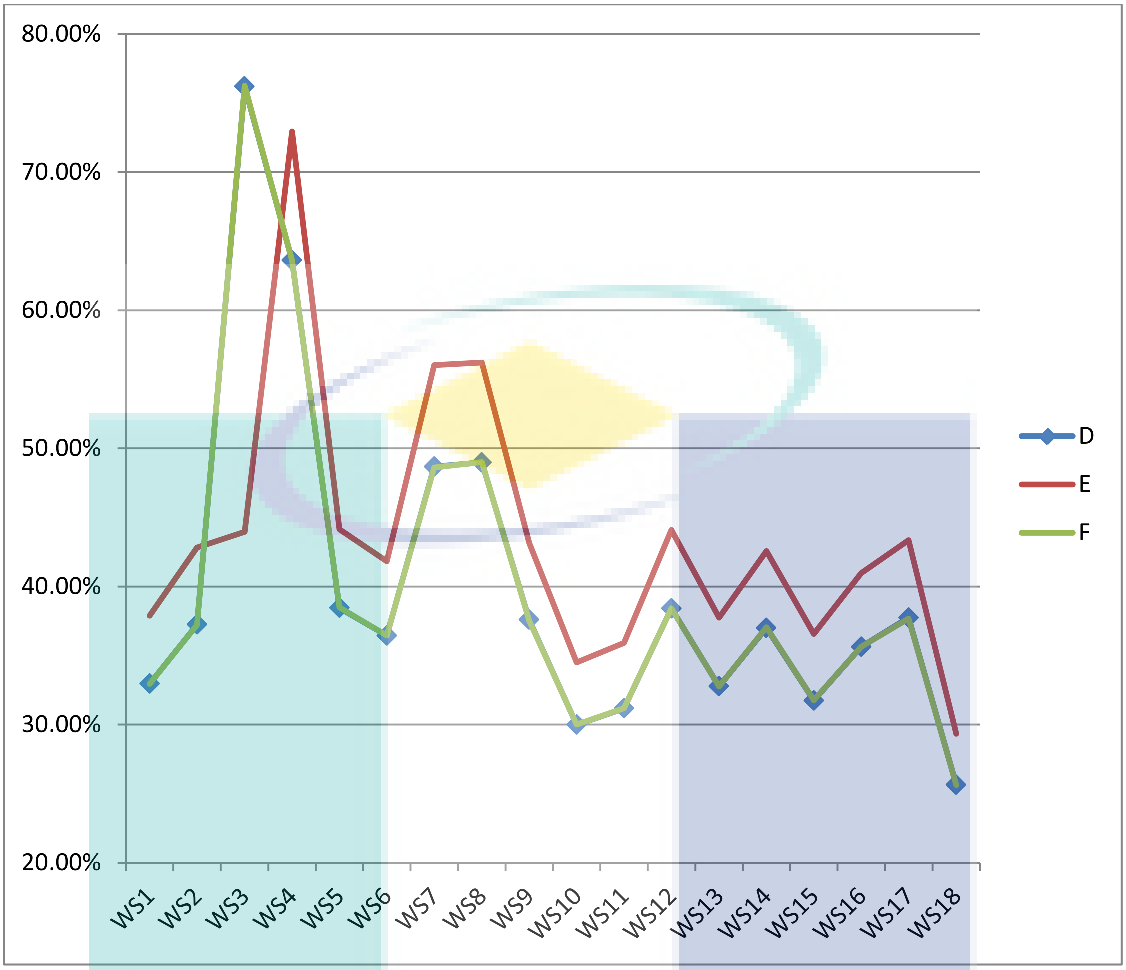


Figure 5.5 Analysis of Manpower Utilisation

5.2.5 Cost Effective for Using Time Saving Tricks

Table 5.5 shows cost effective or additional cost for production line based on previous outcomes. For this analysis, only strategy D, E and F had gone through the cost calculation. As can be seen in Table 5.5, strategy D and E just prefer working on extra hour while strategy F suggests to add new worker to support WS3 which reported has highest buffer or WIP. By accepting that, hiring new workers affects new addition cost RM 80.00 daily. Although, adding one new employee in critical workstation, the strategy proved that it was able to be a cost effective strategy compared to D and E. Figure 5.6 shows that working with extra hour provide bad financial impact.

Table 5.4 Cost Effective for Using Time Saving Tricks

	New worker	Over time (1.5 Hrs)	Over time (2 Hrs)	Additional Cost (RM) *	
				Day	Month
D	-	-	18	540.00	13500.00
E	-	18	-	405.00	10125.00
F	1	-	-	80.00	2000.00

NOTE: * Assumption cost:

New Worker = RM 2000.00/ Month ~ RM 2000.00/25 = RM80.00/ Day
Average number workings per month = 25 days
Overtime = RM 15.00/ hour

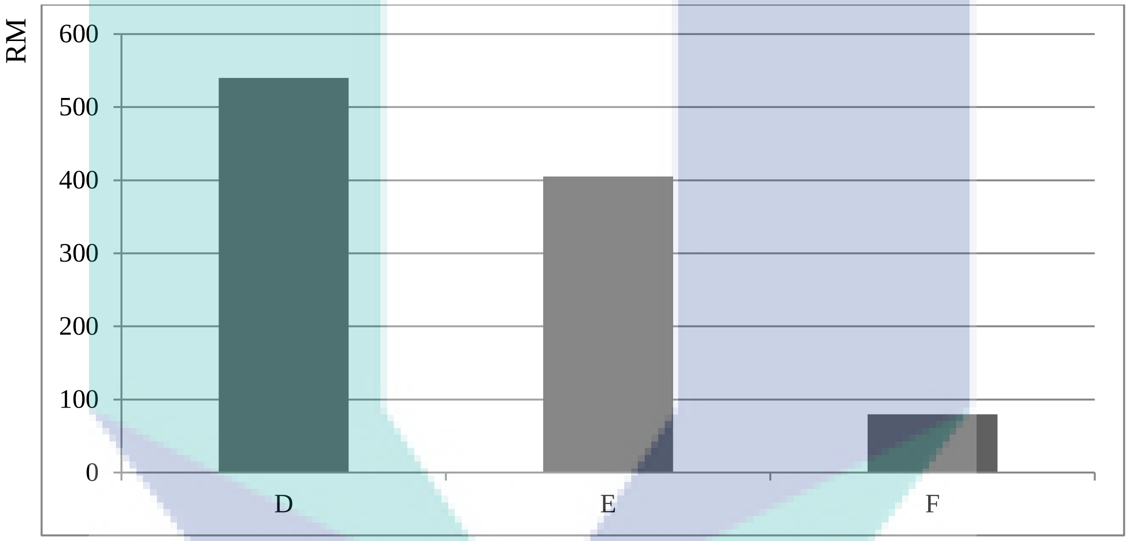


Figure 5.6 Daily additional Cost Expenditure

5.3 Case study 2: Method of improvement

The scope of this second case study focusses on the use of method of improvement (LS1) in assembly production line. Regarding the productivity, one of the production assembly line was considered a problem when the amount of product per day less than what was targeted. Production line personnel and several operators mentioned that there needs some improvement to reduce production time without involving major change on the current layout and workstation. The information such as the layout, the target setting, cycle time were all gathered. The results were presented by project consists 13 methods of improvement. The projects had different types of problem statement as shown in Table 5.5.

Table 5.5 Method of improvement Project Details

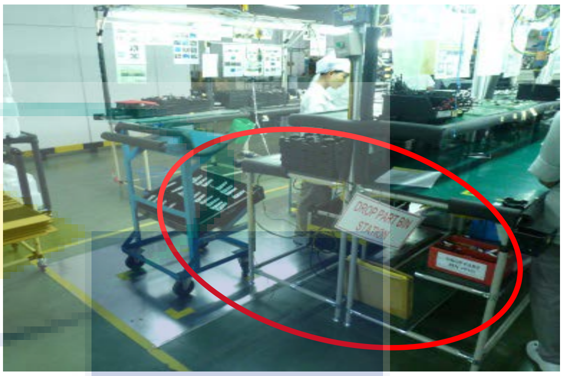
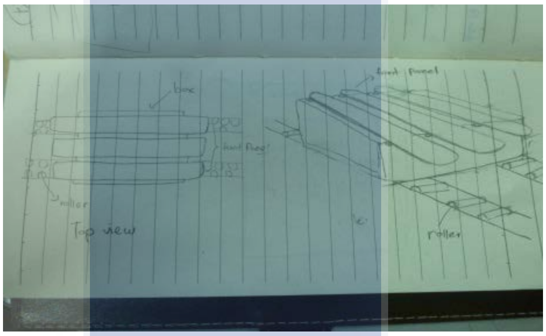
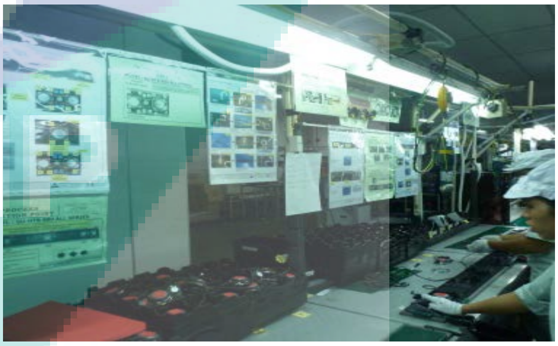
Project Description	**Figures**
Project 1: Problem statement: Lead time almost fluctuating due to moving operator from WS3 to WS4. See Figure 5.7. Counter measure: Make a roller conveyor with box between WS3 to WS4 to reduce lead time and increase the efficiency of carrying front panel. See Figure 5.8. Impact: Reduce by 0.1 sec	 Figure 5.7 WS3 and WS4  Figure 5.8 Example of Roller Conveyor
Project 2: Problem statement: WS2 to WS8 facing problem regarding missing component on front panel. See Figure 5.9. Counter measure: Provide checking template to every station to make sure the next operator will do quick checking to the component assembled by a previous operator before starting their next process. Impact: Reduce by 2.0 sec	 Figure 5.9 WS8

Table 5.5 Continued

Project Description	Figures

Project 3:

Problem statement:
Problem carrying panel from one station to another (passing set). Defect of the front panel that come from a box. Usually operator WS1 (see Figure 5.10) needs to do checking first to make sure the panel OK or NG. Waste on movement. Walk 4 foots step.

Counter measure:
Make a roller conveyor with fixture on each of table station to reduce movement of operator sending set to another station and reduce no of cabinet used.

(i) Add process for RP-Prep operator for checking front appearance before arranging at cabinet.
(ii) Provide light at the front and rear cabinet so the operator is easier to check for defect (see Figure 5.11). Reduce movement time.

Impact: Reduce by 0.2 sec

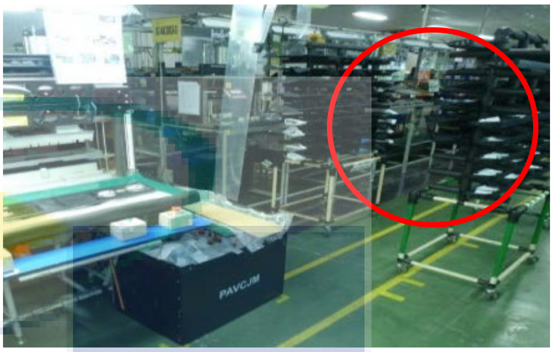


Figure 5.10 WS1

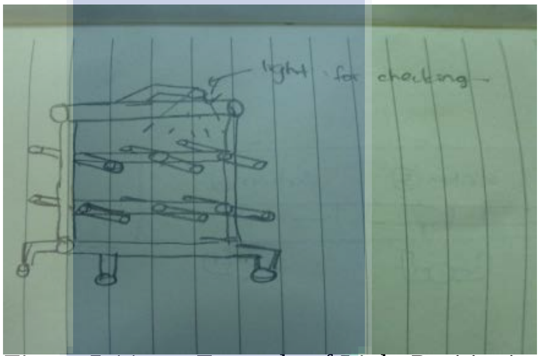


Figure 5.11 Example of Light Positioning

Project 4:

Problem statement:
The box carries items such as PCB are usually placed at the bottom of floor.

Counter measure:
Make a small table to hold the box carry item such as PCB from supplier to ease the operator in order to take the item from the box without many movements. It can avoid the operator to suddenly kick into the box.

Impact: Reduce by 0.1 sec


Figure 5.12 Example of PCB

Table 5.5 Continued

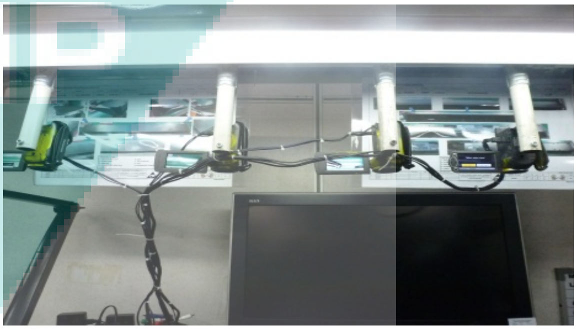
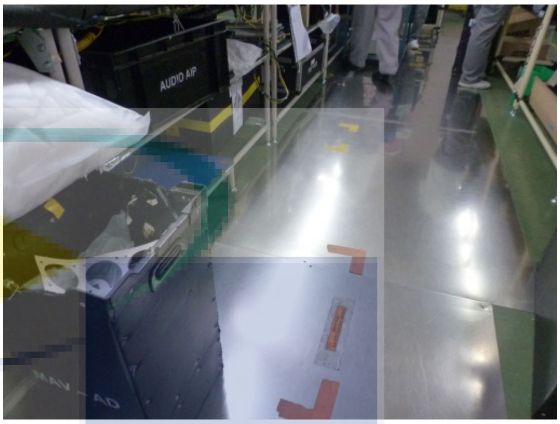
Project Description	Figures
Project 5: Problem statement: One unused table place between WS8 and 9 (see Figure 5.13). Counter measure: Remove one table station between WS9 and 8 so it can reduce the length on an assembly line. Impact: Reduce length by 1.3 m. Reduce by 0.5 sec	 Figure 5.13 Unactive Workstation
Project 6: Problem statement: The operator takes a time for making alignment net on a cold press jig (see Figure 5.14). Counter measure: Make more stoppers on a jig in cold press machine to reduce time for alignment of the net done by the operator on WS1. Impact: Reduce by 0.1 sec	 Figure 5.14 Cold Press Machine
Project 7: Problem statement: Checking the appearance and screw on rear panel taking long time that make the checking slow. Counter measure: Provide camera with high resolution on the appearance check station to provide better vision tracing the defect on set and checking the number of screws on set. (see Figure 5.15) Impact: Reduce by 0.1 sec	 Figure 5.15 Example of Camera Positioning

Table 5.5 Continued

Project Description	**Figures**
Project 8: Problem statement: Subwoofer assembly's places are rather too far from the pairing station. It takes about 7 seconds to go to pairing station, WS23. See Figure 5.16. Counter measure: Place the subwoofer assembly station beside the pairing station to make the delivery of set easier. Impact: Reduce by 0.1 sec	 Figure 5.16 WS23
Project 9: Problem statement: Problem with less efficient sending set to another station, especially for sending set from appearance check to packaging. Counter measure: Make a double way roller pallet for appearance check station and packaging to reduce time delivering set. See Figure 5.17. Impact: Reduce by 0.1 sec	 Figure 5.17 Double Way Roller
Project 10: Problem statement: The operator uses too much time on pasting hemilon on front panel. Counter measure: Make a roller jig to reduce time for an operator to paste hemilon. See Figure 5.18. Impact: Reduce by 0.1 sec	 Figure 5.18 Example of Roller Jig

Table 5.5 Continued

Project Description	**Figures**
Project 11: Problem statement: Bin (Figure 5.19) is too far from the operator to throw away unused things. Counter measure: Placed small bin on suitable table station to reduce the length for the operator to throw away the unused things. Impact: Reduce by 0.1 sec	 Figure 5.19 Bin
Project 12: Problem statement: Checking the appearance and screw on rear panel taking a long time because of the lighting on the station was poor illumination. Counter measure: Add few more lighting to provide brightness during checking the appearances. See Figure 5.20 for example. Impact: Reduce by 0.1 sec	 Figure 5.20 Example of Lamp
Project 13: Problem statement: The assembly line was too long. There was a big gap existed between the workstations. Counter measure: Remove the appearances, check the table station out from the assembly line and placed beside the wall to reduce the line length. See Figure 5.21. Impact: Reduce length by 1.5 m. Reduce by 0.5 sec	 Figure 5.21 Example of Gap

The findings show that at least 13 projects had been performed to improve the lead time reduction program. The method of improvement project also had encouraged operator to participate in the research. The operators were the process owner and have had longer experience in the assembly line and able to provide basic information on the process. Besides, the process owners also the experts because he or she spent most of the working time and the input from them were very crucial to support decision making (Coffey & Thornley, 2006). Table 5.6 summarise the project lean waste identification and suggestion for counter measure from method for improvement.

Table 5.6 Summary of the project lean waste identification and suggestion for counter measure from method for improvement

Project No	Problem Statement (Lean waste)	Suggestion for Counter measure
1	Motion	Use roller convenyor to eliminate unnessary motion
2	Overprocessing	Introduce new checking template to guide the operator as new standard operation procedure (SOP) to minimize overprocessing activities while perform inspection.
3	Transportation	Design and develop new jig and fixture that significant with material handling activities.
4	Overprocessing	Re-arangge and new setting for PCB rack to minimize overprocessing and operator motion.
5	Motion	Remove unused workstation to reduce motion while improving the time to deliver for the next workstation.
6	Overprocessing/Defect	Provide a poka yoke guideline (stopper) to avoid defect and overprocessing activities including rework.
7	Overprocessing/Defect	Use visual control device such as camera to monitor the process as a signal for missing part of misplace items.

Table 5.6 Continued

Project No	Problem Statement (Lean waste)	Suggestion for Counter measure
8	Motion	Detach workstation which use same tool or equipment for assembly process and reconsider the job scope of particular workstation towards job line balancing.
9	Transportation	Improve conveyor system by reconsidering the gap workstation to reduce time to delivery.
10	Overprocessing/Defect	Use a special jig to minimise the probability of the failure or defect on the final product.
11	Motion	Replacement of waste bin to minimise operator motion to throw away the unused items (physical waste).

From the observation, it was found that the range or workstation gap had influenced unnecessary time or also called as non-value added time for lead time. Project 1, 3, 5, 8, and 13 were the examples of the issue. The line manager should be aware about this because the neglects on these settings would affect the poor lead time result (Domingo et al., 2007). The layout had utilized more space (not purely optimised) and the scenario able to add the cost of the energy and moving. Next, the use of special jig and fixture were required to improve lead time on the assembly line. Project 1, 2, 3, 4, 6, 7, 8, 10 and 11 show that by having a new or additional jig and fixtures, it was able to reduce cycle time. Besides, poor ergonomics, workstation were influenced bad result in time consuming as indicated by project 12.

Prashar (2014) suggested that the assembly line should be able to redesign and every single member of the assembly line group must be accountable to the process improvement in the workstations. Analysis of performance must regularly be performed on the basis of daily demand, which in line with customer Takt time. An assembly line must extent to achieve the ultimate goal, such as perfection and ideal state of production operation.

5.4 Case Study 3: Improve Workstation Layout

From observation and group discussion with production line personnel, the usage of the current layout was considered beyond the capacity. Besides, the assembly line required operators employ unnecessary time for taking material from previous process and passing the work in progress product to the next station. Motion lost by the operator, the operator needs to take the set and walk to their station to begin assembling. In addition, the material handling or inventory are too messy and not suit lead to problem on sending inventory and material for assembly were not enough which caused the assembly process delay. The production line was too long, there were unnecessary table placed in the line make the line longer. Figure 5.22 shows the current layout of the assembly line.

After considering the above factors and other constraints such several operators who only skilled at using a certain machine and each of the operators have an approval tag as evidence that the operator itself skilled at certain station for handling certain equipment, proposed layout is determined as in Figure 5.23.

As can be seen in Figure 5.23, there are several strategies that had been identified, including minimise working space, remove backward conveyor, applying one-piece flow production line, and relocating buffer for WIP material handling. The proposed layout may improve at least six workstations; WS3, WS11, WS14, WS18, WS22 and WS23 with specific improvement ratio. Table 5.7 shows comparative cycle time distribution analyses (current vs. proposed layout) while the details time is presented in APPENDIX E.

Based on the analysis, the proposed layout was improved at least 22.68% space utilisation in the production area. In other word, the manufacturing company will improve the production capacity.

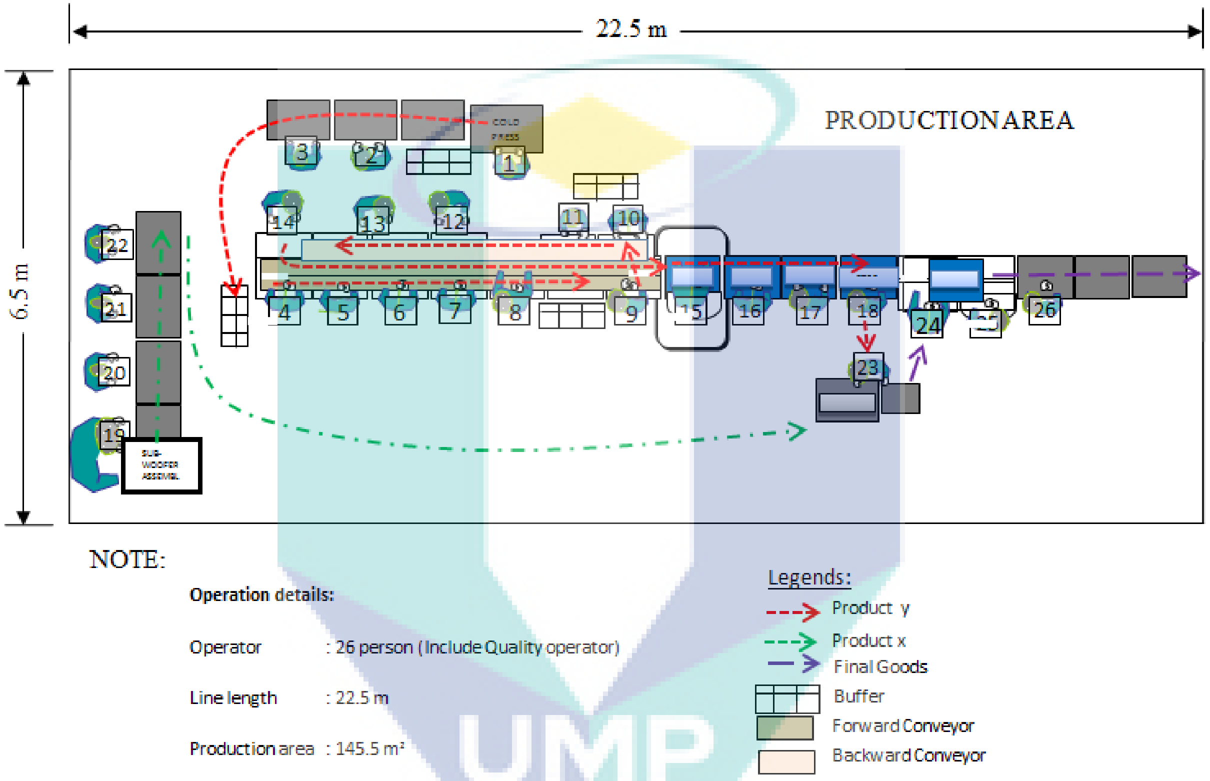
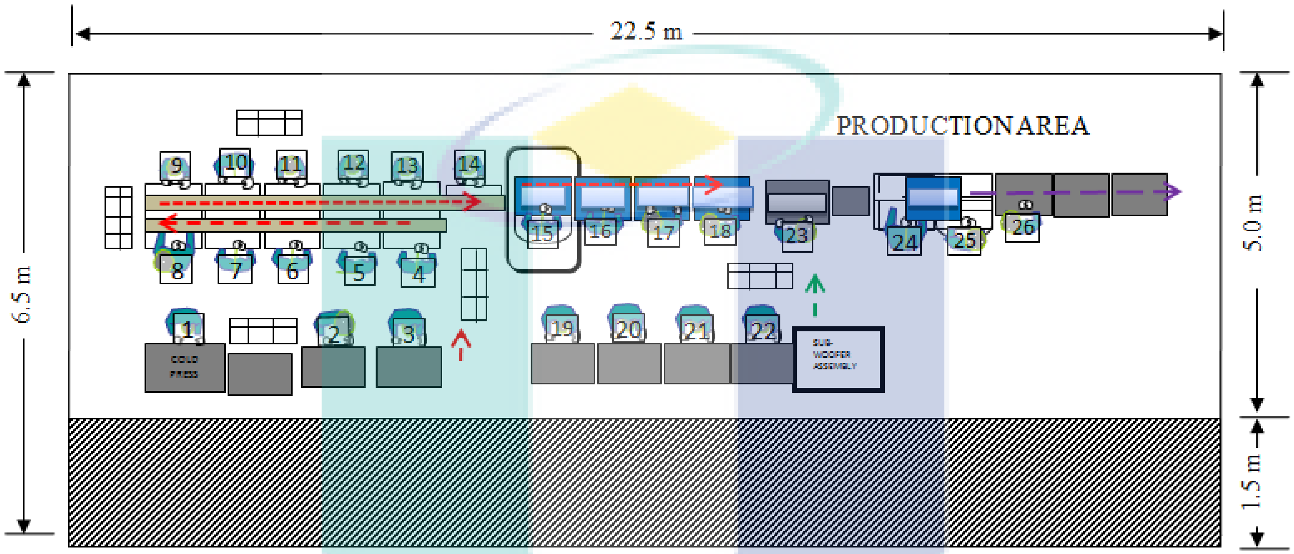


Figure 5.22 Current Layout of an Assembly Line



NOTE:

Operation details:

Operator : 26 person (Include Quality operator)

Line length : 22.5 m

Production area : 112.5 m²

Legends:

- Product y
- Product x
- Final Goods
- Buffer
- Forward Conveyor
- Extra Production Area

Figure 5.23 Proposed Layout of an Assembly Line

Table 5.7 Comparative Cycle Time Distribution Analysis (Current vs Proposed Layout)

WS	CT Distribution (Original Layout)	Improvement Ratio	CT Distribution (Proposed Layout)
WS1	75.1 + 1.45 * BETA(1.43, 1.63)	1:1	75.1 + 1.45 * BETA(1.43, 1.63)
WS2	84 + 2.96 * BETA(1.17, 0.951)	1:1	84 + 2.96 * BETA(1.17, 0.951)
WS3	TRIA(173, 176, 177)	**1:3**	**TRIA(173, 175, 176)**
WS4	143 + 5.72 * BETA(1.07, 0.9)	1:1	143 + 5.72 * BETA(1.07, 0.9)
WS5	85 + 6 * BETA(0.991, 0.708)	1:1	85 + 6 * BETA(0.991, 0.708)
WS6	82.1 + LOGN(1.75, 1.44)	1:1	82.1 + LOGN(1.75, 1.44)
WS7	110 + LOGN(1.93, 1.3)	1:1	110 + LOGN(1.93, 1.3)
WS8	109 + 7 * BETA(0.893, 0.848)	1:1	109 + 7 * BETA(0.893, 0.848)
WS9	TRIA(83.1, 87.1, 88.8)	1:1	TRIA(83.1, 87.1, 88.8)
WS10	66 + 5 * BETA(0.835, 0.525)	1:1	66 + 5 * BETA(0.835, 0.525)
WS11	TRIA(70.3, 70.6, 74.5)	**1:1.5**	**68 + WEIB(1.6, 1.47)**
WS12	85 + 6 * BETA(1.1, 0.777)	1:1	85 + 6 * BETA(1.1, 0.777)
WS13	UNIF(73, 78)	1:1	UNIF(73, 78)
WS14	NORM(85.1, 1.39)	**1:5**	**NORM(82.5, 1.37)**
WS15	71 + GAMM(0.989, 2.11)	1:1	71 + GAMM(0.989, 2.11)
WS16	UNIF(80, 84)	1:1	UNIF(80, 84)
WS17	TRIA(83.2, 88, 89)	1:1	TRIA(83.2, 88, 89)
WS18	56.3 + LOGN(2.45, 1.83)	**1:1.5**	**55.5 + LOGN(2.41, 1.83)**
WS19	58.1 + 6.84 * BETA(1.86, 1.18)	1:1	58.1 + 6.84 * BETA(1.86, 1.18)
WS20	85 + ERLA(1.79, 2)	1:1	85 + ERLA(1.79, 2)
WS21	TRIA(68, 70.4, 73)	1:1	TRIA(68, 70.4, 73)
WS22	83.1 + 2.53 * BETA(1.3, 1.45)	**1:7**	**77 + 1.79 * BETA(0.9, 0.7)**
WS23	79.6 + ERLA(0.41, 3)	**1:1.2**	**79.2 + GAMM(0.386, 3.19)**
WS24	NORM(62.3, 0.659)	1:1	NORM(62.3, 0.659)
WS25	TRIA(40.7, 41.2, 43.3)	1:1	TRIA(40.7, 41.2, 43.3)
WS26	64 + 8 * BETA(0.646, 0.347)		64 + 8 * BETA(0.646, 0.347)

5.4.1 Simulation Model Development for Re-Layout

The simulation model was developed based on Figure 5.2 but it expanded up to 26 workstations. Each workstation (WS) required at least one operator to do the assembly job. All of the operators work daily from 8:00 a.m. to 5:30 p.m. with an hour break between 9:30 a.m. and 10:00 a.m., one hour lunch break from 1:00 p.m. to 2:00 p.m., and 30 minutes' tea break after 3:30 p.m. The overtime was allowed but not more than two hours.

Figure 5.24 shows a simulation model for the current layout with 26 workstations. There were two parts required to assemble in an assembly line. Compare to Figure 5.2, only a single part (part Y) was focused. At this time, WS19 to WS22 were prepare part X before delivering to WS23 for main assembly preparation. WS23 was also considered pre-assembly workstation between part X and Y. This was the bottleneck area because the workstation received both part X and Y at the same time. However, the simulation model assumes that no bottleneck in WS 22 while WS19 to WS 21 were not included in the modelling phase. The next process in WS24 to WS26 were involved the main assembly operation and final packaging. The scope of simulation model was ended at the point.

Meanwhile, Figure 5.25 shows a simulation model for the proposed layout with 26 workstations. From Figure 5.25, five workstations were involved in the improvement strategy. The improvement strategies were based on the reduction time by reducing the gap of material transportation. Improvement ratio as in Table 5.8 was considered in the simulation model.

5.4.2 Input and Output Analysis

The simulation result for 8 hour operation is shown in Table 5.8. The proposed layout is able to improve at least 0.56 percent of production rate. The simulation result gave the production personnel to decide the best improvement workstation layout. Investment cost and time to prepare the new layout influenced the manager to re-consider the improvement methods.

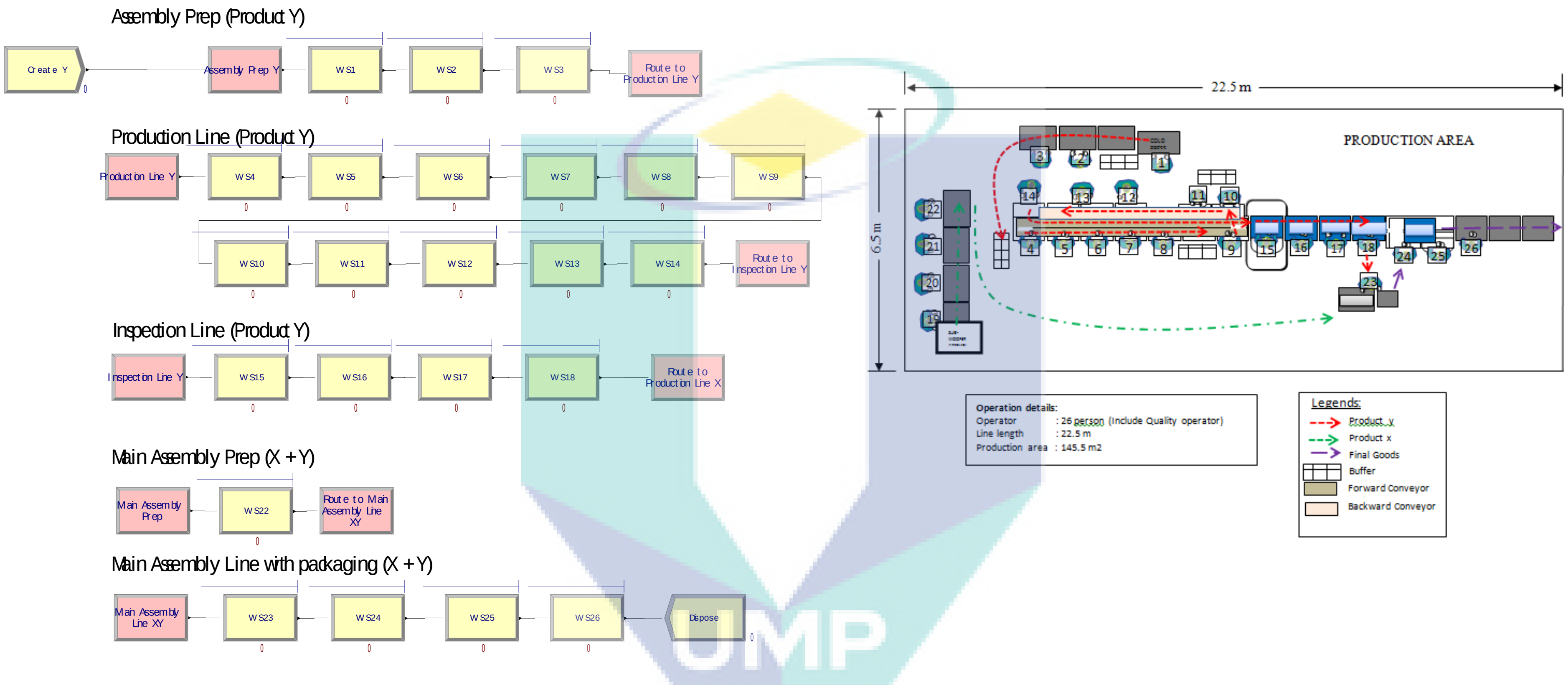
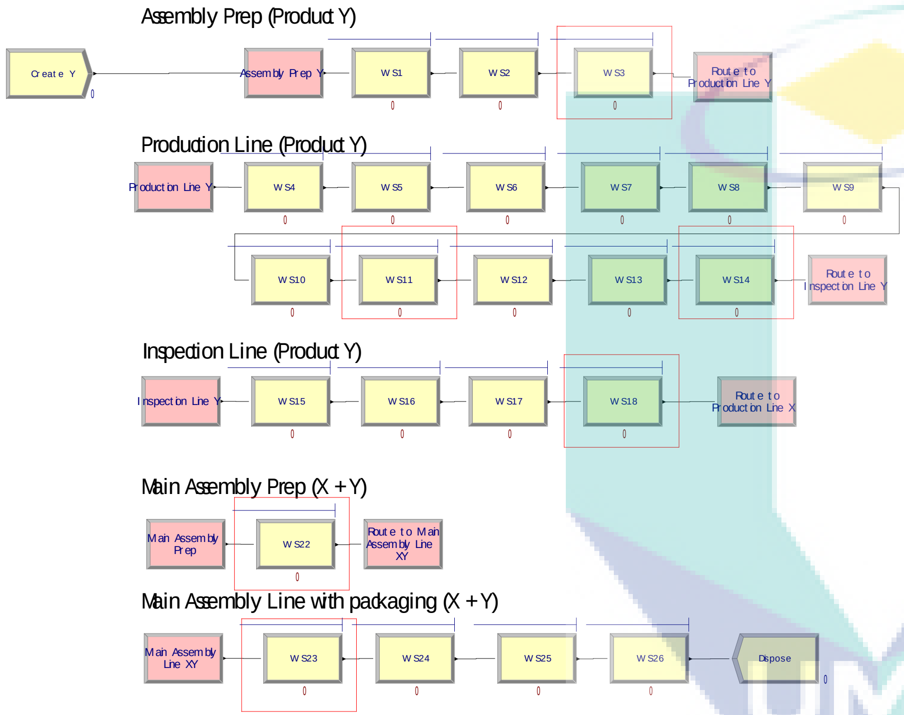
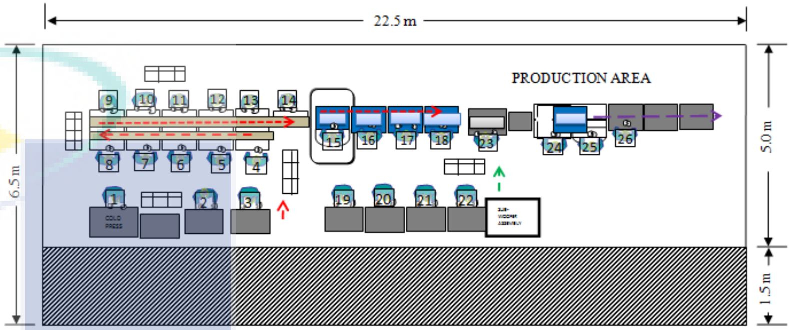


Figure 5.24 Simulation Model for Current Layout with 26 Workstations





WS	CT Distribution (Original Layout)	Improvement Ratio	CT Distribution (Proposed Layout)
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WS3	TRIA(173, 176, 177)	**1:3**	**TRIA(173, 175, 176)**
WS4	143 + 5.72 * BETA(1.07, 0.9)	1:1	143 + 5.72 * BETA(1.07, 0.9)
WS5	85 + 6 * BETA(0.991, 0.708)	1:1	85 + 6 * BETA(0.991, 0.708)
WS6	82.1 + LOGN(1.75, 1.44)	1:1	82.1 + LOGN(1.75, 1.44)
WS7	110 + LOGN(1.93, 1.3)	1:1	110 + LOGN(1.93, 1.3)
WS8	109 + 7 * BETA(0.893, 0.848)	1:1	109 + 7 * BETA(0.893, 0.848)
WS9	TRIA(83.1, 87.1, 88.8)	1:1	TRIA(83.1, 87.1, 88.8)
WS10	66 + 5 * BETA(0.835, 0.525)	1:1	66 + 5 * BETA(0.835, 0.525)
WS11	TRIA(70.3, 70.6, 74.5)	**1:1.5**	**68 + WEIB(1.6, 1.47)**
WS12	85 + 6 * BETA(1.1, 0.777)	1:1	85 + 6 * BETA(1.1, 0.777)
WS13	UNIF(73, 78)	1:1	UNIF(73, 78)
WS14	NORM(85.1, 1.39)	**1:5**	**NORM(82.5, 1.37)**
WS15	71 + GAMM(0.989, 2.11)	1:1	71 + GAMM(0.989, 2.11)
WS16	UNIF(80, 84)	1:1	UNIF(80, 84)
WS17	TRIA(83.2, 88, 89)	1:1	TRIA(83.2, 88, 89)
WS18	56.3 + LOGN(2.45, 1.83)	**1:1.5**	**55.5 + LOGN(2.41, 1.83)**
WS19	58.1 + 6.84 * BETA(1.86, 1.18)	1:1	58.1 + 6.84 * BETA(1.86, 1.18)
WS20	85 + ERLA(1.79, 2)	1:1	85 + ERLA(1.79, 2)
WS21	TRIA(68, 70.4, 73)	1:1	TRIA(68, 70.4, 73)
WS22	83.1 + 2.53 * BETA(1.3, 1.45)	**1:7**	**77 + 1.79 * BETA(0.9, 0.7)**
WS23	79.6 + ERLA(0.41, 3)	**1:1.2**	**79.2 + GAMM(0.386, 3.19)**
WS24	NORM(62.3, 0.659)	1:1	NORM(62.3, 0.659)
WS25	TRIA(40.7, 41.2, 43.3)	1:1	TRIA(40.7, 41.2, 43.3)
WS26	64 + 8 * BETA(0.646, 0.347)		64 + 8 * BETA(0.646, 0.347)

Figure 5.25 Simulation Model for Proposed Layout with 26 Workstations

Table 5.8 Input and Output Analysis

	Current layout	Proposed Layout	Improvement Rate
Input	180	180	1/180*100 = 0.56%
WIP	37	36	
Output	143	144	

5.4.3 Analysis of WIP and Manpower Utilisation

Table 5.9 compares both current layout and proposed layout performances by a number of works in progress and manpower utilisation in every 26 workstations. Meanwhile, Figure 5.26 shows manpower utilisation analysis between two different types of layout. Based on Table 5.9 and Figure 5.26, it was found that the proposed layout reduced the utilisation of manpower while improving the number of works in progress especially at WS3.

Table 5.9 WIP and Manpower Utilisation Analysis

	Current layout		Proposed layout	
	WIP	**MU**	**WIP**	**MU**
WS1	-	39.86%	-	39.91%
WS2	-	45.12%	-	45.08%
WS3	27	78.47%	21	78.47%
WS4	1	64.97%	1	65.30%
WS5	1	39.15%	-	39.37%
WS6	-	37.02%	1	37.30%
WS7	1	49.21%	-	49.55%
WS8	-	49.41%	1	49.43%
WS9	1	37.62%	-	37.85%
WS10	-	30.07%	1	30.20%
WS11	1	31.09%	-	30.25%
WS12	-	38.29%	1	38.49%
WS13	1	32.45%	-	32.67%
WS14	-	36.48%	1	35.52%
WS15	1	31.32%	-	31.35%
WS16	-	35.07%	1	35.28%
WS17	1	36.95%	-	37.00%
WS18	-	24.96%	-	24.73%
WS22	-	35.74%	1	33.15%
WS23	1	34.02%	-	34.04%
WS24	-	26.28%	1	26.34%
WS25	-	17.60%	-	17.57%
WS26	1	28.99%	-	29.02%
Total	37	-	36	-

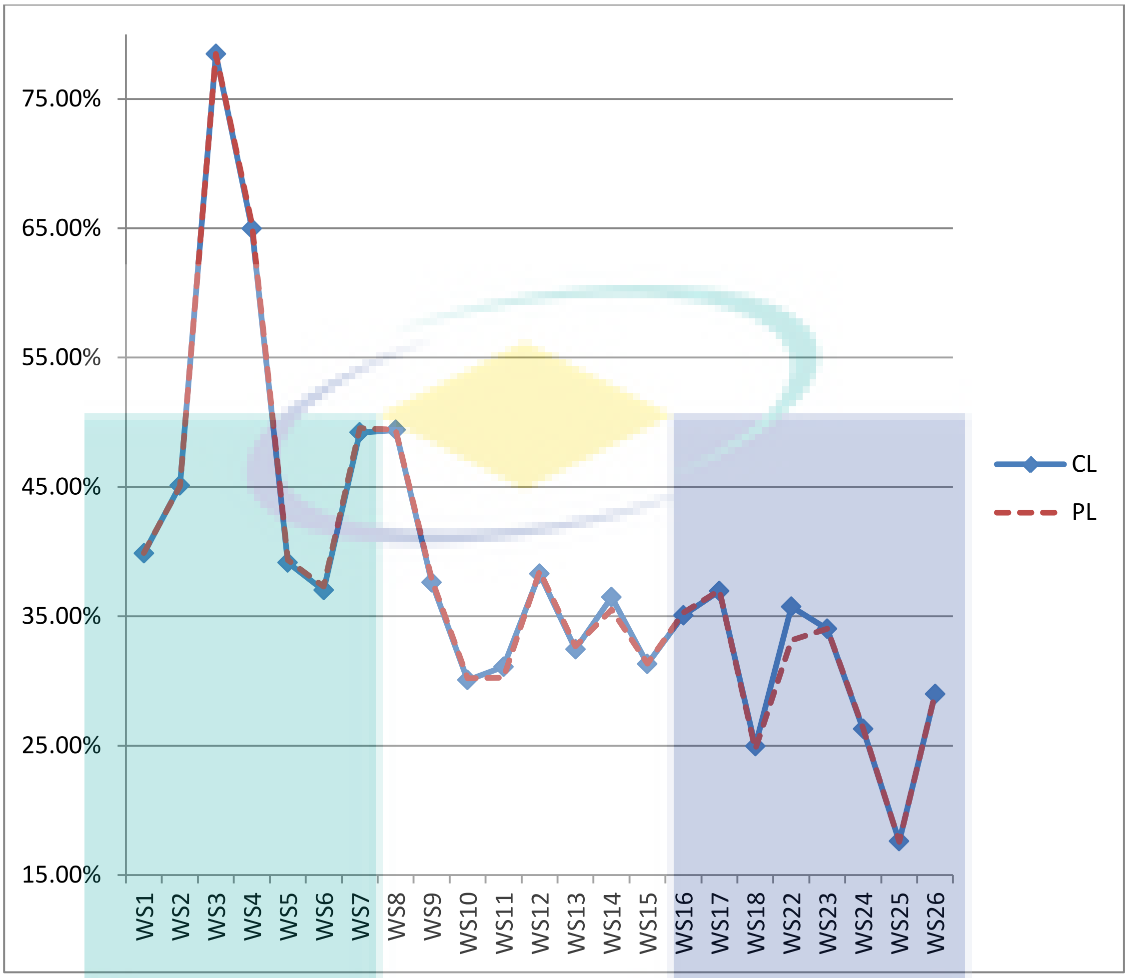

Figure 5.26 Manpower Utilisation Comparison Analysis

5.4.4 Analysis of Efficiency Measure

Table 5.10 shows an efficiency measure for improving workstation layout based on discussion outcome with production line personnel. New proposed layout was able to improve 22.68 percent space utilisation. However, for output and WIP only 0.56 percent were able to count for efficiency measure. In other words, the proposed layout showed the very less impact to the productivity. Compared to using time saving tricks as proposed by Das et al. (2010), without new layout the production line was able to meet quantity demand within takt time. However, Narayanamurthy & Gurumurthy (2016) mentioned that lean practices encourage small improvement to enhance morale among operators and shows a good indicator for the next lean strategies improvement.

Table 5.10 Efficiency measure for improving workstation layout

	Space utilisation	**Output**	**WIP**
Efficiency measure	22.68%	144/180 ~ 80%	0.56%

5.5 Summary

In summary, the chapter has explained that lean continuous improvement strategies can be implemented in many efforts. There are no specific ways, but required the organisation to define the best towards productivity improvement. In other words, observation, interviews, and review of documents of the case study company can confirm that each indicator of each element in the AHP – QFD model has high influence on the manufacturing operational performance. In fact, the integration of the AHP and QFD makes it possible because each approach has an equivalent performance basis. Meanwhile, the simulation test was used to validate the method, and the elements of the research model that can be implemented in achieving a better lean performance.

CHAPTER 6

CONCLUSION

6.1 Introduction

The results and findings from the present research are summarised and concluded in this chapter. It starts with the conclusion from the research findings, followed by the discussion of the research contributions and recommendations for potential future research.

6.2 Summary of the Findings

The first two objectives of this research are to investigate which lean practices and lean continuous improvement strategies are important to the Malaysian manufacturing industry and how significant the difference between priority and current achievement. The results revealed that there are 28 items in lean practices have been considerably adopted and implemented by Malaysian manufacturing firms from a wide variety of product groups. On the other hand, 7 other parameters in lean continuous improvement strategies were measured. Survey analysis shows that the parameter had a moderate correlation to each other’s while some of the items have strong significant relationship, such as LP22 with LP23 and LP24, LP23 with P24 and P9, LP25 with LP10, and LP26 with LP28. However, most of the items did not meet the priorities achievement. In other words, Malaysia manufacturing firms are currently struggling to enhance the strategies for productivity improvement. In depth analysis also shows that:

i. The lean assembly line model can be developed by considering both the lean practices and lean continuous improvement strategies as the parameters.

ii. Strong correlation items are preferable while higher gap between the priorities and achievement are the basis.

iii. The manufacturing firms do not prefer to add additional manpower or machine and work for extra hours for lean assembly line model parameters.

Focusing on the third objectives, the results from Analytic Hierarchy Process (AHP) verified that some parameters are less important. Although all four lean practice categories have almost similar significant influence, man and machine use were considerably the most priorities in the selected case study company. To be specific, process line balancing, effective pace of production (takt time), and efficient production levelling (finished goods) had higher priorities weightage. Quality Function Deployment (QFD) analysis confirmed that the three parameters in lean continuous improvement strategies, including method of improvement, use time for saving tricks and improve workstation layout have a significant relationship with the listed items in lean practices from AHP results. The results also proved that lean hierarchical function deployment framework for assembly line performance improvement can be developed.

For last objective, to propose lean assembly line model best practices in order to facilitate better production operation using simulation analysis. The results are as follows:

i. The method of improvement requires specific knowledge on technical skills and working experience in the workstation. This is because, the operators had spent more time on the production line and aware the weaknesses or potential improvement. Besides, it required higher technical knowledge to enhance workstation and operation procedure.

ii. The usage time for saving tricks need creativity of line supervisor or operator to identify or re-arrange the job specification and working time. It involved job assignments, number of required operators in particular workstation, and different type of working hours. The arrangement of the parameter influenced different result and the success of the plan is also based on commitment from all parties, including operator, production line’s leader, and top management.

iii. For workstation layout improvement, it focuses on the workspace reduction through reduction of work in progress product transportation time. These results are likely to be related to a specific task in the particular workstation. The simulation test was successful as it was able to identify the effectiveness of less transportation time in assembly line.

6.3 Novelty of Research

The findings from this research offer the basis approaches to integrate the lean practices and lean continuous improvement strategies to achieve better assembly line toward productivity enhancement. Theoretically formulated and empirically tested, the AHP and QFD model of lean assembly line is beneficial for researchers, industrial practitioners, government, and local authorities in setting the preferred actions and strategies in achieving good manufacturing practices. Identically, this research has contributed to:

6.3.1 Contribution to the New Knowledge

i. This research has established a validated lean hierarchical function deployment framework that integrates AHP and QFD methodologies with simulation. The empirical data in this research have proven that the integration of the lean practices and lean continuous improvement strategies were feasible for a better parameter for lean assembly line.

ii. Understanding the fundamental elements or factors that contribute to lean practices efficiency in Malaysian based manufacturing industries.

iii. Expose the researchers and organisational to the quantitative and qualitative parameters methodology.

iv. Understanding the fundamental key correlation between lean practices and lean continuous improvement strategies and the development of a new approach for the deployment.

v. This study can be considered the first of its kind of study that integrate a comprehensive AHP and QFD methodologies with simulation in improving lean practices and can it be considered as filling the current gap in the body of knowledge.

6.3.2 Contribution to the Industry

i. This research provides a better understanding about the impact of the integration of lean practices and lean continuous improvement strategies. This eventually allows manufacturers to identify strengths and weaknesses, and thus set a better strategy to achieve a higher productivity performance.

ii. The knowledge generated and the model developed could be refereed to or used both policy makers and practitioners operating within the Malaysia manufacturing industries.

iii. Apply new way of approach in sustaining good manufacturing system and with optimal parameters condition toward better competitiveness and productivity.

iv. The generated knowledge and tested hybrid model could be used for initial manufacturing system setting and basis for future development of optimisation model.

6.3.3 Contribution to the Nation

i. The establishment of this Lean Hierarchical Function Deployment framework supports the intention of Malaysian government in encouraging the implementation of value added activities in Malaysian economic growth as mentioned in the Malaysian Plan.

ii. The research is intended to support the fundamental aim of improving participation of internal stakeholder towards the achievement of the National Roadmap for Lean. The generated knowledge and tested hybrid model could be used for initial manufacturing system setting and basis for future development of optimisation model.

6.4 Future study

Future studies need to take into account the following suggestion for further enhancement in the lean practices:

i. The main focus of this research is only emphasised on the effects of the integration of the lean practices and lean continuous improvement strategies, developing a lean assembly line using AHP and QFD approaches. Thus, further research should be undertaken to investigate the other lean tools and techniques in streamlining the integration effect of lean assembly line performance.

ii. The validated lean hierarchical function deployment framework can be tested through a comparative case study involving several manufacturing firms, mainly to compare the effects of the integration of the other lean practices or lean continuous improvement strategies.

iii. Instead of only focusing on lean practices or lean continuous improvement strategies, there may be other variables that can enhance lean assembly performance.

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APPENDICES

APPENDIX A

QUESTIONAIRE SURVEY

LEAN ASSEMBLY LINE'S MODEL: A SURVEY

Lean Production is an approach of management that focuses on cutting out waste, whilst ensuring quality for more efficient and responsive to market needs.

The main purpose of this survey is to examine the level of implementation of Lean practices in manufacturing companies in Malaysia.

Your cooperation is solicited in filling the questionnaire on behalf of your company. Please pass this questionnaire to the appropriate member (s) of your organization (at least 2 years' experience in manufacturing operation) if you do not feel comfortable to complete it.

The information given is **STRICTLY CONFIDENTIAL** and will be used only as a material for academic research.

A high response rate is vital for the success of this study. We would be delighted to answer any query regarding the questionnaire. Please return the completed questionnaire using the enclosed envelope.

Thank you for your time and kindness.

INTAN BAZLIAH MOHD
PhD Student
Faculty of Engineering Technology
Universiti Malaysia Pahang

Tel : 013-6188100
Email: intanbazliahmohd80@gmail.com

QUESTIONNAIRE
[SOAL SELIDIK]

INSTRUCTION:
To complete this questionnaire, you are just required to TICK (√) boxes and write in the space of the required information provided, if necessary.
[ARAHAN:
Untuk menjawab soal selidik ini, anda dikehendaki untuk menanda (√) pada kotak jawapan dan menulis maklumat yang dikehendaki pada ruangan yang telah disediakan , jika perlu.]

SECTION A: COMPANY INFORMATION
[BAHAGIAN A: MAKLUMAT SYARIKAT]

1. Company Name *[Nama Syarikat]* : ____

2. Ownership *Pemilikan* : ☐ Local (Malaysia) *[Syarikat tempatan]* ☐ Foreign, please specify : ______________ *[Syarikat asing, sila nyatakan:]*

3.	Industry Product Groups *[Kumpulan Produk Industry]*	:	
	☐ Automotive product group *[Kumpulan produk automotif]*	☐ Electric or Electronics products group *[Kumpulan produk electric atau elektronik]*	
	☐ Mechanical engineering product groups *[Kumpulan produk mekanikal]*	☐ Chemical or Scientific product group *[Kumpulan produk kimia atau saintifik]*	
	☐ Others, please specify *[Lain-lain, sila nyatakan]*	:	______________________________

4. Main Product *[Produk utama]* : ______________________________

SECTION B : INFORMATION ON THE CURRENT LEAN PRACTICES

1. Within the past three years, what are the priority and current performance of the **lean practices** implemented in your organisation?

No.	Lean Practices	Not Applicable	Priority: Unimportant	Slightly Important	Important	Very Important	Extremely important	Current Performance / Achievement: Poor	Fair	Good	Very good	Excellent
1	Adaptation Of New Technology [penggunaan teknologi baharu]	0	1	2	3	4	5	1	2	3	4	5
2	Decrease Customer Lead Time [pengurangan masa menunggu kepada pelanggan]	0	1	2	3	4	5	1	2	3	4	5
3	Decrease Throughput Time [pengurangan masa pengeluaran]	0	1	2	3	4	5	1	2	3	4	5
4	Enhanced Product Variety [meningkatkan kepelbagaian produk]	0	1	2	3	4	5	1	2	3	4	5
5	High Capacity Of Innovation [kapasiti kepada inovasi]	0	1	2	3	4	5	1	2	3	4	5
6	Minimise Setup Time [meminimumkan masa penyediaan]	0	1	2	3	4	5	1	2	3	4	5
7	On Time Delivery [penghantaran tepat]	0	1	2	3	4	5	1	2	3	4	5
8	Speed Up Changeover Time [meningkatkan kecekapan pertukaran masa]	0	1	2	3	4	5	1	2	3	4	5
9	Effective Machine Optimization [Optimumkan keberkesanan mesin]	0	1	2	3	4	5	1	2	3	4	5
10	Increasing Kaizen Activities [meningkatkan aktiviti kaizen/penambahbaikan berterusan]	0	1	2	3	4	5	1	2	3	4	5
11	Minimise Machine Configuration [meminimumkan konfigurasi mesin]	0	1	2	3	4	5	1	2	3	4	5
12	Operator Flexibility and Innovativeness [operator yang fleksibel dan berinovasi]	0	1	2	3	4	5	1	2	3	4	5
13	Optimise Poka-Yoke [mengoptimumkan poka-yoke]	0	1	2	3	4	5	1	2	3	4	5
14	Proactive TPM Practice [mempraktiskan TPM secara proaktif]	0	1	2	3	4	5	1	2	3	4	5

No.	Lean Practices	Not Applicable	Priority: Unimportant	Slightly Important	Important	Very Important	Extremely important	Current Performance / Achievement: Poor	Fair	Good	Very good	Excellent
15	Process Line Balancing [imbangan aliran proses/ pengeluaran]	0	1	2	3	4	5	1	2	3	4	5
16	Effective Pace Of Production (Takt Time) [keberkesanan kepantasan pengeluaran]	0	1	2	3	4	5	1	2	3	4	5
17	Efficient Production Levelling (Finished Goods) [kebekesanan pengeluaran setara]	0	1	2	3	4	5	1	2	3	4	5
18	Organized JIT (Raw Material) [pengurusan bahan mental JIT]	0	1	2	3	4	5	1	2	3	4	5
19	Organized Kanban System (WIP) [pengurusan sistem Kanban]	0	1	2	3	4	5	1	2	3	4	5
20	Zero Missing/Misplace Material [kehilangan bahan – sifar]	0	1	2	3	4	5	1	2	3	4	5
21	Zero WIP (One Piece Flow) [WIP- Sifar]	0	1	2	3	4	5	1	2	3	4	5
22	Effective Layout Configuration [konfigurasi susunatur yang berkesan]	0	1	2	3	4	5	1	2	3	4	5
23	Effective Material Flow [aliran bahan yang efektif]	0	1	2	3	4	5	1	2	3	4	5
24	Efficient Space Utilization [pengunaan ruang yang cekap]	0	1	2	3	4	5	1	2	3	4	5
25	Minimise Number Of Workstation [stesen kerja yang minimum]	0	1	2	3	4	5	1	2	3	4	5
26	Minimum Cost [kos minimum]	0	1	2	3	4	5	1	2	3	4	5
27	Product Quality [kualiti produk]	0	1	2	3	4	5	1	2	3	4	5
28	Simplified Operation Procedure [prosedur operasi yang ringkas]	0	1	2	3	4	5	1	2	3	4	5
	Other, Please specify:											

SECTION B	**:**	**INFORMATION ON THE CURRENT PRACTICES OF LEAN CONTINUOUS IMPROVEMENT STRATEGIES**
[BAHAGIAN B	*:*	*MAKLUMAT BERKAITAN AMALAN SEMASA PENGELUARAN LEAN]*

1. Within the past three years, what are the priority and current performance of the **Lean continuous improvement strategies** implemented in your organisation?
[*Dalam tempoh tiga tahun kebelakangan, apakah keutamaan dan prestasi semasa strategi pembuatan lean yang diguna pakai dalam organisasi anda?*]

No	Lean Continuous Improvement Strategies		**Priority**					**Current Performance / Achievement**				
		Not Applicable	Unimportant	Slightly Important	Important	Very Important	Extremely important	Poor	Fair	Good	Very good	Excellent
1	Method of improvement [*kaedah penambahbaikan berkesan*]	0	1	2	3	4	5	1	2	3	4	5
2	Share capacity [*perkongsian kapasiti pengeluaran/inventori*]	0	1	2	3	4	5	1	2	3	4	5
3	Add additional manpower or machine [*tambahan pekerja atau mesin*]	0	1	2	3	4	5	1	2	3	4	5
4	Improve workstation layout [*menambahbaik susunatur*]	0	1	2	3	4	5	1	2	3	4	5
5	Better operator allocation [*susunan semula pekerja*]	0	1	2	3	4	5	1	2	3	4	5
6	Work for extra hours [*kerja lebih masa*]	0	1	2	3	4	5	1	2	3	4	5
7	Production time saving tricks (flexible working time) [*masa kerja fleksibel*]	0	1	2	3	4	5	1	2	3	4	5
8	Other, Please specify:	0	1	2	3	4	5	1	2	3	4	5

GENERAL INFORMATIONS
[MAKLUMAT AM]

Respondents Information :
[Maklumat Responden]

Name :
[Nama]

Job title :
[Jawatan]

Department :
[Jabatan]

Working experience (years) :
[Pengalaman kerja (tahun)]

Contact number :
[Number untuk dihubungi]

E-mail :
[Emel]

Would you like to receive a concise summary of the results from the survey?
[Adakah anda berminat untuk mendapatkan keputusan kajian tinjauan?

☐ Yes *[Ya]*   ☐ Tidak *[No]*

Would you like to take part in the next phase of this study?
[Adakah anda ingin mengambil bahagian untuk fasa seterusnya dalam kajian ini?

☐ Yes *[Ya]*   ☐ Tidak *[No]*

Thank you very much for your time and kind-co-operation. Please ensure that you answer as many question as possible. For analysis purpose, please return the questionnaire even if your company is not engage in lean production practices.
[Terima kasih untuk masa dan kerjasama anda. Sila pastikan bahawa anda menjawab sebanyak soalan yang mungkin. Bagi tujuan analisis, sila kembalikan borang tinjuan ini walaupun syarikat anda tidak terlibat dalam amalan pengeluaran lean]

--END OF SURVEY--------------------------------------
[Kaji selidik Tamat]

APPENDIX B

ASSESSMENT OF QUESTIONNAIRE (PRE-TEST) FORM

ASSESSMENT OF QUESTIONNAIRE (PRE-TEST)
[PENILAIAN SOAL SELIDIK (PRE-TEST)]

INSTRUCTION:
Please indicate your response by circling the most appropriate and write in the space of the required information provided, if necessary.

[*ARAHAN:*
Sila nyatakan ulasan anda dengan bulatkan yang paling sesuai dan menulis dalam ruang maklumat yang diperlukan disediakan, jika perlu.]

SECTION A [BAHAGIAN A]
OVERALL STYLE AND ORGANISATION [GAYA DAN PENYUSUSNAN KESELURUHAN]

Not appropriate at all ↔ Most appropriate

1.	In terms of contents, the questionnaire is *Dari segi kandungan, soalan kaji selidik adalah*	1	2	3	4	5
	Comments/ *ulasan* …………………………………………………………………… …………………………………………………………………… ……………………………………………………………………					

Not clear at all ↔ Very clear

2.	In terms of clarity of presentation, the questionnaire is *Dari segi kejelasan penyampaian, soalan kaji selidik adalah*	1	2	3	4	5
	Comments/ *ulasan* …………………………………………………………………… …………………………………………………………………… …………………………………………………………………… ……………………………………………………………………					

Very poorly organised ↔ Very well organised

3.	In terms of organisation, the questionnaire is *Dari segi susuan keseluruhan, soalan kaji selidik adalah*	1	2	3	4	5
	Comments/ *ulasan* …………………………………………………………………… ……………………………………………………………………					

Not accurate at all ⟷ Very accurate

		1	2	3	4	5
4.	In terms of terminology used, the questionnaire is *Dari segi peristilahan yang digunakan, soalan kaji selidik adalah*	1	2	3	4	5
	Comments/ *ulasan* …………………………………………………………… …………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………………					

Not appropriate at all ⟷ Most appropriate

		1	2	3	4	5
5.	In terms of language and grammar, the questionnaire is *Dari segi penggunaan bahasa dan tatabahasa, soalan kaji selidik adalah*	1	2	3	4	5
	Comments/ *ulasan* …………………………………………………………… …………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………………					

SECTION B [BAHAGIAN B]

2.	Major Revision Required (if any) *Pembetulan utama yang perlu dilaksanaka/dibuat (jika ada)*
	…………………………………………………………… …………………………………………………………… …………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………………

SECTION C [BAHAGIAN C]
ACKNOWLEDGEMENT [PERAKUAN]

Most sufficient

Not sufficient at all

1.	Overall, the questionnaire is *keseluruhannya, soalan kaji selidik adalah*	1	2	3	4	5
	Comments/ *ulasan* …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… …………………………………………………………………………… ……………………………………………………………………………					

Name [*Nama*] : ______________________

Job title [*Jawatan*] : ______________________

Department [*Jabatan*] : ______________________

Contact No. [*Nombor telefon*] : ______________________

Email [*Emel*] : ______________________

APPENDIX C

LIST OF EXPERT PANEL FOR
QUESTIONNAIRE CONTENTS VALIDATION/
MODEL OF LEAN HIERARCHICAL FUNCTION DEPLOYMENT

Academic Panel

Name : Associate Professor Dr. Mohd Nizam Ab Rahman
Job title : Senior Lecturer
Department : Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia
Research Interest : Quality and Operations Management in Manufacturing
Engineering with Specialization in Optimization and Lean Supply Chain Management

Name : Dr. Muhammad Ashlyzan Razik
Job title : Senior Lecturer
Department : Fakulti Keusahawanan dan Perniagaan, Universiti Malaysia Kelantan
Research Interest : Logistics and Supply Chain Management

Industrial Professional Panel

Name : Mr. Mohd Ghazali Othman
Job title : Lean Senior Executive
Infineon Technologies (Malaysia) Sdn Bhd.
Department : Taman Perindustrian Batu Berendam, 75350 Batu Berendam, Melaka
Working experience (years) : 16 years

Name : Mr. Gen Wee Teo
Job title : Manager
Panasonic AVC Networks Johor Malaysia Sdn.Bhd.
Department : IE PLO 460 Jalan Bandar
81700 Pasir Gudang, Johor Malaysia
Working experience (years) : 13 years

APPENDIX D

LIST OF SURVEY RESPONDENT

1. AFCI (M) Sdn Bhd
2. Armstrong Electronics Sdn Bhd
3. Asian Resinated Felt Sdn Bhd
4. Autolive Hirotako(M) Sdn Bhd
5. Avcom Crop Care Sdn Bhd
6. Bahru Stainless Sdn Bhd
7. Careglove Global Sdn Bhd
8. Celestica Electronic (M) Sdn Bhd
9. Composite Technology Research Malaysia (Ctrm)
10. Delphi Packard Electric Sdn Bhd
11. Denso (M) Sdn Bhd
12. Dongwha (M) Sdn Bhd
13. Dyson Manufacturing Sdn Bhd
14. Escatel Electronics Sdn Bhd
15. Eson Batu Pahat Precision Engineer Sdn Bhd
16. Favelle Favco Cranes (M) Sdn Bhd
17. Finisar (M) Sdn Bhd
18. Ge-Shen Plastic (M) Sdn Bhd
19. Hartalega Ngc Sdn Bhd
20. Hicom Automotive Manufacturer (M) Sdn Bhd
21. Infineon Technologies (M) Sdn Bhd
22. INOKOM Corporation Sdn Bhd
23. Kerry Ingredients (M) Sdn Bhd
24. Knowless Electronics (M) Sdn Bhd
25. Konica MinoltaSbh Bhd
26. Kossan Rubber Industries (Ideal Quality Sdn Bhd)
27. Lama Tile Sdn Bhd
28. Lumileds (M) Sdn Bhd
29. Nexperia (M) Sdn Bhd
30. ON Semiconductor (M) Sdn Bhd

31. Osram Opto Semiconductors (M) Sdn Bhd
32. Panasonic AVC Networks Johor Malaysia Sdn.Bhd.
33. Perodua Global Manufacturing Sdn Bhd
34. Pioneer Technology (M) Sdn Bhd
35. Plexus Manufacturing Sdn Bhd
36. Proton Tanjung Malim Sdn Bhd
37. Purecircle Sdn Bhd
38. Recron (M) Sdn Bhd
39. Rohm-Wako Electronics (M) Sdn Bhd
40. S&O Elecronics (M) Sdn Bhd Sharp
41. Safran Landing System Sdn Bhd
42. Sam Meerkat (M) Sdn Bhd
43. Samsung Electronic Sdn Bhd
44. Seagate Techology (M) Sdn Bhd
45. Shimano Component (M) Sdn Bhd
46. Silterra (M) Sdn Bhd
47. Sony EMCS (M) Sdn Bhd
48. ST Microelectronics Sdn Bhd
49. Sunpower Malaysia Manufacturing Sdn Bhd
50. Synturn (M) Sdn Bhd
51. Technomeiji Rubber Sdn Bhd
52. TF-AMD (M) Sdn Bhd
53. Tonasco (M) Sdn Bhd
54. Top Glove Sdn Bhd
55. Unisem (M) Sdn Bhd
56. VAT Manufacturing (M) Sdn Bhd
57. Vishay Semiconductor (M) Sdn Bhd
58. Volvo Car Manufacturing (M) Sdn Bhd
59. Western Digital (M) Sdn Bhd
60. Yamaha Electronic Manufacturing (M) Sdn Bhd
61. Sapura Machining Corporation Sdn Bhd

APPENDIX E

TIME STUDY DATA

WS 1	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take & Remove Double Side Tape Sheet At Speaker Net	15.0	0.0	14.0	0.0	14.8	0.0	14.9	0.0	15.0	0.0	15.2	0.0	15.2	0.0	15.0	0.0	15.2	0.0	15.0	0.0
Place At Cold Press Machine & Alignment	21.6	0.0	21.3	0.0	21.3	0.0	21.5	0.0	21.3	0.0	21.4	0.0	21.3	0.0	21.9	0.0	21.6	0.0	21.9	0.0
Remove Double Side Tape Sheet At Speaker Net	11.0	0.0	11.5	0.0	11.2	0.0	11.1	0.0	11.3	0.0	11.1	0.0	11.0	0.0	11.1	0.0	11.0	0.0	11.1	0.0
Take Front Panel & Check Appearance	8.7	0.0	8.1	0.0	8.8	0.0	8.5	0.0	8.9	0.0	8.9	0.0	8.8	0.0	8.8	0.0	8.8	0.0	8.9	0.0
Remove Double Side Tape Sheet & Fix Ir Filter	4.5	0.0	5.0	0.0	5.1	0.0	4.9	0.0	4.6	0.0	4.7	0.0	4.6	0.0	4.3	0.0	4.5	0.0	4.5	0.0
Remove Protector Sheet	2.9	0.0	3.0	0.0	2.8	0.0	2.8	0.0	2.7	0.0	2.8	0.0	2.8	0.0	2.8	0.0	2.8	0.0	2.8	0.0
Place Front Panel At Cold Press	4.2	0.0	4.1	0.0	4.1	0.0	4.3	0.0	4.1	0.0	4.3	0.0	4.3	0.0	4.1	0.0	4.2	0.0	4.3	0.0
Press Button To Press	0.6	0.0	0.9	0.0	0.5	0.0	0.9	0.0	0.6	0.0	0.9	0.0	0.7	0.0	0.9	0.0	0.2	0.0	0.6	0.0
Cold Press Net Pressing Process 15sc	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0
Take Out Front Panel From Cold Press & Net Checking	5.1	0.0	4.9	0.0	4.8	0.0	5.2	0.0	5.0	0.0	5.2	0.0	5.2	0.0	5.2	0.0	5.7	0.0	5.3	0.0
Pass To Next Station	1.8	0.0	2.4	0.0	2.0	0.0	2.0	0.0	1.9	0.0	1.9	0.0	1.9	0.0	1.9	0.0	1.7	0.0	1.7	0.0
	75.4		75.2		75.4		76.1		75.4		76.4		75.8		76.0		75.7		76.1	

WS 2	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Fr. Panel & Paste Hemilon At Front Area 2pc (Rmq2311)	23.5	0.0	23.7	0.0	23.1	0.0	23.0	0.0	23.7	0.0	24.3	0.0	23.8	0.0	23.6	0.0	23.2	0.0	23.5	0.0
Paste Hemilon At Rear Area 3pcs (Rmq2311) (Custom Made)	30.5	0.0	31.0	0.0	30.1	0.0	30.4	0.0	30.6	0.0	30.4	0.0	30.6	0.0	30.7	0.0	30.6	0.0	30.4	0.0
Paste Hemilon At Tx Pcb Area 2pcs (Rmq2311f)	7.10	0.0	6.80	0.0	6.90	0.0	7.0	0.0	7.30	0.0	7.0	0.0	7.20	0.0	7.20	0.0	7.10	0.0	7.0	0.0
Paste Hemilon At Optical Pcb Area 1pcs (Rmq2311f)	2.20	0.0	2.10	0.0	2.20	0.0	2.0	0.0	2.30	0.0	2.40	0.0	2.20	0.0	2.40	0.0	2.30	0.0	2.20	0.0
Paste Hemilon At Bluethoot Area 1pcs (Rmf0681)	6.10	0.0	6.20	0.0	6.20	0.0	6.40	0.0	6.40	0.0	6.30	0.0	6.0	0.0	6.50	0.0	6.0	0.0	6.40	0.0
Paste Hemilon At Fl Display Area 2pcs (Rmf0681)	8.20	0.0	8.50	0.0	8.10	0.0	8.20	0.0	8.30	0.0	8.30	0.0	8.20	0.0	8.30	0.0	8.0	0.0	8.10	0.0
Paste Hemilon At Near Fl Display Area (Rmf0681)	6.10	0.0	6.0	0.0	5.90	0.0	6.0	0.0	6.50	0.0	6.50	0.0	6.0	0.0	6.0	0.0	6.30	0.0	6.20	0.0
Pass To Next Station	1.70	0.0	1.80	0.0	1.80	0.0	1.50	0.0	1.80	0.0	1.0	0.0	1.90	0.0	1.80	0.0	1.70	0.0	1.90	0.0
	85.4		86.1		84.3		84.5		86.9		86.2		85.9		86.5		85.2		85.7	

WS 3	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Front Panel & Place At Pallet	1.50	0.0	1.60	0.0	1.50	0.0	1.10	0.0	1.70	0.0	1.50	0.0	1.30	0.0	1.20	0.0	1.40	0.0	1.50	0.0
Take Front Panel & Place At Pallet (PROPOSED LAYOUT) [Improvement Ratio = 1: 3]	0.5	0.0	0.5	0.0	0.5	0.0	0.4	0.0	0.6	0.0	0.5	0.0	0.4	0.0	0.4	0.0	0.5	0.0	0.5	0.0
Fix Sp Gasket 7 Pcs	25.4	0.0	25.3	0.0	25.0	0.0	26.0	0.0	25.4	0.0	25.3	0.0	25.0	0.0	25.2	0.0	25.9	0.0	25.4	0.0
Fix L Sp	1.70	0.0	1.70	0.0	1.50	0.0	1.90	0.0	1.80	0.0	1.50	0.0	1.20	0.0	1.90	0.0	1.90	0.0	1.60	0.0
Fix R Sp	2.80	0.0	2.90	0.0	2.50	0.0	2.80	0.0	3.0	0.0	2.60	0.0	2.80	0.0	2.90	0.0	3.0	0.0	2.80	0.0
Fix L Sr Sp	3.90	0.0	4.10	0.0	4.20	0.0	3.90	0.0	3.50	0.0	3.80	0.0	3.80	0.0	3.80	0.0	3.90	0.0	3.70	0.0
Fix R Sr Sp	4.10	0.0	3.90	0.0	4.30	0.0	4.0	0.0	4.30	0.0	4.30	0.0	4.20	0.0	4.30	0.0	4.10	0.0	4.40	0.0
Fix L Twr Sp	3.10	0.0	3.20	0.0	3.10	0.0	3.10	0.0	3.20	0.0	3.60	0.0	3.30	0.0	3.10	0.0	3.50	0.0	3.30	0.0
Fix R Twr Sp	2.30	0.0	2.50	0.0	2.30	0.0	2.0	0.0	2.50	0.0	1.90	0.0	2.0	0.0	2.80	0.0	2.30	0.0	2.20	0.0
Fix C Sp	1.10	0.0	1.0	0.0	1.0	0.0	1.40	0.0	1.0	0.0	1.40	0.0	1.40	0.0	1.20	0.0	1.0	0.0	1.10	0.0
Screw L Sp 3pcs	18.4	0.0	18.5	0.0	18.5	0.0	17.7	0.0	18.3	0.0	18.3	0.0	18.8	0.0	18.3	0.0	18.3	0.0	18.4	0.0
Screw L Twr 4pcs	19.9	0.0	19.5	0.0	19.3	0.0	18.7	0.0	19.7	0.0	19.7	0.0	19.6	0.0	19.8	0.0	19.9	0.0	19.7	0.0
Screw L Sr Sp 4pcs	20.0	0.0	20.0	0.0	20.0	0.0	21.0	0.0	20.8	0.0	20.4	0.0	20.3	0.0	20.0	0.0	20.0	0.0	20.3	0.0
Screw C Sp 3pcs	19.1	0.0	19.4	0.0	19.4	0.0	19.2	0.0	19.2	0.0	19.5	0.0	19.2	0.0	19.2	0.0	19.1	0.0	19.9	0.0
Screw R Sp 3pcs	19.8	0.0	19.9	0.0	19.8	0.0	18.8	0.0	19.6	0.0	19.4	0.0	19.7	0.0	19.7	0.0	19.5	0.0	19.7	0.0
Screw R Twr 4pcs	14.5	0.0	14.3	0.0	14.5	0.0	14.5	0.0	14.3	0.0	14.6	0.0	14.5	0.0	14.3	0.0	14.3	0.0	14.3	0.0
Screw R Sr Sp 4pcs	14.7	0.0	14.4	0.0	14.6	0.0	14.7	0.0	14.6	0.0	14.7	0.0	14.7	0.0	14.5	0.0	14.6	0.0	14.4	0.0
Paste Eva At "L" Sp 2pcs	1.60	0.0	1.80	0.0	1.80	0.0	1.60	0.0	1.80	0.0	1.80	0.0	1.80	0.0	1.80	0.0	1.80	0.0	1.80	0.0
Paste Eva At Center And "R" Sp 3pcs	1.90	0.0	1.50	0.0	1.90	0.0	1.30	0.0	1.90	0.0	1.80	0.0	1.70	0.0	1.90	0.0	1.50	0.0	1.0	0.0
Total	175.8		175.5		175.2		173.7		176.6		176.1		175.3		175.9		176.0		175.5	
Total (PROPOSED LAYOUT)	174.8		174.4		174.2		173.0		175.5		175.1		174.4		175.1		175.1		174.5	

WS 4	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Double Side Tape	1.80	0.0	1.90	0.0	1.80	0.0	1.20	0.0	1.10	0.0	1.90	0.0	1.70	0.0	1.80	0.0	1.50	0.0	1.70	0.0
Remove Double Side Tape Sheet	1.90	0.0	1.90	0.0	1.50	0.0	1.30	0.0	1.40	0.0	1.30	0.0	2.10	0.0	1.50	0.0	1.90	0.0	1.20	0.0
Paste Double Side Tape At 15p Ffc	2.50	0.0	2.40	0.0	2.40	0.0	2.0	0.0	2.70	0.0	2.50	0.0	2.50	0.0	2.10	0.0	2.90	0.0	2.20	0.0
Remove Double Side Tape Sheet	2.40	0.0	2.40	0.0	2.20	0.0	2.10	0.0	2.80	0.0	2.0	0.0	2.30	0.0	2.20	0.0	2.10	0.0	2.10	0.0
Fix 15p Ffc	6.20	0.0	6.30	0.0	6.0	0.0	6.0	0.0	6.80	0.0	6.10	0.0	6.20	0.0	6.50	0.0	6.30	0.0	6.20	0.0
Paste Hemilon At 15p Ffc Wire 1pcs (Rmq2311h)	3.60	0.0	3.70	0.0	3.30	0.0	3.60	0.0	3.50	0.0	3.10	0.0	2.70	0.0	3.40	0.0	3.40	0.0	3.30	0.0
Remove Double Side Tape Sheet At Button Pcb	6.20	0.0	6.20	0.0	6.0	0.0	5.90	0.0	6.10	0.0	6.10	0.0	6.50	0.0	6.20	0.0	6.30	0.0	6.60	0.0
Paste Button Pcb To Front Panel	6.90	0.0	6.90	0.0	6.70	0.0	6.50	0.0	6.30	0.0	6.40	0.0	6.0	0.0	6.20	0.0	6.40	0.0	6.20	0.0
Remove Double Side Tape Sheet At Nfc Pcb	4.40	0.0	4.50	0.0	4.0	0.0	4.10	0.0	4.80	0.0	3.90	0.0	5.70	0.0	4.20	0.0	4.0	0.0	4.60	0.0
Paste Nfc Pcb At Front Panel	6.20	0.0	6.30	0.0	6.0	0.0	6.80	0.0	6.60	0.0	6.0	0.0	6.10	0.0	5.60	0.0	6.10	0.0	5.50	0.0
Fix Optical Pcb At Front Panel & Screw 1pcs	11.5	0.0	11.4	0.0	11.6	0.0	11.1	0.0	11.9	0.0	11.5	0.0	11.5	0.0	11.2	0.0	11.6	0.0	11.3	0.0
Fix Ir Sensor Pcb At Front Panel & Screw 1pcs	13.6	0.0	13.5	0.0	13.5	0.0	13.9	0.0	12.9	0.0	13.1	0.0	13.0	0.0	13.7	0.0	13.4	0.0	13.5	0.0
Take C Sp Wire	5.0	0.0	5.10	0.0	5.0	0.0	5.10	0.0	5.0	0.0	5.50	0.0	5.90	0.0	5.20	0.0	5.10	0.0	5.0	0.0
Fix C Sp Wire (-+)	3.60	0.0	3.70	0.0	3.20	0.0	3.0	0.0	3.90	0.0	4.10	0.0	4.0	0.0	3.70	0.0	3.40	0.0	3.30	0.0
Dress C Sp Wire	9.70	0.0	9.80	0.0	9.20	0.0	9.40	0.0	9.30	0.0	9.10	0.0	9.50	0.0	9.10	0.0	9.0	0.0	10.0	0.0
Take L Sp Wire	5.0	0.0	5.60	0.0	5.20	0.0	5.70	0.0	5.70	0.0	5.30	0.0	5.50	0.0	5.0	0.0	5.10	0.0	5.80	0.0
Dress L Sp Wire	3.30	0.0	3.20	0.0	3.30	0.0	3.40	0.0	3.0	0.0	2.80	0.0	3.70	0.0	3.60	0.0	3.70	0.0	3.90	0.0
Fix L Twr Wire Sp (S) (With Capacitor)	4.0	0.0	4.30	0.0	4.50	0.0	4.70	0.0	4.60	0.0	4.80	0.0	4.0	0.0	4.10	0.0	4.20	0.0	4.40	0.0
Fix L Sr Wire Sp (B)	7.50	0.0	7.60	0.0	7.10	0.0	7.70	0.0	7.80	0.0	7.20	0.0	7.0	0.0	7.20	0.0	7.50	0.0	7.90	0.0
Fix L Sr Wire Sp (S)	5.20	0.0	5.40	0.0	5.10	0.0	5.10	0.0	5.0	0.0	5.0	0.0	5.90	0.0	5.30	0.0	5.90	0.0	6.20	0.0
Fix L Twr Wire Sp (B)	4.30	0.0	4.20	0.0	4.50	0.0	4.30	0.0	4.90	0.0	4.30	0.0	4.10	0.0	4.90	0.0	4.30	0.0	4.20	0.0
Dress L Twr Wire Sp (With Capacitor)	5.60	0.0	5.10	0.0	5.50	0.0	5.90	0.0	5.10	0.0	5.80	0.0	5.0	0.0	5.90	0.0	5.50	0.0	5.40	0.0
Dress L Sp Wire	5.30	0.0	5.30	0.0	5.40	0.0	5.30	0.0	5.90	0.0	6.20	0.0	6.0	0.0	5.20	0.0	5.10	0.0	5.30	0.0
Fix L Sp Wire (S)	3.60	0.0	3.20	0.0	3.30	0.0	3.0	0.0	3.10	0.0	3.70	0.0	3.70	0.0	3.20	0.0	4.10	0.0	2.80	0.0
Fix L Sp Wire (B)	4.20	0.0	4.30	0.0	4.20	0.0	4.50	0.0	4.80	0.0	4.90	0.0	4.0	0.0	5.10	0.0	5.0	0.0	4.30	0.0
Dress L Sp Wire	10.6	0.0	10.7	0.0	10.2	0.0	10.2	0.0	10.7	0.0	10.5	0.0	10.8	0.0	10.9	0.0	10.9	0.0	10.6	0.0
Pass To Next Station	2.40	0.0	2.30	0.0	2.30	0.0	2.10	0.0	2.0	0.0	2.70	0.0	2.80	0.0	2.60	0.0	2.60	0.0	2.30	0.0
	146.5		147.2		143.0		143.9		147.7		145.8		148.2		145.6		147.3		145.8	

WS 5	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Pull Pallet	2.40	0.0	2.40	0.0	2.50	0.0	2.0	0.0	2.10	0.0	2.10	0.0	2.90	0.0	2.0	0.0	3.10	0.0	3.0	0.0
Take R Sp Wire	4.30	0.0	4.40	0.0	4.0	0.0	3.80	0.0	4.50	0.0	4.90	0.0	4.10	0.0	4.10	0.0	4.0	0.0	4.50	0.0
Dress R Sp Wire	14.10	0.0	14.40	0.0	14.0	0.0	14.10	0.0	14.80	0.0	14.30	0.0	14.30	0.0	14.0	0.0	14.50	0.0	14.10	0.0
Fix R Twr Wire Sp (S)	7.20	0.0	7.30	0.0	7.0	0.0	7.10	0.0	7.90	0.0	7.30	0.0	7.10	0.0	7.10	0.0	7.90	0.0	7.0	0.0
Fix R Sr Wire Sp (B)	4.70	0.0	4.80	0.0	4.80	0.0	4.0	0.0	4.10	0.0	5.0	0.0	5.20	0.0	5.10	0.0	5.10	0.0	4.80	0.0
Fix R Sr Wire Sp (S)	3.40	0.0	3.60	0.0	2.80	0.0	2.90	0.0	3.50	0.0	3.50	0.0	3.40	0.0	3.70	0.0	3.60	0.0	3.50	0.0
Fix R Twr Wire Sp (B)	4.0	0.0	4.50	0.0	3.90	0.0	4.10	0.0	4.80	0.0	3.60	0.0	3.60	0.0	4.90	0.0	4.10	0.0	4.20	0.0
Dress R Twr Wire Sp (With Capacitor)	7.60	0.0	7.20	0.0	7.0	0.0	7.90	0.0	8.20	0.0	8.0	0.0	7.60	0.0	7.90	0.0	7.90	0.0	7.20	0.0
Dress R Sp Wire	8.90	0.0	8.0	0.0	7.90	0.0	8.50	0.0	8.50	0.0	8.70	0.0	8.80	0.0	8.40	0.0	8.50	0.0	8.50	0.0
Fix R Sp Wire (S)	5.10	0.0	5.0	0.0	5.80	0.0	5.10	0.0	5.80	0.0	5.20	0.0	5.40	0.0	5.40	0.0	5.40	0.0	6.0	0.0
Fix R Sp Wire (B)	3.70	0.0	3.80	0.0	3.40	0.0	3.10	0.0	3.0	0.0	3.90	0.0	2.90	0.0	3.0	0.0	4.0	0.0	3.80	0.0
Dress R Sp Wire	7.20	0.0	7.30	0.0	7.0	0.0	7.90	0.0	6.80	0.0	6.90	0.0	6.50	0.0	7.30	0.0	7.20	0.0	7.20	0.0
Insert IR Sensor Wire To IR Sensor PCB & Dressing	13.50	0.0	13.60	0.0	13.10	0.0	13.10	0.0	13.90	0.0	14.0	0.0	12.90	0.0	13.40	0.0	13.60	0.0	13.60	0.0
Pass To Next Station	2.0	0.0	2.10	0.0	2.30	0.0	2.50	0.0	2.60	0.0	2.60	0.0	2.60	0.0	2.60	0.0	2.0	0.0	1.90	0.0
	88.10		88.40		85.50		86.10		90.50		90.0		87.30		88.90		90.90		89.30	

WS 6	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Pull Pallet	2	0	2.3	0	2	0	2.1	0	2.9	0	3.4	0	2.5	0	2.3	0	2.1	0	2.1	0
Fix Main PCB At Front Panel	12.3	0	12.2	0	12	0	13.5	0	12	0	12	0	13.2	0	13.1	0	12.5	0	12.6	0
Take SMPS Wire	1.2	0	1.1	0	0.9	0	1.5	0	1	0	1.8	0	1.8	0	1.4	0	1.2	0	1.2	0
Dress Main PCB Wire	17.2	0	17	0	17.5	0	17.2	0	17	0	17.4	0	17.4	0	17.2	0	17	0	17	0
Paste Hemilon At Main PCB Wire 1pcs	4.8	0	4.9	0	4.5	0	4.2	0	4.2	0	3.9	0	4.1	0	4	0	4.2	0	4.2	0
Take Optical Wire	1	0	1.1	0	0.8	0	1.5	0	1.6	0	1.5	0	1	0	1.1	0	1.2	0	1.1	0
Insert Optical Wire & Dressing	13	0	13	0	13.4	0	13.7	0	12.7	0	12.6	0	13.2	0	13.2	0	13.5	0	13.5	0
Take NFC Wire	3.4	0	3.2	0	3	0	3.3	0	3.5	0	3.2	0	3.2	0	4.1	0	3	0	3.7	0
Insert Wire To NFC PCB Connector & Dressing	15.3	0	15.2	0	15.5	0	16	0	14.8	0	14.2	0	15.1	0	15.7	0	14.2	0	14.9	0
Insert 24p FFC To Main PCB	4.2	0	4.3	0	4.3	0	4.5	0	4.9	0	3.8	0	4.5	0	4.2	0	4.8	0	4.2	0
Insert 24p FFC To Front Panel Slot	5.2	0	5.9	0	5.4	0	5.3	0	5.5	0	5.8	0	5	0	4.9	0	4.7	0	4.8	0
Pass To Next Station	3.3	0	3.3	0	3.2	0	3.6	0	3.8	0	3.9	0	3.7	0	3.6	0	4.2	0	4.1	0
	82.9		83.5		82.5		86.4		83.9		83.5		84.7		84.8		82.6		83.4	

WS 7	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Pull Pallet	3.20	0.0	3.50	0.0	3.60	0.0	3.0	0.0	4.10	0.0	4.30	0.0	4.0	0.0	2.90	0.0	3.10	0.0	3.0	0.0
Fix Hdmi Pcb To Main	6.80	0.0	6.50	0.0	6.90	0.0	6.30	0.0	7.0	0.0	6.50	0.0	6.50	0.0	6.20	0.0	6.0	0.0	6.80	0.0
Screw Hdmi Pcb To Main 4pcs	21.8	0.0	21.3	0.0	21.5	0.0	22.0	0.0	21.2	0.0	21.7	0.0	21.7	0.0	22.1	0.0	20.9	0.0	21.7	0.0
Insert 30p Ffc To Hdmi	9.90	0.0	9.80	0.0	9.40	0.0	9.50	0.0	9.60	0.0	9.60	0.0	9.40	0.0	9.0	0.0	9.50	0.0	9.30	0.0
Take & Insert Wire To Button Pcb Connector And Dressing	19.6	0.0	19.5	0.0	19.3	0.0	19.6	0.0	19.6	0.0	19.3	0.0	19.9	0.0	20.0	0.0	20.1	0.0	19.7	0.0
Insert Smps Wire To Main Pcb	5.30	0.0	5.20	0.0	5.0	0.0	5.70	0.0	5.90	0.0	5.90	0.0	5.0	0.0	5.30	0.0	5.40	0.0	5.60	0.0
Insert C Sp Wire To Main Pcb	7.10	0.0	7.40	0.0	7.40	0.0	7.90	0.0	7.30	0.0	7.50	0.0	6.90	0.0	6.80	0.0	7.0	0.0	7.10	0.0
Insert L Sp Wire To Main Pcb	7.70	0.0	7.80	0.0	7.50	0.0	7.20	0.0	7.30	0.0	8.0	0.0	7.20	0.0	7.60	0.0	7.60	0.0	7.50	0.0
Insert R Sp Wire To Main Pcb	7.40	0.0	7.60	0.0	7.20	0.0	7.0	0.0	7.50	0.0	7.50	0.0	7.90	0.0	7.40	0.0	7.40	0.0	7.10	0.0
Insert Optical Wire To Main Pcb	5.70	0.0	5.50	0.0	5.90	0.0	5.60	0.0	5.10	0.0	5.40	0.0	5.30	0.0	5.90	0.0	5.90	0.0	5.20	0.0
Insert 15p Ffc Wire To Main Pcb	9.30	0.0	9.40	0.0	9.0	0.0	9.0	0.0	9.10	0.0	9.30	0.0	9.80	0.0	9.90	0.0	9.50	0.0	9.70	0.0
Insert Button Wire To Main Pcb & Dressing	6.70	0.0	6.50	0.0	6.40	0.0	6.20	0.0	6.90	0.0	6.80	0.0	6.30	0.0	6.10	0.0	6.20	0.0	7.10	0.0
Pass To Next Station	2.0	0.0	2.10	0.0	2.40	0.0	2.70	0.0	2.70	0.0	2.80	0.0	2.40	0.0	2.30	0.0	2.10	0.0	2.0	0.0
	112.5		112.1		111.5		111.7		113.3		114.6		112.3		111.5		110.7		111.8	

WS 8	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Pull Pallet	3.80	0.0	3.50	0.0	3.10	0.0	3.10	0.0	3.90	0.0	3.90	0.0	4.20	0.0	4.50	0.0	4.10	0.0	4.10	0.0
Insert16p Ffc To Ferrite Core	2.80	0.0	2.90	0.0	3.40	0.0	3.30	0.0	3.30	0.0	2.80	0.0	2.70	0.0	2.70	0.0	2.30	0.0	4.0	0.0
Remove Double Side Tape At Ferrite Core & Paset To Front Panel	3.30	0.0	3.40	0.0	3.20	0.0	3.30	0.0	3.30	0.0	4.10	0.0	3.90	0.0	3.10	0.0	3.50	0.0	3.20	0.0
Paste Hemilon At Ferrite Core	2.70	0.0	2.80	0.0	2.70	0.0	2.70	0.0	2.90	0.0	2.10	0.0	3.40	0.0	3.30	0.0	3.50	0.0	2.90	0.0
Fix Bluethoot Pcb To Front Panel & Screw.	11.8	0.0	11.2	0.0	11.9	0.0	11.5	0.0	11.9	0.0	12.1	0.0	12.1	0.0	12.5	0.0	12.4	0.0	12.3	0.0
Insert 16p Ffc Wire Bluetooth Pcb	5.50	0.0	5.90	0.0	5.70	0.0	5.10	0.0	5.10	0.0	5.80	0.0	5.80	0.0	4.90	0.0	5.80	0.0	6.10	0.0
Insert 24p Ffc Wire To Tx Pcb	4.30	0.0	4.20	0.0	4.70	0.0	4.10	0.0	4.80	0.0	3.10	0.0	3.90	0.0	3.90	0.0	4.10	0.0	3.80	0.0
Fix Tx Pcb To Front Panel	6.80	0.0	6.90	0.0	6.40	0.0	6.80	0.0	7.20	0.0	7.0	0.0	7.0	0.0	6.70	0.0	6.90	0.0	7.10	0.0
Screw Tx Pcb To Front Panel	8.30	0.0	8.20	0.0	8.20	0.0	8.90	0.0	8.70	0.0	9.10	0.0	8.50	0.0	8.40	0.0	8.30	0.0	8.20	0.0
Take Fl Display	4.10	0.0	4.10	0.0	4.0	0.0	4.90	0.0	4.50	0.0	4.80	0.0	4.80	0.0	5.10	0.0	5.20	0.0	5.20	0.0
Remove Fl Filter Protector Sheet	2.10	0.0	2.50	0.0	2.40	0.0	2.40	0.0	2.10	0.0	2.80	0.0	2.0	0.0	2.60	0.0	3.10	0.0	3.0	0.0
Insert 15p Ffc Wire From Main Pcb To Fl Display	10.2	0.0	10.6	0.0	10.0	0.0	10.0	0.0	9.90	0.0	10.1	0.0	10.1	0.0	9.80	0.0	10.3	0.0	10.4	0.0
Insert Nfc Wire To Fl Display	8.0	0.0	8.10	0.0	8.10	0.0	8.70	0.0	8.70	0.0	8.60	0.0	8.0	0.0	9.10	0.0	8.50	0.0	8.60	0.0
Insert Ir Sensor Wire To Fl Display	8.30	0.0	8.20	0.0	8.20	0.0	8.70	0.0	8.40	0.0	8.40	0.0	9.0	0.0	8.20	0.0	8.30	0.0	8.30	0.0
Fix Fl Display To Front Panel	8.10	0.0	8.0	0.0	8.0	0.0	8.40	0.0	8.50	0.0	8.20	0.0	9.10	0.0	9.10	0.0	9.90	0.0	8.50	0.0
Insert Smps Wire To Smps Pcb	5.20	0.0	5.10	0.0	5.30	0.0	5.30	0.0	5.90	0.0	5.0	0.0	4.90	0.0	4.90	0.0	4.80	0.0	5.0	0.0
Dressing & Checking Wire Insertion	10.0	0.0	10.1	0.0	10.4	0.0	10.4	0.0	10.9	0.0	10.1	0.0	10.0	0.0	9.80	0.0	9.70	0.0	9.70	0.0
Pass To Next Station	4.20	0.0	4.60	0.0	4.60	0.0	4.90	0.0	4.20	0.0	4.0	0.0	4.10	0.0	4.10	0.0	4.80	0.0	5.0	0.0
	109.5		110.3		110.3		112.5		114.2		112.0		113.5		112.7		115.5		115.4	

WS 9	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Pull Pallet	2.70	0.0	2.80	0.0	2.20	0.0	2.20	0.0	3.0	0.0	2.10	0.0	2.10	0.0	2.40	0.0	2.90	0.0	2.60	0.0
Fix Rear Panel	7.90	0.0	7.80	0.0	7.20	0.0	7.0	0.0	7.0	0.0	7.50	0.0	7.40	0.0	7.90	0.0	6.90	0.0	8.0	0.0
Check Gap & Dressing Wire Sandwich	19.7	0.0	20.0	0.0	20.0	0.0	19.1	0.0	19.60	0.0	19.5	0.0	19.5	0.0	18.3	0.0	19.0	0.0	20.1	0.0
Place Pallet At Clamp Jig & Pull Holder To Clamp	3.10	0.0	3.20	0.0	3.20	0.0	3.90	0.0	2.80	0.0	3.70	0.0	3.90	0.0	3.50	0.0	3.50	0.0	3.0	0.0
Check Gap	1.60	0.0	1.20	0.0	1.60	0.0	1.90	0.0	2.10	0.0	2.30	0.0	2.80	0.0	2.60	0.0	2.80	0.0	2.80	0.0
Screw 18 Pcs	39.7	0.0	39.6	0.0	39.5	0.0	39.5	0.0	39.0	0.0	40.2	0.0	40.2	0.0	39.5	0.0	39.50	0.0	37.4	0.0
Remove Clamp Jig	9.70	0.0	9.50	0.0	9.70	0.0	9.70	0.0	9.30	0.0	9.10	0.0	9.90	0.0	11.1	0.0	10.50	0.0	10.1	0.0
Pass To Next Station	2.20	0.0	2.30	0.0	3.10	0.0	3.50	0.0	2.50	0.0	2.60	0.0	2.50	0.0	2.0	0.0	1.10	0.0	1.30	0.0
	86.6		83.6		86.5		86.8		85.30		87.0		88.3		87.3		86.2		85.3	

WS 10	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Rear Panel	4.90	0.0	4.80	0.0	4.20	0.0	4.20	0.0	5.30	0.0	5.20	0.0	5.20	0.0	5.50	0.0	5.0	0.0	5.10	0.0
Paste Hemilon At L Area 4pcs	15.8	0.0	15.8	0.0	15.2	0.0	15.2	0.0	15.5	0.0	15.9	0.0	15.0	0.0	16.1	0.0	16.0	0.0	16.0	0.0
Paste Hemilon At L Area 1pcs	4.0	0.0	4.0	0.0	4.30	0.0	4.80	0.0	4.80	0.0	4.70	0.0	4.70	0.0	4.80	0.0	4.80	0.0	4.90	0.0
Paste Hemilon At L Area 1pcs	3.0	0.0	3.20	0.0	3.90	0.0	4.30	0.0	4.90	0.0	5.30	0.0	5.20	0.0	5.0	0.0	5.60	0.0	5.60	0.0
Paste Hemilon At C Area 3pcs	9.70	0.0	9.60	0.0	9.20	0.0	9.70	0.0	9.20	0.0	9.20	0.0	9.0	0.0	9.10	0.0	8.30	0.0	8.20	0.0
Paste Hemilon At R Area 1pcs	5.10	0.0	5.20	0.0	6.0	0.0	5.20	0.0	5.10	0.0	5.30	0.0	5.20	0.0	5.20	0.0	5.0	0.0	5.90	0.0
Paste Hemilon At R Area 1pcs	4.90	0.0	4.30	0.0	4.0	0.0	4.70	0.0	4.80	0.0	4.80	0.0	5.10	0.0	4.20	0.0	4.20	0.0	4.0	0.0
Paste Hemilon At R Area 4pcs	12.0	0.0	11.9	0.0	12.6	0.0	12.0	0.0	12.1	0.0	11.8	0.0	11.50	0.0	11.9	0.0	12.8	0.0	12.4	0.0
Paste Eva At Centre Area 1pcs	5.0	0.0	5.20	0.0	5.50	0.0	5.30	0.0	5.10	0.0	5.0	0.0	5.20	0.0	5.40	0.0	5.40	0.0	4.90	0.0
Pass To Next Station	2.0	0.0	2.50	0.0	2.90	0.0	4.0	0.0	3.50	0.0	3.40	0.0	3.40	0.0	3.10	0.0	3.0	0.0	2.80	0.0
	66.4		66.5		67.8		69.4		70.3		70.6		69.50		70.3		70.1		69.8	

WS 11	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Rear Panel	7.10	0.0	7.20	0.0	7.20	0.0	7.50	0.0	7.20	0.0	7.60	0.0	7.60	0.0	7.0	0.0	6.80	0.0	6.80	0.0
Take Rear Panel (PROPOSED LAYOUT) [Improvement Ratio = 1: 1.5]	4.7	0.0	4.8	0.0	4.8	0.0	5.0	0.0	4.8	0.0	5.1	0.0	5.1	0.0	4.7	0.0	4.5	0.0	4.5	0.0
Remove Double Side Tape & Paste At Rear Panel	8.10	0.0	8.0	0.0	8.20	0.0	8.20	0.0	8.50	0.0	8.20	0.0	8.10	0.0	8.70	0.0	8.20	0.0	8.20	0.0
Remove Double Side Tape Sheet At Spacer	6.0	0.0	6.10	0.0	6.10	0.0	5.0	0.0	4.90	0.0	5.80	0.0	6.20	0.0	5.30	0.0	5.20	0.0	6.60	0.0
Paste Spacer At Rear Area	3.0	0.0	3.20	0.0	3.30	0.0	3.40	0.0	3.10	0.0	3.80	0.0	3.80	0.0	3.90	0.0	3.50	0.0	3.0	0.0
Remove Double Side Tape	18.0	0.0	18.20	0.0	18.60	0.0	18.60	0.0	18.0	0.0	18.40	0.0	18.30	0.0	18.40	0.0	18.50	0.0	18.60	0.0
Paste Acoustic Absorber 5pcs	20.70	0.0	20.70	0.0	20.90	0.0	20.0	0.0	20.10	0.0	20.10	0.0	20.50	0.0	20.30	0.0	20.50	0.0	20.80	0.0
Paste Chusion 4pcs	2.90	0.0	2.70	0.0	2.40	0.0	2.40	0.0	3.10	0.0	3.10	0.0	3.80	0.0	3.60	0.0	3.60	0.0	3.70	0.0
Total	70.80		71.30		71.70		71.0		70.70		72.90		74.20		72.30		71.30		72.20	
Total (PROPOSED LAYOUT)	68.4		68.9		69.3		68.5		68.3		70.4		71.7		70.0		69.0		69.9	

WS 12	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Smps Pcb & Breaking Breaking	15.50	0.0	15.90	0.0	16.0	0.0	16.20	0.0	16.70	0.0	16.70	0.0	16.30	0.0	16.50	0.0	16.80	0.0	16.80	0.0
Remove Double Side Tape At Insulation Sheet	2.70	0.0	2.50	0.0	2.50	0.0	2.0	0.0	3.40	0.0	4.0	0.0	4.0	0.0	3.50	0.0	3.20	0.0	3.10	0.0
Paste Insulation Sheet At Smps Chassis	3.10	0.0	3.20	0.0	3.40	0.0	3.40	0.0	3.60	0.0	3.10	0.0	3.10	0.0	3.0	0.0	3.60	0.0	3.60	0.0
Place Smps Chassis At Support Jig	4.30	0.0	4.20	0.0	4.20	0.0	4.10	0.0	4.50	0.0	4.60	0.0	4.90	0.0	4.90	0.0	4.10	0.0	4.10	0.0
Fix Smps Pcb At Chassis	3.10	0.0	3.80	0.0	3.80	0.0	3.20	0.0	3.0	0.0	3.50	0.0	3.10	0.0	3.60	0.0	3.50	0.0	3.60	0.0
Screw Pcb To Smps Chassis 4pcs	16.20	0.0	16.30	0.0	16.90	0.0	16.0	0.0	16.20	0.0	16.50	0.0	16.50	0.0	16.30	0.0	16.30	0.0	16.90	0.0
Pass To Next Station	2.0	0.0	2.0	0.0	2.30	0.0	2.50	0.0	2.90	0.0	2.50	0.0	2.0	0.0	3.20	0.0	3.20	0.0	3.40	0.0
Place Fl Display Chassis To Support Jig	4.40	0.0	4.10	0.0	4.70	0.0	4.90	0.0	4.90	0.0	4.20	0.0	5.10	0.0	5.0	0.0	5.20	0.0	5.10	0.0
Fix Fl Display Pcb At Chassis	5.70	0.0	5.20	0.0	5.30	0.0	5.30	0.0	5.30	0.0	5.10	0.0	5.0	0.0	5.50	0.0	5.50	0.0	5.0	0.0
Screw Fl Display To Chassis 4pcs	15.50	0.0	15.60	0.0	15.70	0.0	15.40	0.0	15.0	0.0	15.60	0.0	15.40	0.0	15.30	0.0	15.20	0.0	15.0	0.0
Remove Double Side Tape At Fl Display Protector	4.60	0.0	4.50	0.0	4.90	0.0	5.0	0.0	5.0	0.0	5.60	0.0	5.80	0.0	4.10	0.0	4.20	0.0	4.20	0.0
Paste Display Protector At Fl Display	6.0	0.0	6.10	0.0	6.20	0.0	6.70	0.0	6.80	0.0	6.0	0.0	6.20	0.0	6.40	0.0	6.50	0.0	5.90	0.0
Pass To Next Station	2.30	0.0	2.50	0.0	2.50	0.0	2.0	0.0	3.30	0.0	2.40	0.0	2.0	0.0	3.50	0.0	3.0	0.0	2.10	0.0
	85.40		85.90		88.40		86.70		90.60		89.80		89.40		90.80		90.30		88.80	

WS 13	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Main Pcb & Breaking	14.30	0.0	14.40	0.0	14.50	0.0	14.20	0.0	14.50	0.0	14.0	0.0	14.20	0.0	14.90	0.0	14.0	0.0	14.0	0.0
Pass To Next Station	3.20	0.0	3.30	0.0	3.20	0.0	3.10	0.0	3.90	0.0	3.50	0.0	3.20	0.0	3.60	0.0	3.20	0.0	3.70	0.0
Remove Double Side Tape	4.20	0.0	4.90	0.0	4.10	0.0	4.60	0.0	4.30	0.0	4.30	0.0	3.80	0.0	3.20	0.0	3.90	0.0	4.10	0.0
Paste At Button Pcb	3.0	0.0	3.0	0.0	3.20	0.0	3.90	0.0	3.90	0.0	3.60	0.0	3.50	0.0	3.0	0.0	3.0	0.0	3.40	0.0
Pass To Next Station	2.0	0.0	2.30	0.0	3.40	0.0	2.20	0.0	3.80	0.0	3.10	0.0	2.40	0.0	2.50	0.0	2.60	0.0	2.80	0.0
Remove Double Side Tape	2.90	0.0	3.50	0.0	3.0	0.0	2.70	0.0	2.90	0.0	3.50	0.0	3.10	0.0	3.10	0.0	3.40	0.0	3.20	0.0
Paste At Nfc Pcb	3.0	0.0	3.0	0.0	3.50	0.0	3.80	0.0	3.90	0.0	3.50	0.0	3.60	0.0	3.10	0.0	3.40	0.0	3.80	0.0
Pass To Next Station	2.90	0.0	2.80	0.0	2.90	0.0	2.10	0.0	2.50	0.0	2.50	0.0	2.40	0.0	2.0	0.0	2.60	0.0	2.70	0.0
Fix Hdmi Chassis To Hdmi Pcb	6.10	0.0	6.20	0.0	6.10	0.0	6.30	0.0	6.30	0.0	6.40	0.0	6.20	0.0	6.40	0.0	6.50	0.0	6.0	0.0
Screw Hdmi Chassis To Hdmi Pcb 3pcs	11.20	0.0	11.20	0.0	11.80	0.0	12.40	0.0	12.50	0.0	12.30	0.0	12.0	0.0	12.0	0.0	11.10	0.0	10.90	0.0
Paste Hemilon At Hdmi Chassis 3pcs	8.70	0.0	8.40	0.0	8.50	0.0	8.40	0.0	8.30	0.0	8.40	0.0	8.50	0.0	8.20	0.0	8.10	0.0	8.20	0.0
Pass To Next Station	2.60	0.0	2.70	0.0	2.10	0.0	2.0	0.0	2.0	0.0	3.10	0.0	3.20	0.0	3.50	0.0	2.50	0.0	2.80	0.0
Paste Hemilon At Optical Pcb 1pcs (Rmq2311h)	2.90	0.0	2.80	0.0	2.50	0.0	2.50	0.0	2.10	0.0	2.40	0.0	2.90	0.0	3.40	0.0	3.20	0.0	3.10	0.0
Paste Hemilon At Ir Blaster (Rmq2311h)	4.10	0.0	4.20	0.0	4.30	0.0	3.90	0.0	4.50	0.0	4.10	0.0	4.60	0.0	4.20	0.0	4.10	0.0	4.20	0.0
Pass To Next Station	2.30	0.0	2.30	0.0	2.40	0.0	2.50	0.0	2.50	0.0	2.90	0.0	2.90	0.0	2.10	0.0	2.0	0.0	2.30	0.0
	73.40		75.0		75.50		74.60		77.90		77.60		76.50		75.20		73.60		75.20	

WS 14	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Main Pcb & Breaking	10.40	0.0	10.30	0.0	10.50	0.0	10.70	0.0	10.90	0.0	10.10	0.0	10.0	0.0	10.80	0.0	10.40	0.0	10.30	0.0
Remove Double Side Tape At Main Insulation Sheet	2.0	0.0	2.0	0.0	2.90	0.0	2.30	0.0	2.50	0.0	2.60	0.0	3.40	0.0	3.50	0.0	2.50	0.0	2.60	0.0
Paste Main Insulation Sheet At Main Pcb Chassis	3.10	0.0	3.20	0.0	3.50	0.0	3.60	0.0	3.10	0.0	3.0	0.0	3.0	0.0	5.10	0.0	3.40	0.0	3.50	0.0
Attach Thermal Absorber At Main Pcb Chassis 2pcs	5.70	0.0	5.20	0.0	5.40	0.0	5.40	0.0	5.90	0.0	6.0	0.0	6.10	0.0	5.30	0.0	5.80	0.0	5.70	0.0
Place Main Pcb Chassis At Support Jig	2.90	0.0	2.80	0.0	2.40	0.0	2.50	0.0	2.70	0.0	2.70	0.0	2.80	0.0	2.10	0.0	2.50	0.0	2.60	0.0
Fix Main Pcb To Main Pcb Chassis	4.30	0.0	4.80	0.0	4.10	0.0	4.20	0.0	4.50	0.0	4.50	0.0	4.10	0.0	4.0	0.0	3.60	0.0	3.90	0.0
Screw Main Pcb To Chassis 4pcs	13.10	0.0	12.90	0.0	13.40	0.0	13.50	0.0	13.60	0.0	13.70	0.0	13.90	0.0	13.60	0.0	13.70	0.0	13.50	0.0
Paste Ept Sealer To Main Pcb Chassis 2 Pcs	6.30	0.0	6.40	0.0	6.50	0.0	6.10	0.0	6.0	0.0	6.80	0.0	6.20	0.0	6.50	0.0	6.30	0.0	6.20	0.0
Paste Ept Sealer To 16p Ffc Wire	5.10	0.0	5.20	0.0	5.30	0.0	5.30	0.0	5.60	0.0	5.70	0.0	5.90	0.0	5.10	0.0	5.10	0.0	5.30	0.0
Insert 16p Ffc To Main Pcb	3.60	0.0	3.70	0.0	3.50	0.0	3.50	0.0	3.10	0.0	3.90	0.0	3.20	0.0	3.70	0.0	3.10	0.0	3.0	0.0
Dress 16p Ffc & Paste Tape 2pcs	5.0	0.0	5.30	0.0	5.20	0.0	5.20	0.0	5.10	0.0	5.0	0.0	5.20	0.0	5.80	0.0	5.60	0.0	5.0	0.0
Insert 30p Ffc To Main Pcb	4.60	0.0	4.60	0.0	4.70	0.0	4.10	0.0	4.0	0.0	3.90	0.0	3.80	0.0	5.10	0.0	5.20	0.0	5.60	0.0
Art 20 Checking	14.0	0.0	14.90	0.0	15.10	0.0	14.20	0.0	13.90	0.0	14.70	0.0	14.80	0.0	14.60	0.0	14.90	0.0	14.0	0.0
Pass To Next Station	3.10	0.0	3.10	0.0	3.15	0.0	3.19	0.0	3.35	0.0	3.52	0.0	3.25	0.0	3.16	0.0	3.19	0.0	3.16	0.0
Pass To Next Station (PROPOSED LAYOUT) [Improvement Ratio = 1: 5]	0.62	0.00	0.62	0.00	0.63	0.00	0.64	0.00	0.67	0.00	0.70	0.00	0.65	0.00	0.63	0.00	0.64	0.00	0.63	0.00
	83.20		84.40		85.65		83.79		84.25		86.12		85.65		88.36		85.29		84.36	
Total (PROPOSED LAYOUT)	80.72		81.92		83.13		81.24		81.57		83.30		83.05		85.83		82.74		81.83	

WS 15	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Set & Paste Name Plate	7.90	0.0	7.80	0.0	7.0	0.0	7.80	0.0	7.40	0.0	7.40	0.0	7.20	0.0	7.30	0.0	7.70	0.0	7.20	0.0
Paste Show Sticker	11.80	0.0	11.40	0.0	11.90	0.0	11.50	0.0	11.30	0.0	11.30	0.0	11.20	0.0	11.0	0.0	12.20	0.0	12.10	0.0
Insert Ac Cord ,Optical & Remote Wire	3.20	0.0	3.40	0.0	3.40	0.0	3.70	0.0	3.90	0.0	3.10	0.0	3.20	0.0	3.90	0.0	3.80	0.0	3.80	0.0
Check Version, Model, Region	17.60	0.0	17.40	0.0	17.40	0.0	15.90	0.0	16.20	0.0	16.40	0.0	16.20	0.0	16.90	0.0	17.20	0.0	17.50	0.0
Bbd Checking	24.90	0.0	24.0	0.0	25.10	0.0	25.30	0.0	25.30	0.0	25.40	0.0	25.80	0.0	25.10	0.0	25.80	0.0	25.30	0.0
Off Power & Remove All Wires	3.90	0.0	3.80	0.0	3.60	0.0	3.10	0.0	3.80	0.0	4.20	0.0	4.70	0.0	4.30	0.0	4.40	0.0	4.80	0.0
Pass To Next Station	4.60	0.0	4.80	0.0	4.50	0.0	3.90	0.0	4.50	0.0	4.10	0.0	4.30	0.0	4.50	0.0	4.50	0.0	4.10	0.0
	73.90		72.60		72.90		71.20		72.40		71.90		72.60		73.0		75.60		74.80	

WS 16	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Set & Checking Rocking	6.70	0.0	6.10	0.0	6.80	0.0	7.10	0.0	7.20	0.0	6.10	0.0	6.30	0.0	6.40	0.0	6.30	0.0	6.30	0.0
Insert Ac Cord & Hdmi Cable	3.90	0.0	3.80	0.0	3.10	0.0	3.50	0.0	3.20	0.0	4.30	0.0	4.50	0.0	4.20	0.0	4.10	0.0	4.20	0.0
Pairing, Nfc Writing, Sound Mode & Reset	15.10	0.0	15.20	0.0	15.40	0.0	15.20	0.0	15.10	0.0	16.20	0.0	16.0	0.0	15.90	0.0	15.90	0.0	15.80	0.0
Press Sound Check All Equalizer Output	25.80	0.0	25.30	0.0	25.40	0.0	24.10	0.0	26.30	0.0	26.10	0.0	26.30	0.0	26.30	0.0	26.10	0.0	26.0	0.0
Move Set Up & Down To Check Wall & Table Effect	17.0	0.0	17.20	0.0	17.20	0.0	17.40	0.0	17.90	0.0	17.30	0.0	17.50	0.0	17.0	0.0	17.20	0.0	17.10	0.0
Button Checking (Full Segment)	7.0	0.0	7.0	0.0	7.20	0.0	7.30	0.0	7.10	0.0	7.0	0.0	7.40	0.0	7.80	0.0	7.10	0.0	7.30	0.0
Take Ac Cord & Hdmi Cable	3.80	0.0	3.90	0.0	3.60	0.0	3.10	0.0	3.60	0.0	3.60	0.0	3.10	0.0	3.0	0.0	3.50	0.0	3.50	0.0
Pass To Next Station	2.10	0.0	2.10	0.0	2.30	0.0	2.30	0.0	2.50	0.0	2.90	0.0	2.80	0.0	2.10	0.0	2.70	0.0	2.40	0.0
	81.40		80.60		81.0		80.0		82.90		83.50		83.90		82.70		82.90		82.60	

WS 17	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Set	2.0	0.0	2.2	0.0	2.9	0.0	2.5	0.0	2.5	0.0	2.6	0.0	2.1	0.0	2.0	0.0	3.2	0.0	3.2	0.0
Insert Hdmi To Av Out (Arc)	2.3	0.0	2.5	0.0	2.8	0.0	2.9	0.0	2.1	0.0	2.5	0.0	2.7	0.0	2.9	0.0	2.6	0.0	2.1	0.0
Insert Hdmi Wire Sub To Hdmi 2 (Aux)	2.8	0.0	2.9	0.0	2.6	0.0	2.9	0.0	2.9	0.0	3.1	0.0	3.2	0.0	3.1	0.0	3.1	0.0	3.5	0.0
Insert Hdmi Wire Main 4k From Bd To Hdmi 1(Bd/Dvd)	3.6	0.0	3.9	0.0	3.1	0.0	3.0	0.0	2.9	0.0	2.8	0.0	2.9	0.0	3.2	0.0	3.1	0.0	3.5	0.0
Insert Ac Cord	3.9	0.0	3.8	0.0	3.8	0.0	3.5	0.0	4.1	0.0	4.2	0.0	4.2	0.0	4.4	0.0	4.1	0.0	4.5	0.0
Turn Set & Wait Sound From Tv (Checking Tv Ouput)	44.0	0.0	44.2	0.0	44.1	0.0	44.5	0.0	44.9	0.0	44.1	0.0	44.2	0.0	44.2	0.0	44.1	0.0	44.6	0.0
Press Viera Link (Tv Remote) Checking	2.0	0.0	2.1	0.0	2.5	0.0	2.3	0.0	2.6	0.0	2.7	0.0	2.5	0.0	2.5	0.0	2.5	0.0	2.5	0.0
Press Input 1x To Change Input To Aux (Main Set Remote)	1.8	0.0	1.2	0.0	1.9	0.0	1.7	0.0	1.5	0.0	1.6	0.0	1.4	0.0	1.5	0.0	1.8	0.0	1.3	0.0
Reset Main Set	5.2	0.0	5.3	0.0	5.4	0.0	5.8	0.0	5.2	0.0	5.4	0.0	5.2	0.0	5.6	0.0	5.4	0.0	5.8	0.0
Turn Set & Remove Ac Cord	7.7	0.0	7.0	0.0	7.5	0.0	7.3	0.0	7.2	0.0	7.4	0.0	7.5	0.0	7.9	0.0	7.9	0.0	7.2	0.0
Remove Hdmi 1	1.9	0.0	1.4	0.0	1.8	0.0	1.9	0.0	2.5	0.0	2.0	0.0	2.3	0.0	2.2	0.0	2.6	0.0	2.5	0.0
Remove Hdmi 2	1.5	0.0	1.9	0.0	2.0	0.0	2.5	0.0	2.4	0.0	2.8	0.0	2.9	0.0	2.5	0.0	2.4	0.0	2.4	0.0
Remove Hdmi 3	2.0	0.0	2.1	0.0	2.3	0.0	2.9	0.0	2.8	0.0	2.5	0.0	2.5	0.0	2.5	0.0	2.6	0.0	2.1	0.0
Pass Set To Next	3.0	0.0	3.5	0.0	3.1	0.0	3.6	0.0	3.0	0.0	3.9	0.0	3.6	0.0	3.1	0.0	3.5	0.0	3.5	0.0
	83.70		84.0		85.80		87.30		86.60		87.60		87.20		87.60		88.90		88.70	

WS 18	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Set & Insert Ac Cord	3.80	0.0	4.0	0.0	4.20	0.0	4.50	0.0	4.50	0.0	4.0	0.0	5.20	0.0	5.30	0.0	4.0	0.0	4.60	0.0
Nfc & Bluetooth Checking	11.20	0.0	11.30	0.0	11.90	0.0	12.50	0.0	12.0	0.0	12.30	0.0	11.40	0.0	11.40	0.0	11.40	0.0	12.60	0.0
Check Version, Model, Region	8.30	0.0	8.40	0.0	8.30	0.0	8.30	0.0	8.10	0.0	8.10	0.0	9.10	0.0	9.0	0.0	8.10	0.0	8.20	0.0
Serial No Paseting	3.80	0.0	3.80	0.0	3.70	0.0	3.70	0.0	3.10	0.0	3.10	0.0	4.20	0.0	4.20	0.0	4.50	0.0	4.50	0.0
Puncture Test	27.20	0.0	28.0	0.0	27.30	0.0	27.10	0.0	27.30	0.0	27.50	0.0	28.0	0.0	28.30	0.0	28.0	0.0	28.0	0.0
Pass Set To Next Station	2.40	0.0	2.50	0.0	2.50	0.0	2.60	0.0	2.60	0.0	2.80	0.0	2.80	0.0	2.80	0.0	2.10	0.0	2.0	0.0
Pass Set To Next Station (PROPOSED LAYOUT) [Improvement Ratio = 1: 1.5]	1.6	0.0	1.7	0.0	1.7	0.0	1.7	0.0	1.7	0.0	1.9	0.0	1.9	0.0	1.9	0.0	1.4	0.0	1.3	0.0
Total	56.70		58.0		57.90		58.70		57.60		57.80		60.70		61.0		58.10		59.90	
Total (PROPOSED LAYOUT)	55.9		57.2		57.1		57.8		56.7		56.9		59.8		60.1		57.4		59.2	

WS 19	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Front Panel App Check --> Printing/Scratches/Panasonic Badge Check	17.20	0.0	17.30	0.0	15.60	0.0	19.50	0.0	19.60	0.0	17.30	0.0	17.50	0.0	17.50	0.0	17.20	0.0	17.40	0.0
4 Corner Gap Check	15.10	0.0	15.10	0.0	15.0	0.0	15.40	0.0	15.60	0.0	15.30	0.0	16.10	0.0	16.0	0.0	15.80	0.0	15.70	0.0
Air Blow On The Front Panel Spk Net	4.70	0.0	4.80	0.0	4.30	0.0	4.60	0.0	4.80	0.0	4.60	0.0	4.0	0.0	5.70	0.0	4.30	0.0	4.30	0.0
Rear Panel App Check	6.90	0.0	6.90	0.0	6.50	0.0	6.10	0.0	6.10	0.0	6.70	0.0	6.20	0.0	6.20	0.0	6.30	0.0	6.30	0.0
Miramat Packing	12.10	0.0	12.20	0.0	12.20	0.0	12.80	0.0	12.70	0.0	12.60	0.0	11.90	0.0	13.80	0.0	13.20	0.0	13.30	0.0
Pass Set To Next Station	5.10	0.0	5.20	0.0	5.10	0.0	5.40	0.0	5.60	0.0	5.70	0.0	6.0	0.0	5.20	0.0	6.30	0.0	6.50	0.0
	61.10		61.50		58.70		63.80		64.40		62.20		61.70		64.40		63.10		63.50	

WS 20	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Rear Panel Take & Fitting Onto Assy Jig	6.20	0.0	6.0	0.0	6.40	0.0	5.70	0.0	5.50	0.0	6.10	0.0	6.0	0.0	5.90	0.0	6.30	0.0	5.70	0.0
Ac Inlet Insert	3.0	0.0	3.20	0.0	3.50	0.0	3.10	0.0	3.70	0.0	3.70	0.0	3.20	0.0	3.10	0.0	3.90	0.0	2.50	0.0
Smps Chasis Insert	4.20	0.0	4.20	0.0	4.0	0.0	4.90	0.0	4.50	0.0	4.50	0.0	4.0	0.0	3.80	0.0	3.40	0.0	2.40	0.0
Button Pcb Insert & Screwing X 2	7.60	0.0	7.50	0.0	6.60	0.0	6.40	0.0	7.20	0.0	7.90	0.0	7.70	0.0	5.10	0.0	5.20	0.0	5.50	0.0
Smps Chasis Screwing X 4	15.30	0.0	15.50	0.0	15.50	0.0	15.90	0.0	15.20	0.0	14.60	0.0	15.70	0.0	16.10	0.0	16.0	0.0	16.0	0.0
Heat Dissipative Sheet Pasting	3.20	0.0	3.30	0.0	3.0	0.0	3.60	0.0	4.10	0.0	4.50	0.0	3.0	0.0	3.0	0.0	2.90	0.0	3.40	0.0
Smps Pcb Fittig On The Smps Chasis	3.80	0.0	4.0	0.0	3.20	0.0	2.30	0.0	3.50	0.0	5.50	0.0	6.90	0.0	3.40	0.0	3.60	0.0	3.90	0.0
Power Selector Fitting	5.40	0.0	5.50	0.0	5.20	0.0	5.40	0.0	5.50	0.0	5.0	0.0	6.10	0.0	5.20	0.0	5.0	0.0	5.0	0.0
Button Wire Insert	4.70	0.0	4.60	0.0	4.50	0.0	4.40	0.0	4.40	0.0	4.0	0.0	4.50	0.0	4.80	0.0	4.20	0.0	4.20	0.0
Rx Pcb Inseert & Ffc Connection	11.0	0.0	11.0	0.0	11.30	0.0	11.50	0.0	12.0	0.0	11.20	0.0	11.70	0.0	11.60	0.0	11.20	0.0	11.20	0.0
Screwing X 5	15.30	0.0	15.0	0.0	15.20	0.0	15.20	0.0	15.90	0.0	15.0	0.0	14.80	0.0	15.20	0.0	15.30	0.0	15.40	0.0
Flip The Rear Panel & Screw The Ac Inlet X 1	6.60	0.0	6.0	0.0	6.30	0.0	6.30	0.0	6.70	0.0	6.90	0.0	6.80	0.0	6.10	0.0	6.10	0.0	6.0	0.0
Pass Set To Next Station	3.20	0.0	3.20	0.0	3.10	0.0	3.30	0.0	3.50	0.0	3.70	0.0	3.80	0.0	3.20	0.0	3.90	0.0	4.0	0.0
Total	89.50		89.0		87.80		88.0		91.70		92.60		~~94.20~~		86.50		87.0		85.20	

WS 21	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Rx Pcb Sheild Cover Insert & Screwing	10.9	0.0	10.80	0.0	11.0	0.0	11.0	0.0	11.3	0.0	11.5	0.0	11.1	0.0	11.2	0.0	10.4	0.0	10.3	0.0
Sheild Grounding Wire Screwing	4.10	0.0	4.20	0.0	4.30	0.0	4.20	0.0	4.20	0.0	4.90	0.0	4.80	0.0	4.10	0.0	4.20	0.0	3.90	0.0
Smps Pcb Breaking & Ac-In Wire Dressing With Cable Tie Cutting	18.4	0.0	18.20	0.0	18.3	0.0	18.0	0.0	18.0	0.0	18.5	0.0	18.2	0.0	17.9	0.0	17.8	0.0	17.2	0.0
Label Pasting On Rear Panel & Fitting Onto Inspection Jig	8.50	0.0	8.60	0.0	8.0	0.0	8.0	0.0	8.90	0.0	8.80	0.0	8.50	0.0	8.20	0.0	8.50	0.0	8.30	0.0
Wire Connect & Press Start Button	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0
Release The Wire Connection & Take Out The Uut	3.10	0.0	3.0	0.0	4.10	0.0	2.90	0.0	2.90	0.0	3.40	0.0	3.90	0.0	3.70	0.0	3.40	0.0	3.30	0.0
Pass Set To Next Station	3.20	0.0	3.20	0.0	3.0	0.0	3.10	0.0	3.50	0.0	3.50	0.0	3.90	0.0	3.80	0.0	3.50	0.0	3.60	0.0
Total	70.2		70.0		70.7		69.0		70.8		72.6		72.4		70.9		69.9		68.0	

WS 22	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Out The Sub Woofer Unit From Pallet	6.0	0.0	6.9	0.0	5.9	0.0	5.8	0.0	6.2	0.0	6.1	0.0	6.3	0.0	6.7	0.0	6.0	0.0	6.0	0.0
Unpack The Polyform	15.2	0.0	15.3	0.0	15.0	0.0	15.0	0.0	15.1	0.0	15.1	0.0	15.8	0.0	14.9	0.0	14.2	0.0	14.6	0.0
Place The Empty Polyform On The Conveyor	2.7	0.0	2.2	0.0	2.9	0.0	2.8	0.0	2.8	0.0	2.3	0.0	2.4	0.0	3.1	0.0	3.4	0.0	3.5	0.0
Take & Insert The Rear Panel Unit Onto Sub Woofer Unit	35.8	0.0	35.2	0.0	35.0	0.0	35.1	0.0	35.8	0.0	35.7	0.0	35.1	0.0	35.1	0.0	36.0	0.0	36.2	0.0
Screwing X 6	17.2	0.0	17.1	0.0	17.2	0.0	17.8	0.0	17.4	0.0	17.2	0.0	17.8	0.0	17.7	0.0	17.7	0.0	17.3	0.0
Pass Set To Next Station Together With Sound Bar Unit	7.2	0.0	7.3	0.0	7.3	0.0	7.0	0.0	7.1	0.0	7.6	0.0	7.6	0.0	7.9	0.0	7.1	0.0	7.2	0.0
Pass Set To Next Station Together With Sound Bar Unit (PROPOSED LAYOUT) [Improvement Ratio = 1: 7]	1.03	0.00	1.04	0.00	1.04	0.00	1.00	0.00	1.01	0.00	1.09	0.00	1.09	0.00	1.13	0.00	1.01	0.00	1.03	0.00
Total	84.1		84.0		83.3		83.5		84.4		84.0		85.0		85.4		84.4		84.8	
Total (PROPOSED LAYOUT)	77.93		77.74		77.04		77.50		78.31		77.49		78.49		78.63		78.31		78.63	

WS 23	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take Sub Woofer Set	8.40	0.0	8.50	0.0	8.20	0.0	8.0	0.0	8.0	0.0	8.90	0.0	7.80	0.0	7.50	0.0	7.40	0.0	8.90	0.0
Insert Ac Cord A, Punture Test In Progress	7.60	0.0	7.30	0.0	7.60	0.0	7.20	0.0	7.20	0.0	7.90	0.0	7.90	0.0	7.10	0.0	7.40	0.0	7.60	0.0
Take Out Ac Cord A, Insert Ac Cord B For Power Comsuption Test	14.30	0.0	14.80	0.0	15.10	0.0	14.20	0.0	14.70	0.0	14.60	0.0	14.0	0.0	14.0	0.0	14.60	0.0	14.20	0.0
Take Out Ac Cord B	6.30	0.0	6.20	0.0	6.10	0.0	6.90	0.0	6.70	0.0	6.0	0.0	6.80	0.0	6.90	0.0	7.0	0.0	7.10	0.0
Appearance Check On Subwoofer Unit	17.90	0.0	17.80	0.0	17.40	0.0	17.0	0.0	17.10	0.0	17.50	0.0	17.50	0.0	18.20	0.0	18.20	0.0	18.10	0.0
Templete Check & Confirmation	4.0	0.0	4.0	0.0	4.40	0.0	4.50	0.0	4.20	0.0	4.90	0.0	4.80	0.0	5.10	0.0	4.40	0.0	4.60	0.0
Serial No Check & Pasting	15.50	0.0	15.50	0.0	15.30	0.0	15.60	0.0	15.10	0.0	14.90	0.0	14.80	0.0	15.70	0.0	15.20	0.0	15.50	0.0
Set Dressing	4.40	0.0	4.40	0.0	4.10	0.0	4.90	0.0	4.90	0.0	4.20	0.0	4.0	0.0	3.90	0.0	3.90	0.0	3.80	0.0
Pass Set To Next Station	2.10	0.0	2.10	0.0	2.0	0.0	2.90	0.0	2.40	0.0	2.40	0.0	2.30	0.0	2.70	0.0	2.80	0.0	2.80	0.0
Pass Set To Next Station (PROPOSED LAYOUT) [Improvement Ratio = 1: 1.2]	1.8	0.0	1.8	0.0	1.7	0.0	2.4	0.0	2.0	0.0	2.0	0.0	1.9	0.0	2.3	0.0	2.3	0.0	2.3	0.0
Total	80.50		80.60		80.20		81.20		80.30		81.30		79.90		81.10		80.90		82.60	
Total (PROPOSED LAYOUT)	80.2		80.3		79.9		80.7		79.9		80.9		79.5		80.7		80.4		82.1	

WS 24	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Pull Pallet	4.70	0.0	5.0	0.0	4.90	0.0	4.90	0.0	4.20	0.0	4.50	0.0	4.90	0.0	4.10	0.0	4.0	0.0	4.0	0.0
Paste Pairing No & Insert Ac Cord/Optical	8.30	0.0	8.20	0.0	9.10	0.0	9.0	0.0	9.50	0.0	8.40	0.0	8.50	0.0	8.60	0.0	8.70	0.0	8.0	0.0
Pairing	8.20	0.0	8.30	0.0	8.90	0.0	8.10	0.0	7.30	0.0	7.20	0.0	7.20	0.0	7.90	0.0	8.10	0.0	8.50	0.0
Remove Ac Cord	2.0	0.0	2.0	0.0	2.10	0.0	2.10	0.0	2.50	0.0	2.90	0.0	2.70	0.0	2.40	0.0	2.10	0.0	1.90	0.0
Pass Set To Next Station	2.40	0.0	2.0	0.0	2.30	0.0	2.50	0.0	2.80	0.0	2.90	0.0	2.20	0.0	2.30	0.0	2.10	0.0	2.0	0.0
Transfer The Subwoofer Unit To Next Station	5.0	0.0	5.0	0.0	5.20	0.0	5.30	0.0	4.70	0.0	5.50	0.0	5.50	0.0	5.0	0.0	5.10	0.0	5.20	0.0
2nd Time Appearance Check On Sound Bar Unitwith Led Torch Light	18.40	0.0	18.40	0.0	18.20	0.0	17.90	0.0	17.70	0.0	18.60	0.0	18.50	0.0	18.30	0.0	19.0	0.0	19.10	0.0
Serial No Pasting	6.80	0.0	6.70	0.0	6.70	0.0	6.30	0.0	6.10	0.0	6.10	0.0	6.0	0.0	7.0	0.0	7.20	0.0	7.50	0.0
Pass Set To Next Station	6.0	0.0	6.40	0.0	6.40	0.0	6.90	0.0	6.50	0.0	6.20	0.0	6.30	0.0	6.80	0.0	6.10	0.0	6.10	0.0
Total	61.80		62.0		63.80		63.0		61.30		62.30		61.80		62.40		62.40		62.30	

WS 25	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Take The Sub-Woofer Set & Poly Form To Work Station	3.80	0.0	3.40	0.0	3.20	0.0	3.20	0.0	3.0	0.0	4.50	0.0	4.10	0.0	4.0	0.0	3.10	0.0	3.20	0.0
Poly Form Packing Of Sub-Woofer	24.10	0.0	24.20	0.0	24.80	0.0	24.0	0.0	25.10	0.0	23.90	0.0	24.10	0.0	25.20	0.0	25.0	0.0	24.50	0.0
Strapping	12.90	0.0	12.50	0.0	12.10	0.0	13.10	0.0	13.0	0.0	13.70	0.0	12.50	0.0	12.60	0.0	12.70	0.0	12.70	0.0
Pass To Next Station	0.70	0.0	0.80	0.0	0.80	0.0	1.0	0.0	1.20	0.0	1.0	0.0	0.60	0.0	0.90	0.0	0.60	0.0	1.50	0.0
Total	41.50		40.90		40.90		41.30		42.30		43.10		41.30		42.70		41.40		41.90	

WS 26	1		2		3		4		5		6		7		8		9		10	
	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC	M	MC
Carton Box Preparation	10.60	0.0	10.70	0.0	10.0	0.0	9.90	0.0	9.50	0.0	9.60	0.0	10.10	0.0	10.50	0.0	10.40	0.0	10.30	0.0
Complete Set Packing (Sound Bar + Subwoofer)	18.0	0.0	18.0	0.0	17.90	0.0	18.90	0.0	18.70	0.0	18.70	0.0	18.50	0.0	18.40	0.0	18.90	0.0	18.0	0.0
Accessory/Ib Part Insert, Scanning	10.40	0.0	10.40	0.0	18.60	0.0	18.70	0.0	18.90	0.0	18.50	0.0	18.20	0.0	18.20	0.0	18.20	0.0	18.0	0.0
Weighing Inspection	7.80	0.0	7.70	0.0	7.70	0.0	7.10	0.0	7.90	0.0	7.30	0.0	7.40	0.0	7.40	0.0	7.60	0.0	7.60	0.0
Sealing	10.60	0.0	10.50	0.0	10.60	0.0	10.90	0.0	10.0	0.0	10.0	0.0	10.50	0.0	10.50	0.0	10.60	0.0	10.20	0.0
Transfer To Pallet	6.90	0.0	6.90	0.0	6.30	0.0	6.50	0.0	6.0	0.0	6.20	0.0	6.30	0.0	6.30	0.0	6.0	0.0	6.20	0.0
Total	64.30		64.20		71.10		72.0		71.0		70.30		71.0		71.30		71.70		70.30	