CRANFIELD UNIVERSITY

Chao Li

A Customised Lean Model for a Chinese Aerospace OEM (Original Equipment Manufacturer)

SCHOOL OF APPLIED SCIENCES

MSc by Research Thesis
Academic Year: 2010 - 2011

Supervisor: Dr. Paul Baguley
Dr. Ashutosh Tiwari
Apr. 2011

CRANFIELD UNIVERSITY

SCHOOL OF APPLIED SCIENCES

MSc by Research Thesis

Academic Year 2010 - 2011

Chao Li

A Customised Lean Model for a Chinese Aerospace OEM (Original Equipment Manufacturer)

Supervisor: Dr. Paul Baguley
Dr. Ashutosh Tiwari

Apr. 2011

ABSTRACT

The aim of this research is to introduce Lean Thinking in a systematic and cost effective way; moreover, it is to bring Lean Principles and apply Lean Tools to the new aerospace companies. In particular the research will develop a customised Lean manufacturing model. The following objectives will be achieved during the research. 1); Investigate the principal features of Lean Thinking, and identify state of the art in Lean manufacturing implementation. 2); Identify the current situation of a specific Chinese aerospace company and the requirements needed in becoming Lean. 3); Develop a customised Lean model for applying Lean into a new Chinese aerospace company. 4); Validate the Lean manufacturing model by experts in the company and university.

The Chinese traditional thinking is different from lean think. Therefore, to implement Lean in China will face some distinct barriers. The author attempts to resolve these problems through a customised lean model. According to the literature review and researcher's knowledge, there is no paper developing a model linking to the barriers of lean implementation in Chinese manufacturing. Therefore, the author will attempt to fill in this gap during the research.

The questionnaire and assessment tool will be used to collect information from the company. Best practices will help to establish the structure of the model. However, in China, most companies implement lean through copying examples from the United States, UK and other Western countries without combining their current situation and culture. The contribution of this research is to develop a model to link Chinese barriers and a company's situation for lean implementation.

Finally, this model will be validated by company and academic experts. The first validation is based on the sponsoring company. Other validations are achieved by academic experts and industrial expert.

Keywords:
Lean Manufacturing, Lean Model, Lean Tools.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my company – COMAC – for their support for my study.

And heartfelt gratitude to my family, who encouraged me to study hard and gave me the love to live in the UK. Without this, I would feel lonely.

I would like to thank my supervisors Dr. Paul Baguley and Dr. Ashutosh Tiwari for their enormous support through the different stages of this research. I would also like to thank Dr. Ahmed Al-Ashaab for his invaluable support.

Finally, many people have helped me during this thesis, more than I can thank in this section.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TERMS

CM: Cellular Manufacturing

JIT: Just in time

Kb: Kanban

Kz: Kaizen

OPF: One Piece Flow

PY: Poka Yoke

SMED: Single Minute Exchange of Dies

SW: Standardised Work

TPM: Total productive maintenance

VF: Visual Factory

VSM: Value stream mapping

1 INTRODUCTION

This chapter will provide the reader a basic overview about the project. The research background and motivation will be discussed first, followed by an introduction to the customer's company. Based on its demands, the research aim and objectives will be identified and the thesis structure clearly presented.

1.1 Research Background

Since Womack issued a book named "The Machine That Changed the World", the concept of lean has attracted attention of a growing number of experts and scholars from all over the world. Many research reports have been published to show successful implementation examples in the different areas. Aerospace companies have recognized that it is an opportunity to eliminate a lot of waste, and improve the competitiveness of companies.

Aerospace industry had started a reform named "lean". The Lean Advancement Initiative (LAI) at MIT (Massachusetts Institute of Technology) has studied Lean for many years with its participator. They focus on transforming the company or enterprise to become Lean by applying lean thinking and tools (Lean Advancement Initiative, 2010). The goal of lean is to eliminate waste from the production cycle and add customer value. The Automotive industry has implemented Lean over many years. Aerospace Manufacturers have also begun to accept lean thinking. Now, their motivation is to develop faster, higher quality and lower cost lean model.

The examples of Lean implementation were obvious in the United States and UK. In the United States, F – 16, F – 22 fighters and C – 130J military transport aircraft are products of the implementation of lean programs under the support of Lean Aerospace Initiative (LAI) (Ronald, 2003). In the UK, BAE Systems military aircraft factory had also been actively involved in Lean activities in the past (Tyson & Ralph, 2009). The LAI had collaborated with the UK universities (Bath, Cranfield, Nottingham and Warwick) (University of Bath, 2010).

1.2 Research Motivation

Lean Thinking is understood to mean fewer staff and a more efficient time-work ratio. The core of Lean Thinking is a flowing and continuous process, at the right time and as short as possible, with the least waste to achieve customer demands. And Lean manufacturing has attracted the interest of scholars, researchers and managers. Lean manufacturing technology has been extensively discussed and researched. It has become a common production method applied to manufacturers around the world. Although lean manufacturing started in the automotive industry, it has been successfully applied in other areas. As global competition heightens, lean manufacturing has become the pursuit of many enterprises. In this case, lean manufacturing has attracted the attention of various industries around the world. Many managers have implemented or will be implementing it due to its successful implementation in other companies, and because more customers are requesting it (Carreira, 2005; Fawaz & Abdulmalek, 2007; Melton, 2005; Michael, 2005).

The benefits of this project include:

Adjust the flow of materials, and improve the working environment. Delivery of materials could use fewer movements and shorter distance. The work environment will become clean, tidy and standard. This will help reduce inventory and delivery time.

Successful Lean implementation also can improve product quality. It will enhance customer satisfaction as well as enhance the company's image.

1.3 Sponsor Company

COMAC (Commercial Aircraft Corporation of China Ltd.,) is an aircraft manufacturer in Shanghai, China. It was established on May 11, 2008. The company has 19 billion RMB (3 billion U.S. dollars or 1.9 billion pounds) in registered capital. Shareholders include the Chinese government, Shanghai

municipal government, AVIC I and AVIC II. Currently, the company is developing and designing aircraft with more than 150 seats. They hope to increase dependence on large aircraft of Boeing and Airbus. At the same time, the company also hopes to open up world markets and become a world-class enterprise similar to Boeing and Airbus. Currently, the company has independently designed and manufactured a regional aircraft named ARJ21. The new big aircraft – C919 - also pays close attention to development and research. COMAC lacks experience in lean implementation. Therefore, they urgently need to improve through lean to win the international competition.

1.4 Aim and Objectives

1.4.1 Aim

The aim of the research is to understand how to introduce Lean Thinking, Lean Principles and apply Lean Tools into a new Chinese aerospace company. In particular it is hoped the research will develop an example of a customised Lean manufacturing model for the new aerospace company to become Lean.

1.4.2 Objectives

1. Investigate the principal features of Lean Thinking, and identify current state of the art in Lean implementation.
2. Identify the lean tools currently in use in a new Chinese aerospace company and the requirements needed to become Lean.
3. Develop a customised Lean model for applying Lean manufacturing into a new Chinese aerospace company.
4. Validate the Lean model with the academic and industry experts.

1.5 Thesis Structure

Figure 1 presents the thesis structure.

Chapter 1: INTRODUCTION

This chapter introduces the research background, motivation and customer's company. Base on its demands, the research aim and objectives will be identified.

Chapter 2: LITERATURE REVIEW

The current state of the art will be identified in this chapter. The lean thinking and principles will show an overview about lean manufacturing. Some successful lean implementation models will be introduced to help develop a customised model for the later work. Research gaps will also be highlighted.

Chapter 3: RESEARCH METHODOLOGY

This chapter presents the methodology to achieve the research aim and objectives.

Chapter 4: QUESTIONNAIRE

Questionnaire will be designed and sent to collect information from the customer's company. The results will define the current situation of the company.

Chapter 5: ASSESSMENT TOOL

In this chapter, another useful assessment tool will be used to confirm the extent to which the company is lean.

Chapter 6: DEVELOPMENT OF CUSTOMISED LEAN MODEL

Once the data has been collected, the customised lean model will be developed in this chapter.

Chapter 7: VALIDATION

The customised lean manufacturing model will be validated by the experts both in the company and university in this chapter.

Chapter 8: DISCUSSION AND CONCLUSION

This chapter will discuss the harvest and experience during the research project. It includes contribution, research limitations and future work.

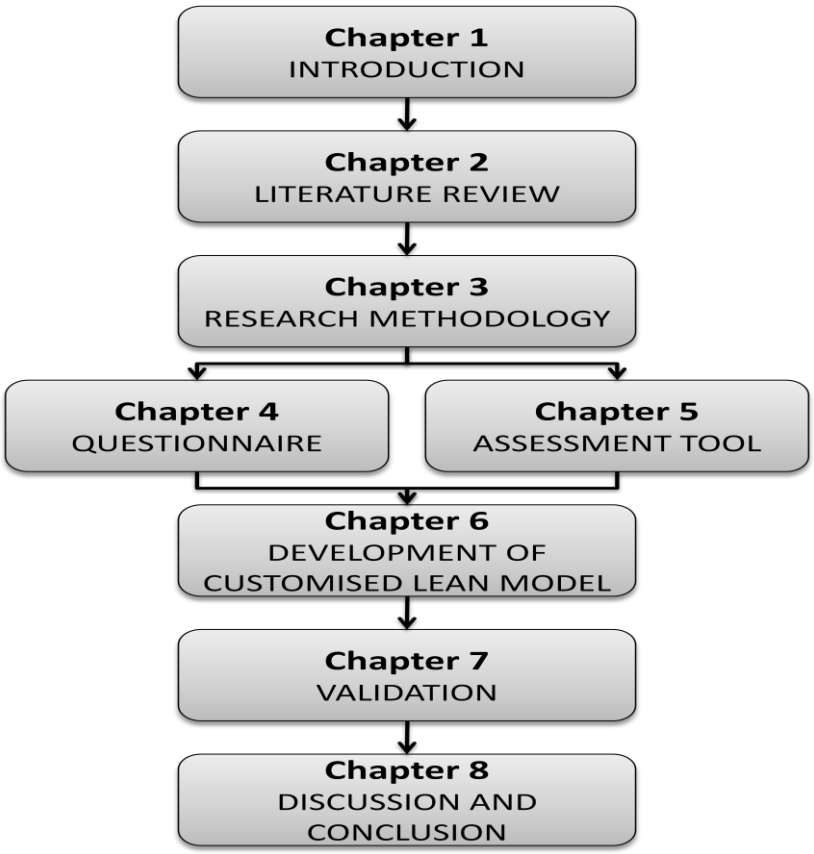


Figure 1: Thesis Structure

2 LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to ascertain the current state of art of Lean Manufacturing in order to realize best practices of lean implementation model that support the development of a lean customised model (section 6.3). Figure 2 presents the structure of the literature review. Lean thinking and lean transformation respectively will be introduced, followed by a review of lean manufacturing in section 2.4, and the value and wastes in manufacturing after that. Section 2.7 selects some popular lean tools to explain. Lean principle and a general application method will be discussed in section 2.8 and 2.9. Some factors that can impact lean implementation will be presented in section 2.10. Ten lean implementation models are explained in section 2.11, and the barriers to lean implementation in China are defined in 2.12. Finally, the research gap will be highlighted and discussed in section 2.13.

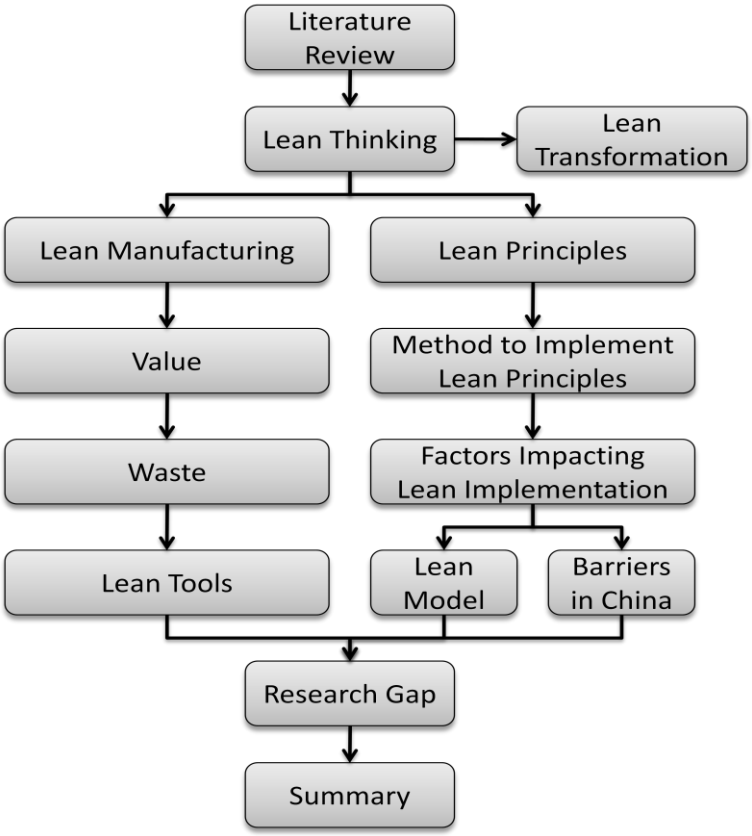


Figure 2: Literature Review Structure

2.2 Lean Thinking

Lean structure and operation principle was created in 1990 by Womack and others following their extensive research within the automotive industry. They compared various car manufacturers in terms of the defect rate, plant capacity, production lead time, engineering development time and resources used. They found that Toyota, a Japanese company, was more effective than comparable U.S. companies in using less time and lower defect rates to produce cars. Thus, they studied the production model of the Toyota, and proposed lean in their book.

Lean Thinking as a concept comprises of two factors: the continued elimination of waste and continued addition of value (Womack & Jones, 2003).

Implementation of lean thinking can reduce the plant's waste and add value to the customers (de Treville & Antonakis, 2006; Hopp & Spearman, 2004; Liker, 2004; Narasimhan et al., 2006). Moreover, in order to implement lean better, many lean tools are developed and used. (Shah & Ward, 2003; White & Prybutok, 2001).

Lean thinking can be seen as a philosophy. Through the interaction of different departments, the motivation of the workforce to improve productivity and product quality, reduce waste increases (Liker, 2004). The successful implementation of lean thinking is a complex task. It requires management commitment, employee autonomy, transparency of information, cultural adaptation and other strategic components (de Treville & Antonakis, 2006; Liker & Meier, 2006; Shah & Ward, 2007).

2.3 Lean Transformation

Lean transformation is a process through lean thinking, lean tools to achieve the ultimate goal of lean. It is usually used to identify a company moving from an old thinking to lean thinking. This process will bring the whole company and all staff into the lean activities. Unnecessary investment and wastes will be reduced by

all staff involvement and communication. This transformation will gradually be extended to all suppliers and customers, who will ultimately become lean with them (Herderson & Larco, 2000).

This transformation is not only a technical application. It is a new thought of production. However, it will take a long time to change people's thinking. Although lean production is a combination of principle, tools and technology, it cannot be limited in this regard. A true lean transformation is to learn and experiment and constantly improve so that it can match with their actual situation (Houshmand & Jamshidnezhad, 2006).

2.4 Lean Manufacturing

Lean manufacturing can be traced back to the late 1980s. At that time, the concept of lean production is considered to be an alternative to traditional production (Lewis, 2000). Lean manufacturing was firstly defined by Womack and Jones, who define lean manufacturing as a method to eliminate waste, reduce costs and improve quality (Womack & Jones, 1990). They explain how to eliminate a company’s waste. This will enable them to develop, produce and sell more products while using less labour, less space, fewer tools, less time and lower costs. Creece (2000) defines lean manufacturing further. It is a manufacturing ideology to shorten delivery times, reduce costs, eliminate waste and improve staff skills and satisfaction.

Lean manufacturing achieves the transformation from the traditional "batch and queue" mass production to the "single piece flow, pull production". This is a huge step forward. If lean manufacturing is implemented properly, the goods will be produced based on the demand of the customer. The inventory thus will decrease immediately without any waste. Therefore, lean manufacturing is a method to improve corporate performance (Cook & Graser, 2002).

Today, more and more companies are implementing lean manufacturing. There are three main reasons. Firstly, companies need to reduce costs in the intensely

competitive global environment. Secondly, the customer's requirements change quickly. Companies need a manufacturing system which can adapt to customer requirements. Finally, the product quality must be high and stable. Lean manufacturing can help companies to complete these three goals. Kilpatrick (2003) defines Lean manufacturing as “A systematic approach to identifying and eliminating waste through continuous improvement by flowing the product at the pull of the customer in pursuit of perfection.”

2.5 Value

Value is not a new concept in the manufacturing industry. The value of a product is usually defined as the combination of quality, cost and delivery (Imai, 1997). In lean manufacturing, value is determined by the customer. The product must meet delivery times and purchase price of customer requirements. Value is what the customers want to pay for. Therefore, to understand and identify the value is an important step during lean implementation (Rother & Shook, 1999)

2.6 Waste

In manufacturing, “any activity that absorbs resources but creates no value is a waste” (Womack & Jones, 2003). In order to eliminate these wastes, it is necessary to determine what behaviour is waste at first. Ohno (1993) analyzed seven kinds of waste, all of which are widely recognized:

(1) Overproduction

Overproduction mostly appeared due to the psychological effects of production line supervisors. This type of the waste is due to early production. Early production is to produce the products in advance without the customer demands. These products will increase inventory and potentially cannot be sold. In the Just-in-time production system, the early production is as worse as the delayed production. Overproduction gives people a false sense of peace of mind. It covers a variety of issues, and hides the scene for clues to improve.

(2) Inventory

Inventory is a fixed area or warehouse to store raw materials, semi-finished products (online in the products). Inventory always helps to hide other wastes.

(3) Transporting

Transporting is an action and does not add value. The waste of transportation includes placing, stacking, moving and sorting.

(4) Motion

Any human action, if not directly producing added value, is not productive. The real value-added action only takes a few seconds during the operator's work. The rest of the action represents no added value, such as the work of picking up or dropping objects.

(5) Processing

The waste of processing is an inefficient process. It means that the process cannot reach the target in the set time, manpower and resources. General inefficiency process is divided into two cases: 1) High quality requirements, resulting in loss of a large number of costs; 2) Inability to meet the standard target.

(6) Defects

Defects refer to the product quality not achieving the customer requirement. It leads to the waste of cost, of materials, machines and labour.

(7) Waiting

Waiting in the manufacturing process means that materials, machines and workers are idle. They are waiting for the next process or action. Unbalanced production line, material shortage, machine breakdown, or poor layout will lead to the waste of waiting.

Although “Ohno’s seven wastes” are the most important, they are not exhaustive. Since Ohno, another waste has completed and added to the original “seven wastes”:

(8) The waste of untapped human potential

This waste refers to the ability of the skills of workers not being utilised. This is not only a waste of human potential, but also frustrates staff enthusiasm (Bicheno, 2004).

Elimination of waste is closely linked with Lean, but the elimination of waste itself is not the sole purpose of Lean. To maximize the value of any activity is the goal of lean manufacturing (Bicheno, 2004).

2.7 Lean Tools

Some popular Lean Tools will be introduced in the following section. Of course there are many others, but these are the primary tools that can resolve most manufacturing issues.

Value stream mapping:

VSM helps companies understand and streamline the production process. Its aim is to identify and reduce waste and it is often used as a strategic tool for management changing tools. From the moment raw materials are purchased, VSM is utilised. It runs through all manufacturing processes until the end product leaves the warehouse. Hence, VSM should be used prior to developing the implementation plan. From this value stream, waste and value can be easily identified and improvement implemented. However, VSM is a professional tool that should be used by the lean expert or manager who has been trained (Hines & Rich, 1997; Rother & Shook, 1999; Sullivan et al., 2003).

5s:

The 5S pillars are sort (seiri), set in order (seiton), shine (seiso), standardize (seiketsu), and sustain (shitsuke). The role of the implementation of 5S is to establish a basis to apply toother tools. Moreover, it can increase the morale of employees (Imai, 1997; Warwood, 2004; Bayo-Moriones et al., 2010).

Total Productive Maintenance:

It is a maintenance management system to enhance the goal of overall equipment efficiency, secure an extensive preventive maintenance process, and achieve full staff involvement. (Chan et al., 2005; Swanson, 2001; Al-Najjar & Alsyonf, 2003).

Standardized work:

Standardization is the most effective lean tool for continuous improvement. It records the current and standard forms of work, and when updated, the new standards will be further improved. Improving the standardization work is a never-ending process (Bicheno, 2004; Pavnascar et al., 2003).

Cellular Manufacturing:

This refers to a production line; more specifically, the operation of the production line producing a variety of products or components of manufacturing processes (Boughton & Arokiam, 2000; Agarwal et al., 2003; Rao & Mohanty, 2003).

Visual Factory:

It is a management method with eyes. It reflects the initiative. It can be used in conjunction with a number of tools, such as: 5S, Kanban, Poka Yoke, etc (Dossenbach, 2006; Klein, 2004; Neese, 2007).

JIT:

The core of JIT production is the pursuit of a non-stock production system, or to minimize the production inventory system. Kanban was developed for this purpose and includes a series of specific methods (Betts & Johnston, 2003; White & Pearson, 1994; Aase et al., 2003).

Kanban:

It relates to achieving a timely production (JIT) and controlling the production process. Timely production of the pull production system can reduce the flow of information. The material in the production process can flow smoothly with specific containers and table (Price et al., 1994; Domingo et al., 2007; Hemamalinin & Rajendran, 2000).

One piece flow:

It is actually an appropriate amount in order to achieve timely production methods. If combined with the use of Kanban, JIT will be thoroughly implemented. The real one piece flow is based on the order of the customer's demand. Process is driven by order to minimize the batch as the goal, to achieve continuous production and to achieve zero-inventory (Bicheno, 2004).

Poka Yoke:

It means "mistake proofing", that is, Error & Mistake Proofing. It is a tool used to obtain the defect, in order to eventually remove quality inspection. The basic idea to apply Poka Yoke will not allow even a few defective products to appear (Bicheno, 2004; Pavnascar et al., 2003).

Single Minute Exchange of Dies:

SMED quick changeover uses external activities rather than internal activities to achieve it. The internal activities can be defined as operations which must be done when the machine is stopped. The external activities can be defined as

operations which should be undertaken when the machine is running (Moxham & Greatbanks, 2001; Nicholas, 1998).

Continuous improvement (Kaizen):

It is a method for improvement by flexible, motivated team members who will continually seek a better way to achieve the aim (Bicheno, 2004; Pavnascar et al., 2003).

2.8 Principles of Lean Thinking

The popularity of lean principles has moved beyond its origins and is now included in an increasing number of industrial applications (Spear, 1999). Womack and Jones devised a series of five steps to allow any manufacturer to successfully implement lean in the usual sense. These steps include:

Specify value:

Value is defined according to customer requirements. The real value is what customers are willing to pay.

Identify the value stream:

Identify all the steps in the value stream for each product. The value stream will be defined from the conceptual design to the final delivery of all activities. It is the sequence of processes from raw material to the customer that create value.

Flow:

Once the value stream has been confirmed and waste has been eliminated, role of the flow is to add value.

Pull:

The main purpose of pull is to avoid overproduction or backlog.

Perfection:

According to Womack and Jones (2003), once the first four stages are successful completed, they can interact in the virtuous circle.

The purpose of the first four steps is to transform to lean manufacturing in turn. The final step is to remind people the pursuit of lean should never end. This process requires continuous improvement (Womack & Jones, 2003).

2.9 Method to Implement Lean Principles

There are many ways to implement lean principles. They are often focussed on eliminating waste. In essence, they usually follow a similar path and can be explained in terms of the Plan, Do, Check, Act cycle, as shown in figure 3 (McCarron, 2006).

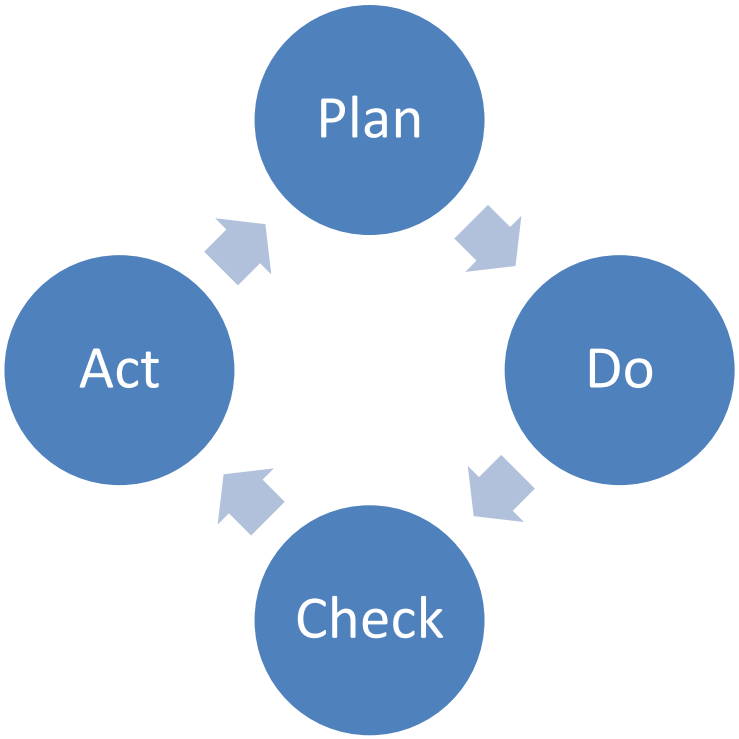


Figure 3: Steps to Implement Lean Principles (McCarron, 2006)

Plan:

At this stage, the need is to define and analyze the existing system (AS-IS) based on the customer perspective. Current information or data can be

displayed through the value stream. It will be able to find areas for improvement from these data. An improvement plan is designed.

Do:

This stage is the implementation process. The "AS-IS" in the first stage will be improved here to become "TO-BE".

Check:

The purpose of this stage is to verify the feasibility of the new system. Check to ensure the success of improvement can eliminate waste and increase value.

Act:

At this stage, implementation of the plan needs to be monitored. Knowledge is learned to know how to improve this new system for the entire cycle.

2.10 Factors Impacting Lean Implementation

Some authors have claimed that the manufacturing sector's economic strategy and leadership may affect the implementation of Lean (Achanga et al., 2006).

Similarly, other scholars believe that the human resource management will also have an effect on lean implementation. They found that cultural factors can directly promote or hinder the implementation process. Therefore, linking lean implementation and culture, it will be a contribution to the improvement activities (Nicholas 1998; Gunasekaran et al., 2001; Scherrer-Rathje et al., 2009).

2.10.1 Leadership & Strategy

Leadership must be given clear and active management commitment in the process of lean implementation (Boyer, 1996; Gunasekaran et al. 2001;

Crandall & Coffey, 2005; Crute et al., 2003; Leitner, 2005). They can decide the lean implementation areas and priority based on the business strategies. Leadership can also provide adequate support to allow all staff to be involved in the Lean improvement. This includes the establishment of the lean team, team member selection, staff training, staff reward and punishment system and equipment investment needed for lean implementation.

2.10.2 Lean Culture

Many scholars now support the building of an enterprise culture as an important basis for the implementation of lean (Henderson, 2000; Shah & Ward, 2007; Spear & Bowen, 1999). The company's continuous improvement and culture are mutually reinforcing. Most large organizations have realized this, and have built their own cultural patterns but this is not the case for some new developing enterprises for whom, lean implementation and corporate culture are inseparable. Moreover, the establishment of a corporate culture requires strong leadership support. These elements include employee education and training, welfare and more attention to increasing the motivation of their own staff. This will realise the maximum potential of staff, and not just see people as a machine of completing command (Liker, 2004; Feld, 2001; Bicheno, 2004; Dennis, 2002). This kind of policy attention and support of staff will make lean implementation more successful. "You need to believe in people and let them try. If they mess it up, support them, and if they mess it up again-support them again" (Crute et al. 2003).

2.11 Lean Manufacturing Models

Several authors have developed their own Lean manufacturing model for lean implementation. In this section, ten models will be reviewed. The structure of the customised model will be built up based on this information. It is presented in table 12 (section 6.3).

Model 1:

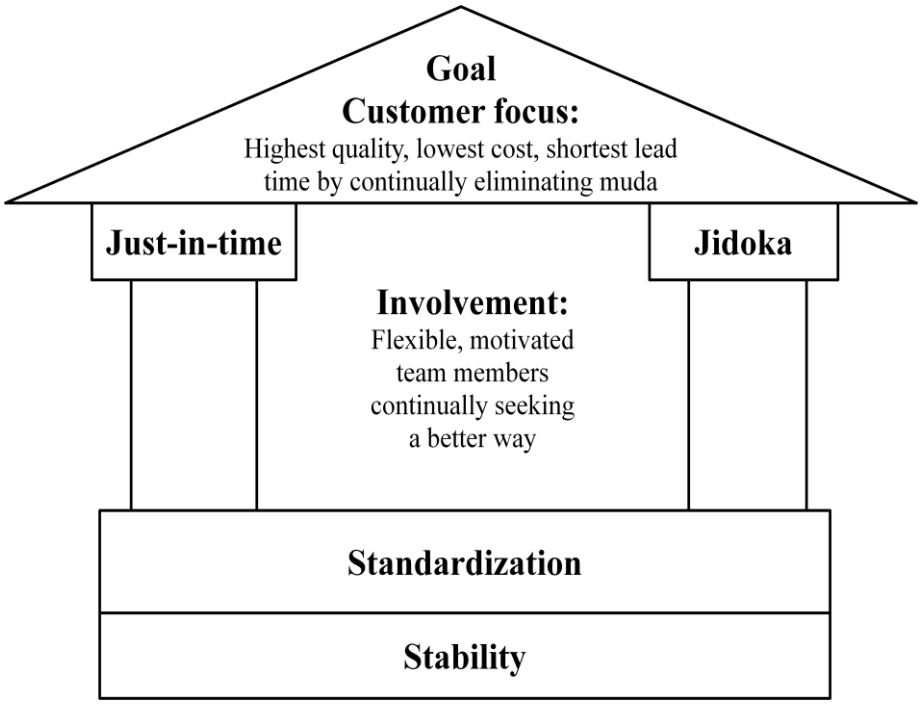


Figure 4: Model 1 (Dennis, 2002)

The lean system was firstly conceived by Toyota (Ohno 1993). This system was extensively researched.by among others Dennis (2002) who devised the house model (figure 4). The foundation of the Lean is stability and standardization. The walls to build up house are Just-in-time and Jidoka (automation). The goal of this model is to “deliver the highest quality to the customer, at the lowest cost, in the shortest lead time”. In order to achieve this aim, member involvement and continuous improvement process are necessary.

Model 2:

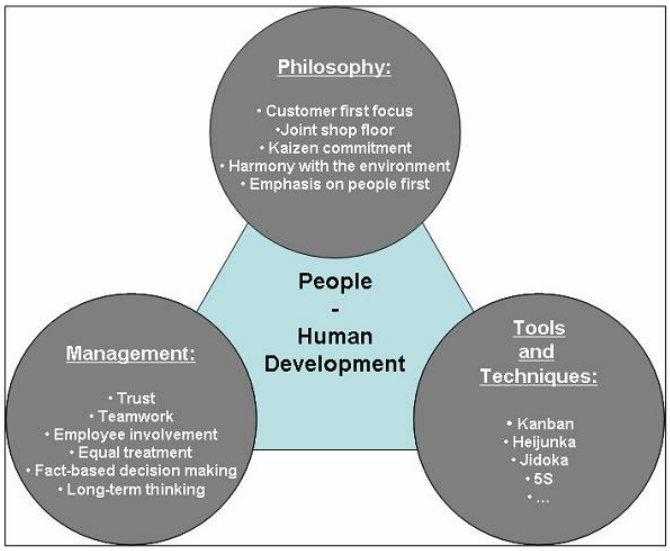


Figure 5: Model 2 (Gray, 2001)

Gray (2001) compared his model with Toyota's model. The figure 5 shows the result. He showed clearly that the Lean model was not only tools. Human development also should be considered to implement lean. The Lean philosophy and Lean management have the coequal position with the Lean tools. The people were the most important factor in his model. It links three aspects to implement lean.

Model 3:

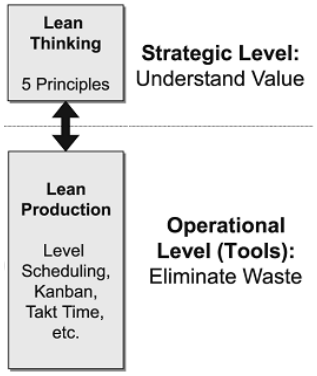


Figure 6: Model 3 (Hines et al., 2004)

Hines et al (2004) firstly developed a lean model from two aspects, as shown in figure 6. They are "strategic level focusing on the principles and operational level focusing on the tools and techniques often associated with Lean".

Model 4:

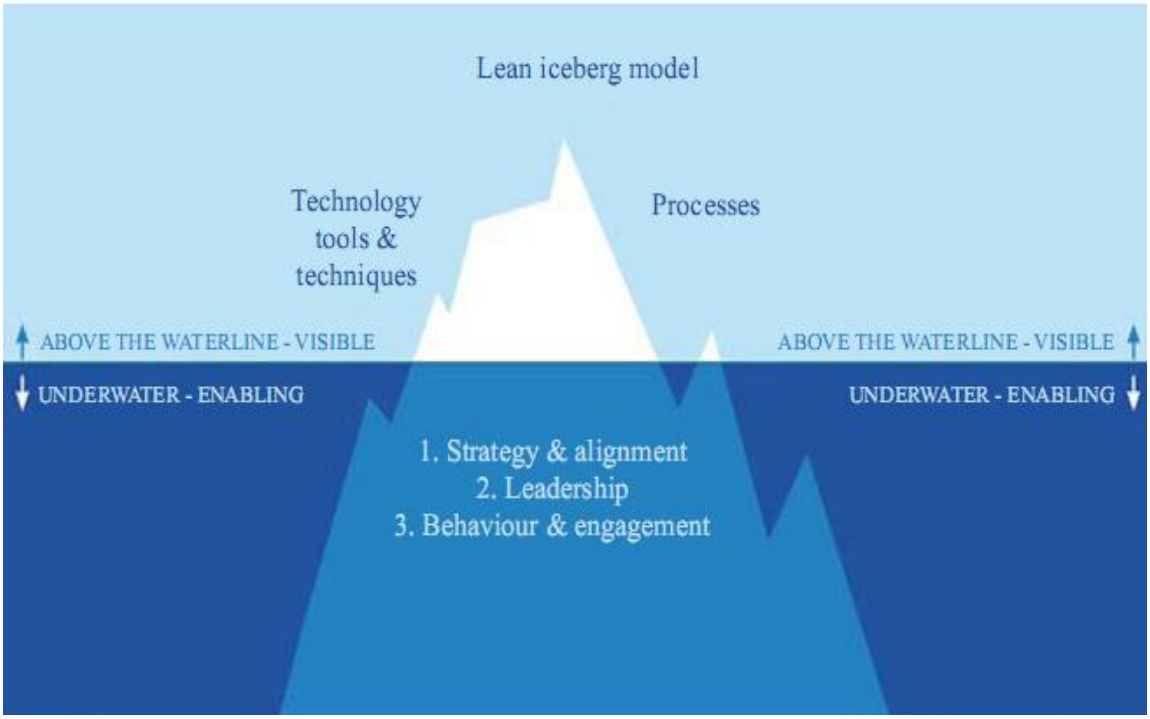


Figure 7: Model 4 (Hines et al., 2008)

Hines et al. (2008) continuously developed their model called “The Iceberg Model” shown in figure 7. They divided their model into two sections:

Underwater: The enabling elements are “strategy and alignment, leadership and behaviour and engagement”.

Above the water: This section contained “technology, tools and techniques and process”.

They view the section of underwater as the foundation of the lean model. All the technology, tools and process should be supported by the leadership. Furthermore, they think the culture can reflect on implementation of underwater section. Hence, the implementing plan should consider cultural factors. .

Model 5:

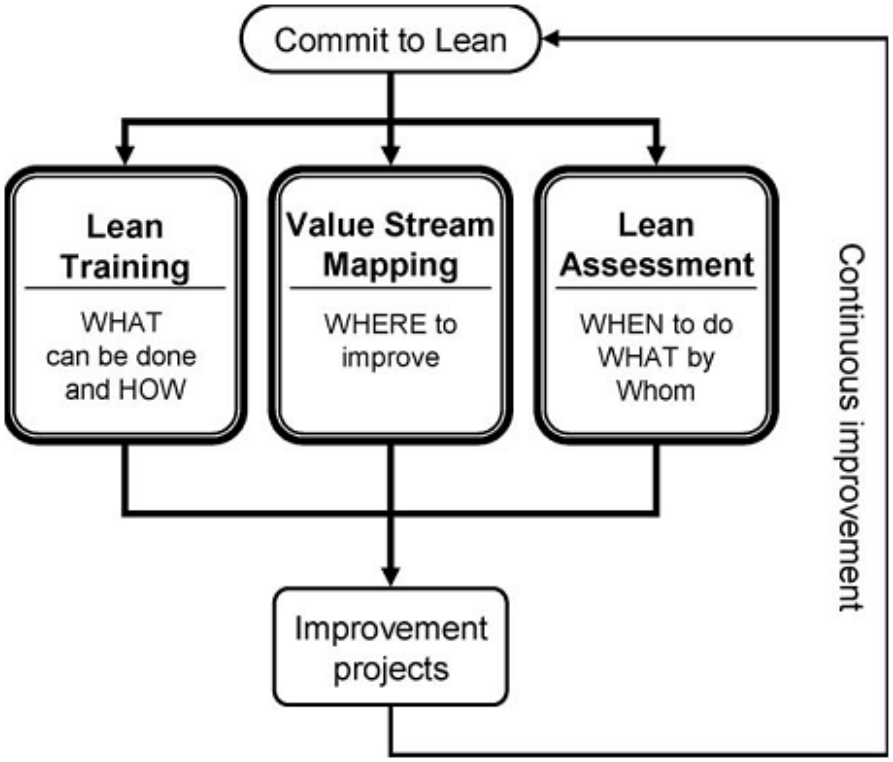


Figure 8: Model 5 (Wan & Chen, 2009)

Wan and Chen (2009) developed a lean implementation cycle model in their research (Figure 8). However, they think it will result in chaos if all lean tools are applied at once. Therefore, they focus on the pre-stage of lean implementation. The tools must be selected in order to fit the actual situation. The pre-stage will help to achieve this work. Firstly, gaining the commitment to lean is necessary. The next stage comprises three steps: to train lean to know “what can be done and how”, use VSM to seek “where to improve” and assess current situation to confirm “when to do what by whom”. When all these steps have finished, the improvement projects can be applied. The tools selected will be used and the continuous improvement can complete the whole cycle.

Model 6:

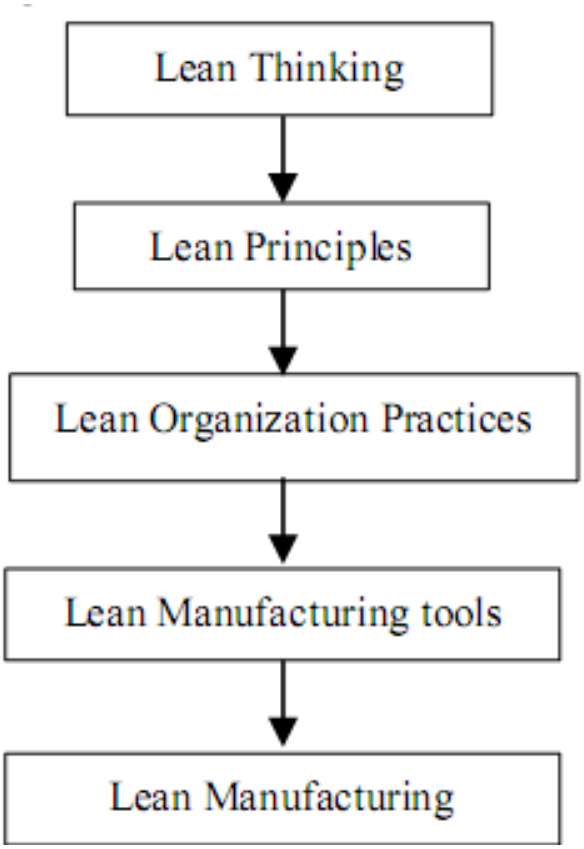


Figure 9: Model 6 (Aulakh & Gill, 2008)

Aulakh and Gill (2008) view the core of lean manufacturing to be lean thinking. “Lean thinking is the dynamic, knowledge driven and customer focused process by which all people in a defined enterprise continuously eliminate waste with the goal of creating value”. Hence, they developed a model to transform lean, as shown in figure 9. First, lean thinking would be better understood. Lean principles will be the next step to make a plan. The practices can transform the plan into the act. That will be helpful to implement lean thinking. Then the lean tools will be applied in the factory to eliminate wastes. Finally, the company will become lean.

Model 7:

Figure 10: Model 7 (John, 2009)

John (2009) showed a lean development and implementation model in figure 10. He used a survey to collect a general assessment of the initial state of the company. This data will be analyzed and measured to define the current situation, and then develop the future plan to implement lean. The third step is applying tools which were confirmed in step two. Finally, the result will be summarized and improved continuously.

Model 8:

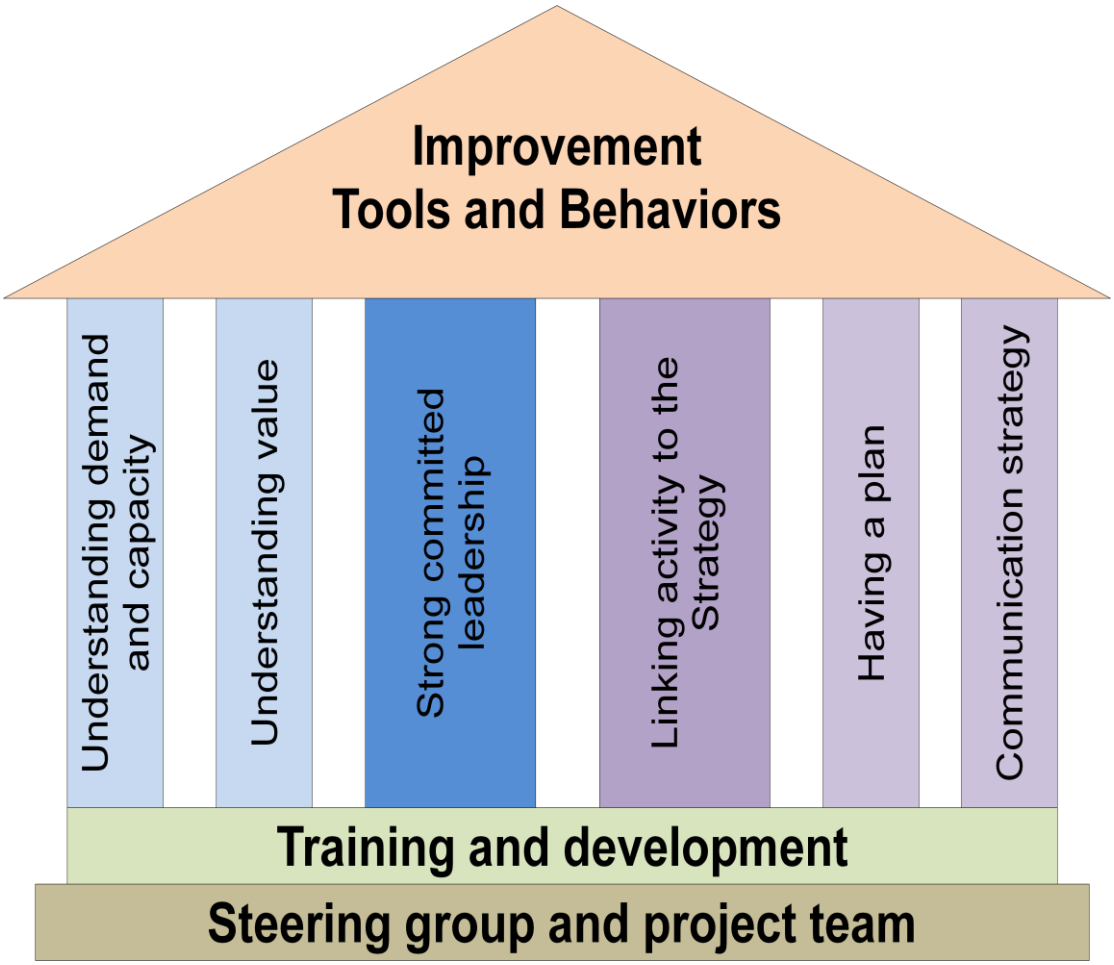


Figure 11: Model 8 (Radnor, 2009)

Another house model was developed by Radnor (2009) in figure 11. The foundation of their model is setting up a lean team to steer the direction of lean improvement. The training follows them. And two strong walls in the middle will support this house. At last, the lean tools and improvement behaviours can establish the entire house to achieve the lean.

Model 9:

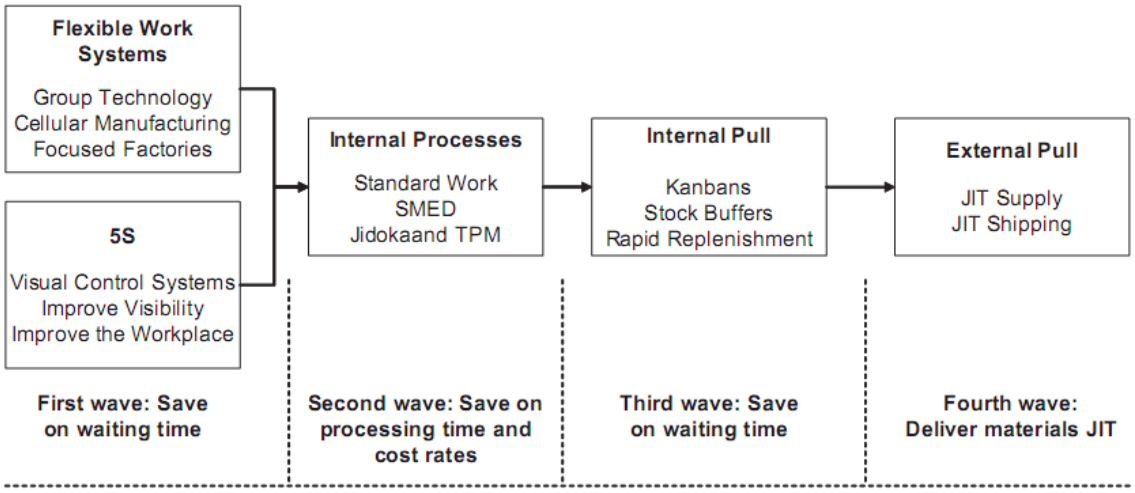


Figure 12: Model 9 (Rivera & Chen, 2007)

Rivera and Chen (2007) developed a “Waves” model to implement lean. Figure 12 shows a basic structure of their model.

They select some tools which can “reduce the waiting time, the processing time, cost rates and deliver the materials” and apply them in sequence by the four waves. The following paragraph is a brief introduction.

First Wave: It will use group technology, cellular manufacturing and focused factories to reduce the waiting time. At the same time 5S and visual control system can improve the workplace which can also reduce the waiting time.

Second Wave: It will focus on the improvement and standardization of internal processes to reduce the process time and cost. And some tools (Standard Work, SMED, Jidoka and TPM) will be applied in this wave.

Third Wave: The further reduction of waiting time will be achieved in this wave by the pull system.

Fourth Wave: At last, the delivery of materials can be improved by JIT.

Model 10:

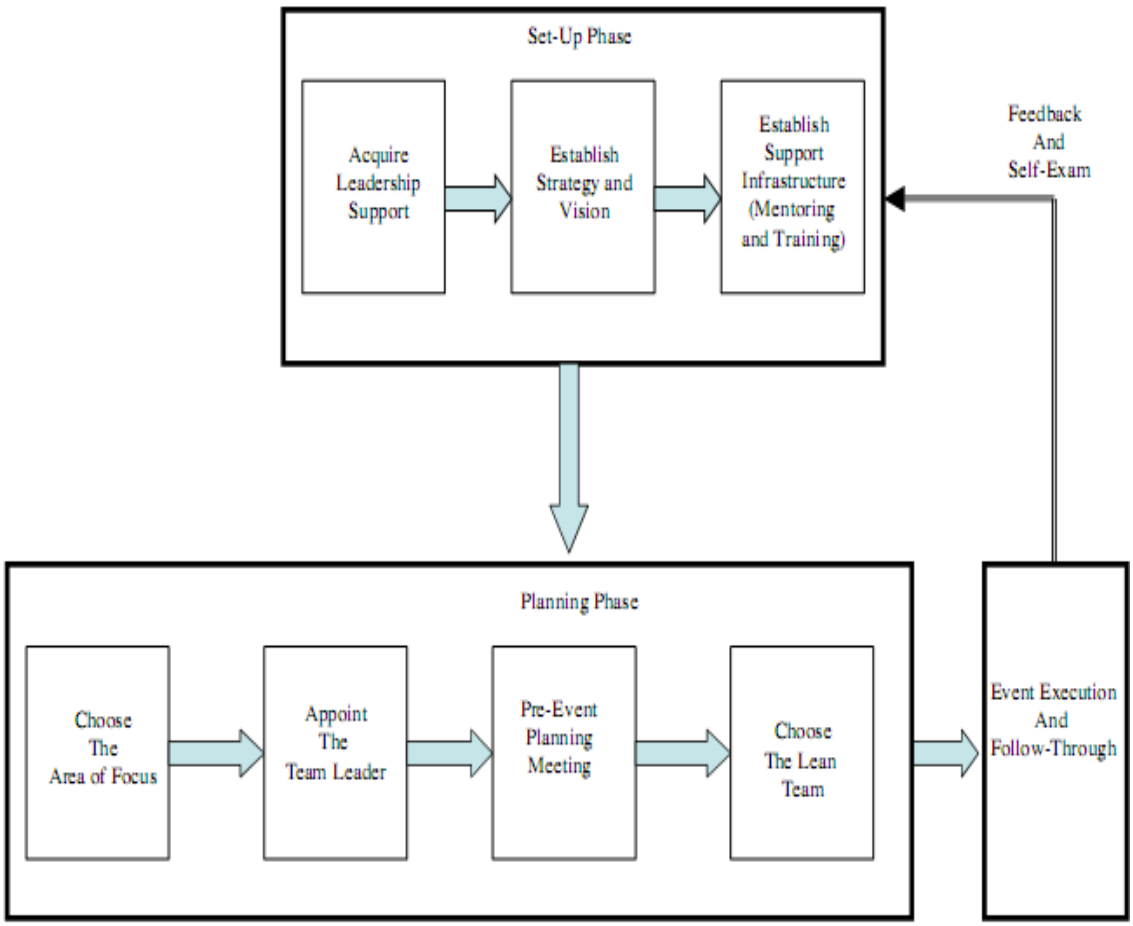


Figure 13: Model 10 (Ronald, 2003)

Ronald (2003) presented a lean cycle model to implement lean. There are three main phases in his model. The first phase is the set-up phase. In this phase, the leadership support needs to be acquired. The strategy will then be established, knowledge and skills will be trained. In the plan phase, the area to be improved is selected. The lean team and leader will be chosen to develop, implement, plan, and chair the meeting. The final phase will assess the result of lean implementation and improve it continuously.

2.12 Barriers in China

In the following section, the researcher will introduce some barriers of Lean implementation in China. These barriers were engendered by the Chinese culture. Though concurrent on some views, authors pointed out many barriers. They will be explained as follows:

1) **Apply tools at first without strategy**

   Most companies start using lean tools without a combination of their actual situation and business strategy. This has led to staff or even leadership not knowing why they are applying lean. The result is that benefits of lean implementation are not obvious to them and they feel disappointed (Bollbach, 2010; Brown & Cih, 2008; Chen & Meng, 2010; Comm & Mathaisel, 2005; Oliver et al., 1998; Paolini et al., 2005).

2) **Weak leadership contribution**

   Chinese people are considered to follow their leaders, so the role of Chinese company leadership in the implementation of lean is seen as more important than in other countries. However, in practice they tend to ignore their leaders. Thus top management cannot achieve commitment to the implementation of lean and cannot communicate directly with employees on a regular time. Moreover, they do not set a reasonable reward system to encourage employees (Aminpour & Woetzel, 2006; Aoki, 2008; Bollbach, 2010; Chen & Meng, 2010; Comm & Mathaisel, 2005).

3) **Want to quick succeed**

   Many companies want to see results or succeed in a very short period of time. But the lean transformation is a long-term task. Toyota even spent 40 years to build this system. Furthermore, they will also continue to improve. Hence, wanting to achieve successful lean implementation very

quickly will lead to failure (Brown & Cih, 2008; Chen & Meng, 2010; Paolini et al., 2005).

4) **Special relationships**

Chinese special relationships will lead to the failure of monitoring and incentive. For example, an employee who is a good friend of the manager will receive more welfare than others even if this person does not work well. Perhaps this is the result of a long cultural tradition, but in the lean implementation, it needs to be improved. In this regard, leadership should play an active role. (Aoki, 2008; Bollbach, 2010; Brown & O'Rourke, 2007; Comm & Mathaisel, 2005; Oliver et al., 1998; Paolini et al., 2005).

5) **High employee turnover**

Due to the high recruitment costs and investment in staff training, the impact of high employee turnover has become an important factor in the lean implementation (Aminpour & Woetzel, 2006; Aoki, 2008; Bollbach, 2010; Brown & O'Rourke, 2007; Paolini et al., 2005; Taj, 2005).

6) **Low skill/education**

The education gap of the Chinese workforce is a key to the Lean implementation. Workers who are at low levels of education and lack skill cannot be successfully engaged in the process of continuous improvement. This lead to all staff involvement improvement become to the leadership improvement. It will greatly decrease its effectiveness. Hence, the low level of education and skill is a barrier (Aminpour & Woetzel, 2006; Bollbach, 2010; Brown & O'Rourke, 2007; Chin & Pun, 2002; Lee, 2004; Oliver et al., 1998; Paolini et al., 2005;).

7) **Weak Supply Chain**

The supply and transportation of materials and products often cannot be done on time. Especially in the process of shipping in logistics, it often

has unpredictable factors (Bollbach, 2010; Brown & Cih, 2008; 6: Chen & Meng, 2010; Comm & Mathaisel, 2005; Lee, 2004; Oliver et al., 1998; Paolini et al., 2005; Taj, 2005).

8) Inapposite plan

In the Lean implementation development phase, they do not specify a good plan. There is not a strict control for the manufacture time. This has led to the VSM and some tools requiring accurate time not collecting data or the data variable being too large. This is also a barrier to the Lean implementation (Aminpour & Woetzel, 2006; Bollbach, 2010; Chen & Meng, 2010; Chin & Pun, 2002; Comm & Mathaisel, 2005; Oliver et al., 1998; Paolini et al., 2005).

9) Complete copy

They usually blindly copy the successful experience of other companies without combining their own actual situation. If they have a failure, they will think lean manufacturing is suitable only for advanced countries (such as the United States, Western Europe, Japan, etc.), and not suitable for them. This is not correct; lean implementation must be integrated with the actual situation and local culture (Bollbach, 2010; Brown & O'Rourke, 2007; Brown & Cih, 2008; Chen & Meng, 2010).

10) High defect rates

For lack of quality control and the low pursuit of quality, defect rates increase. This has led to the repair rate and cost increase (Aminpour & Woetzel, 2006; Aoki, 2008; Bollbach, 2010; Lee, 2004; Oliver et al., 1998; Paolini et al., 2005).

11) Weak Inventory Management

Traditional Chinese thinking views the preparation of a lot of inventory can meet emergency issues. But this idea is not suited to today's economic development and lean thinking. A large number of inventories

and poor inventory management has become a lean implementation barrier to face and resolve (Aminpour & Woetzel, 2006; Bollbach, 2010; Comm & Mathaisel, 2005; Lee, 2004; Oliver et al., 1998; Taj, 2005).

12) Lack of self-initiative

Lack of autonomy of employees is also a barrier to lean implementation. The staff who have innovative and independent spirit can provide good advice for the lean continuous improvement (Aoki, 2008; Bollbach, 2010; Chen & Meng, 2010; Chin & Pun, 2002; Lee, 2004; Paolini et al., 2005; Taj, 2005).

2.13 Research Gap

From the literature review, most Chinese companies start implementing lean at tool level. There are few managers that understand lean. There are few chances to let all employees be involved in the improvement. According to the literature review and researcher's knowledge, some researchers had defined some barriers of lean implementation in China. However, they did not develop a systematic approach to break these barriers. It is missing element in the existing research literature. Therefore, the author will attempt to fill in this gap during the research.

2.14 Summary

This chapter has reviewed the current state of the art. Lean thinking and lean transformation were introduced to give an overview about what lean is. Lean manufacturing, value, wastes and lean tools also were presented. Lean principle and a general method to apply it were explained to know how to achieve lean. Some lean implementation models show the best practices which can support the development of a lean customised model. At last, the barriers of lean implementation in China are defined. The research gap was found based on the above literature review. It will be the main task in the following research.

3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter will introduce the research methodology. In order to achieve the aims, a qualitative approach is employed.

3.2 Methodology

To implement lean manufacturing, it is necessary to carry out a methodology research. A qualitative research methodology was presented by Robson (2002). Suitable for researchers who possibly do not understand their research area very clearly, this method helps them to achieve their aim and objectives as it is unnecessary for researchers to have prior comprehensive knowledge. Hence, the survey is the most important tool for this approach. This thesis focuses on developing a customised lean manufacturing model. Based on the literature review, the survey will be a key method to achieve the aim. For this reason, the qualitative research methodology has been chosen. The research methodology is divided into five phases, as illustrated in figure 14.

3.2.1 Phase 1: State of the Art

In this phase, the researcher will focuses on understanding and the investigation of the thesis project. Extensive literature will be read in order to familiarize with the state of art. The aim of the literature review is to provide to the researcher sufficient information in order to give a general understanding about the area of the research. Although quite time-consuming, it can save time in the latter phase and avoid any misunderstanding which will lead to the failure. Extensive journal papers, books and other researchers' theses will be related to author's research area – Lean Manufacturing. The aim of this phase is to identify the problem of research and define project aims and objectives. At the same time, the researcher can become familiar with the state of art.

3.2.2 Phase 2: Data Collection

In this phase, the information required will be collected. Firstly, based on the literature review, some models developed by other researchers will be selected for analysis. Many useful and successful examples can be taken from these models. At the same time, another two survey methods - questionnaire and assessment tool – are used to collect the current situation from the customer's company. The questionnaire will be sent to many regular employees and several managers to identify the current problems they face. Assessment Tool will be used and completed by a few exclusive managers. That will be more exact to understand the lean situation of a customer's company. All of these results will develop the lean customised model in conjunction with the literature.

3.2.3 Phase 3: Data Analysis

After collecting all the data, phase three – data analysis – is initiated. In this phase, two tasks will be completed. The first task is questionnaire analysis. This result can help the researcher understand the utilisation of information of lean tools, the thinking of employees and some useful feedback from the respondents. The second task is assessment analysis. This is a quick and professional tool to identify the lean current situation. Both of these two analyses can contribute to develop the customised lean model.

3.2.4 Phase 4: Development

In this phase, the customised lean model will be developed. Firstly, the lean model example collected can support the choosing of factors/element of the model. And then, the result of data analysis will help to modify the model and transform it into the customised lean model.

3.2.5 Phase 5: Validation

In the final phase of the research methodology, validation will be achieved by the company and academic expert. They will give feedback about the model.

This model will be validated if it can be implemented and if it established improvement needs. The research thesis will then be written and submitted.

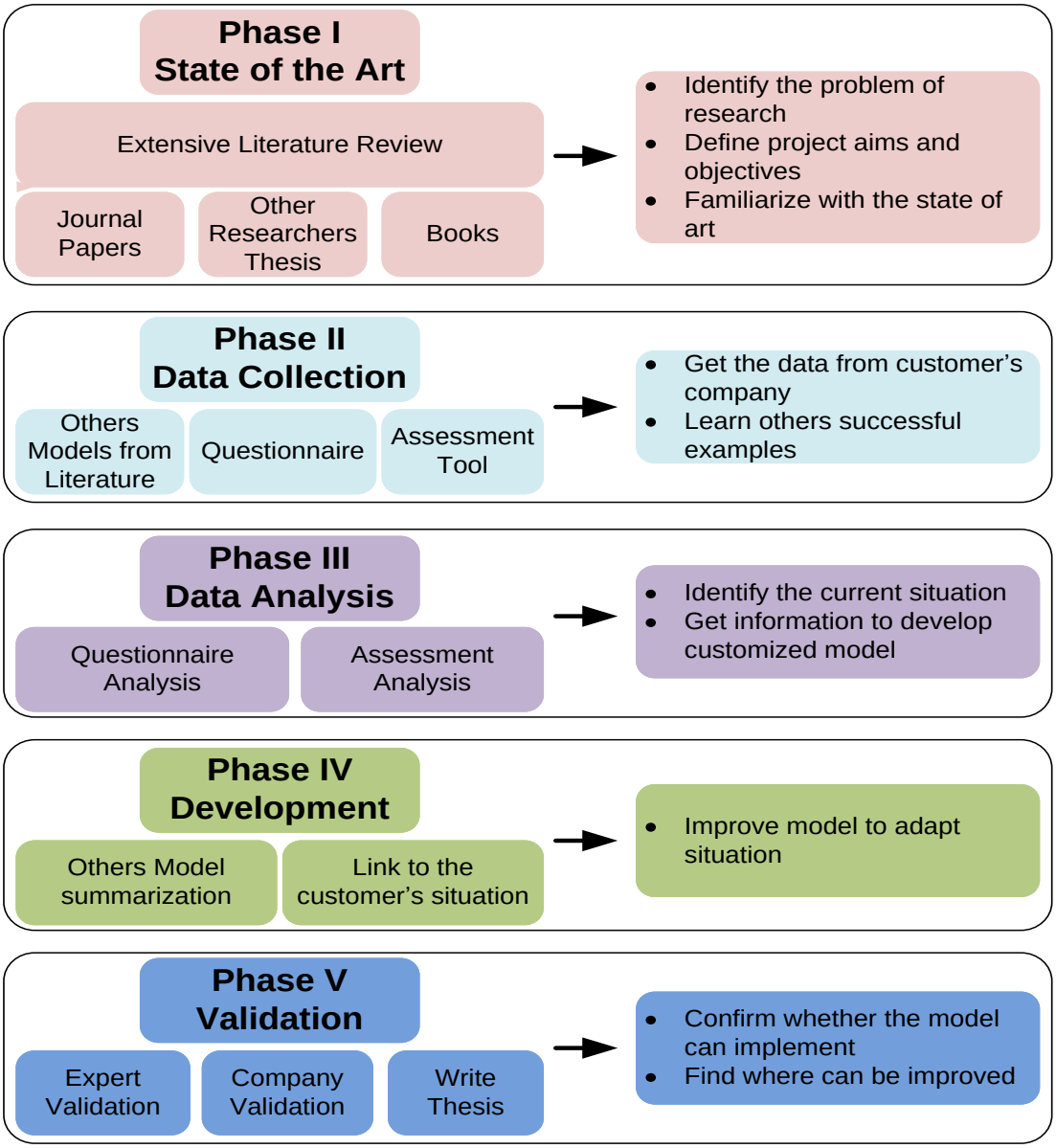


Figure 14: Research Methodology

4 Questionnaire Design and Results

4.1 Introduction

This chapter details the design and deployment of the questionnaire to collect information regarding customer's company. The results define the current situation of the company.

4.2 Goal of the Questionnaire

The questionnaire is employed to collect information on how lean methods are currently being used in the company. Its aim is also to collect information about the current problems in specific areas of the company. The information given will form the basis for developing the lean customised model. It will determine what the current use of lean tools and methods is. Then, it will identify what the current problems are in the company. Hence the questionnaire will form the basis for lean improvements within the company.

4.3 Questionnaire Design

Question 1-10 and 26 were used to gauge which lean tools are currently in use in the Chinese aerospace industry and how they are perceived. These questions will achieve objective 1. Question 1-10 use multiple choice (only one answer) and open questions. Question 26 uses a table with choice and comments .Each tool is given a short description.

Question 11-17 are used to collect information regarding existing waste in the Chinese aerospace industry. These will be part of objective 2. They use multiple choices (only one answer).

Question 18 lists 8 factors that can be improved by Lean Tools, and invites respondents to prioritise the importance of each in numerical order 1-8. Objective 3 will be identified by this question.

Question 19-25 uses open questions to invite respondents to write about their daily work, volume and repetition of product, driving to become lean, and barriers to become lean. Objective 2 will be achieved by these questions.

Three questionnaires were sent out as pilots to obtain feedback including suggestions and corrections of syntax errors. One electronic questionnaire was sent to a named Director who forwarded it to the other respondents.

4.4 Data Collection

The researcher sent one questionnaire to a named Director, who then sent it to 68 respondents. 35 Questionnaires had been received by 23rd August 2010. These 35 replies included: 32 completed questionnaires and 3 vacant questionnaires. Total response level therefore was 32 (47.06%). The respondents of these 32 questionnaires were from five different departments. Table 1 presents the details.

Table 1: Department and Level of Respondents

Departments		Assembly Shop	Numerical Control Shop	Tooling Produce Shop	Tooling Design Department	Research Laboratories
Number	Manager	2	1	2	1	1
	Work	7	5	5	7	1

4.5 Data Analysis

The following contents are the result and analysis of every question.

Not all the respondents wrote a comment for every question. Furthermore, some comments have the same meaning. A number was put in brackets to denote this.

1. Do you do the housekeeping on your shop floor and/or the office?

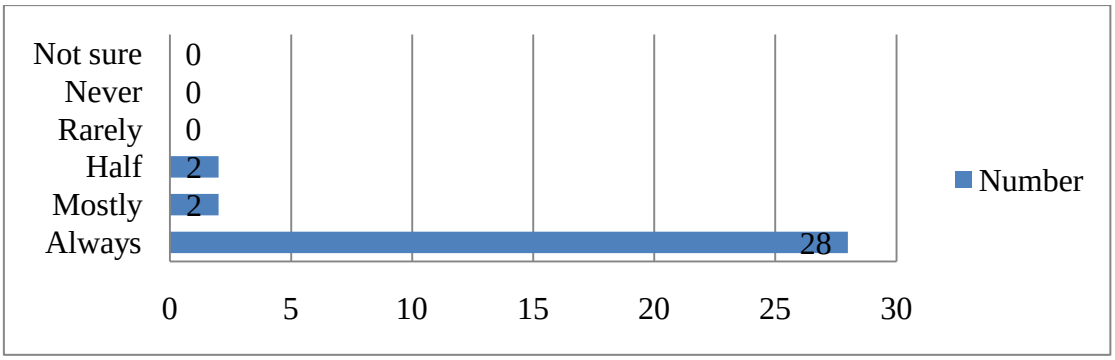


Figure 15: Result of 5S

Comments:

I do the housekeeping every day, but it does not bring enough benefits to me. (8)

I don't know why I must spend time doing this, just for looking clearly? (6)

I think it should be a good way to improve, so we need to spend a lot of time studying how to do the housekeeping. (9)

It can save me some time to find tools. However, I wish more time will be saved. (6)

28 respondents selected "Always" in figure 15, implying that 87.5% respondents do the housekeeping very often. The 5S is popular in this company, despite most of them thinking it does not work well. They may not know what 5S is. They do not quite understand this, so it is difficult to judge its usefulness. Therefore, they need to be trained to know what 5S is and how to implement it. The best way is retain an expert who has experience on applying 5S.

2. How often do you have team meetings?

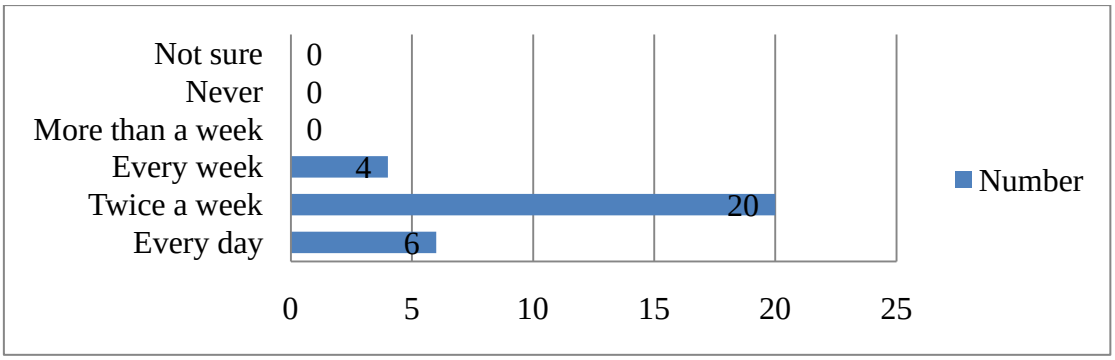


Figure 16: Result of Team Meetings

Comments:

In my team, we will have a meeting on Monday every week. It is a good method to help us to know what we have did last week and what we will do this week. (3)

We have no special time for meeting, normally twice a week. (12)

We discuss some new ideas in the meetings. But it just stops at this phase; the excellent ideas are never adopted for improvement. (3)

We need more manager involvement in meetings; otherwise, it is only a meeting that cannot change anything. (8)

Some useful methods to improve have been advanced in the team meetings, so I will continue to do it. (2)

All the respondents answered they will have a team meeting at least once every week in figure 16. Hence, the Kaizen was adopted in this company. They believed it to be an important method. However, more managers should be involved in these meetings, and accept good ideas for continuous improvement.

3. Is there a picture mapping the material and information flow?

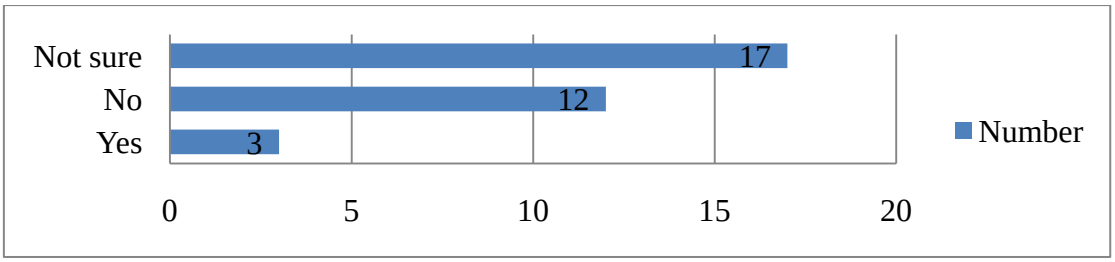


Figure 17: Result of VSM

Comments:

I have never seen that before. (6)

I know it, it is value stream mapping. But I don't think anyone has used it. (1)

I don't know anything about it. (9)

Only 3 respondents think VSM has been used in figure 17. Half have no idea about the VSM. Although VSM was potentially a strong tool to find the waste and eliminate it, it was utilised with low understanding. It is a good start to use VSM to identify the waste.

4. Is there a measure to fix a sudden machine breakdown?

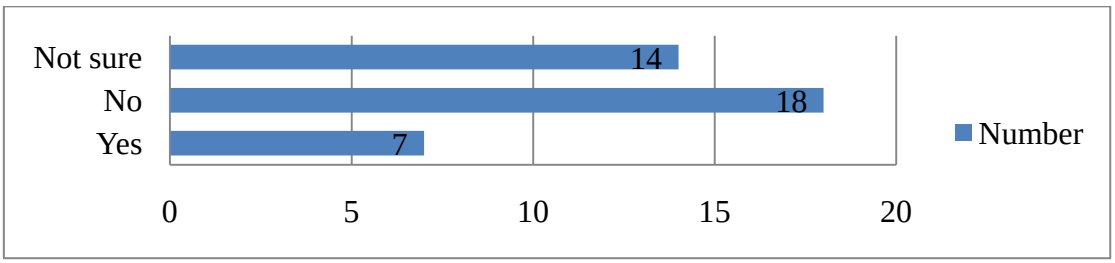


Figure 18: Result of TPM

Comments:

Sometimes, I must wait a long time for the machine to be fixed. (5)

I look after my machine very well. But not all the people do so. (2)

I want to be taught how to fix my machine, because sometimes it was only a little breakdown. (8)

I didn't know we have a measure to do that. (7)

As shown in figure 18, half the respondents think there is not a measure to fix a sudden machine breakdown, and 14 respondents were not clear about it. Thus TPM has a low status in this company. It is obvious that TPM is a significant tool but many were struggling to acquire it.

5. Is there visual display to present information or control the act?

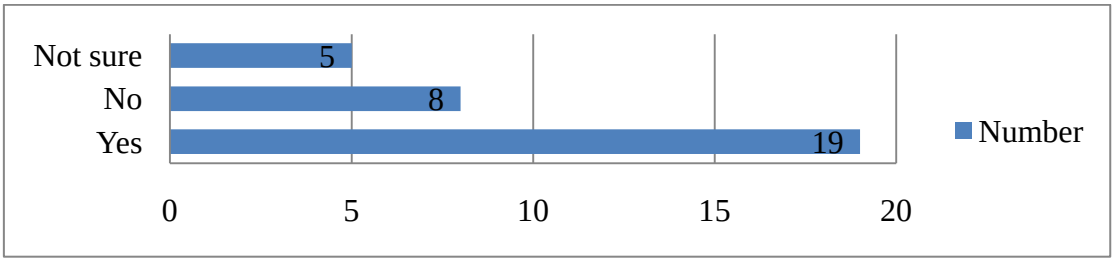


Figure 19: Result of Visual Control

Comments:

Most of them appear on the inside network, but when I am working, I cannot check this on computer. (7)

I saw some signs to tell me that, but I think it was not enough. (8)

Yes, I can find this on the computer, but less on the plant. (11)

More than 50% respondents answered “Yes” for this question (figure 19). However, they stated that more signs were required to show the information, not only on the computer, but also on the workshop.

6. How quickly and efficiently is the change from one product to another?

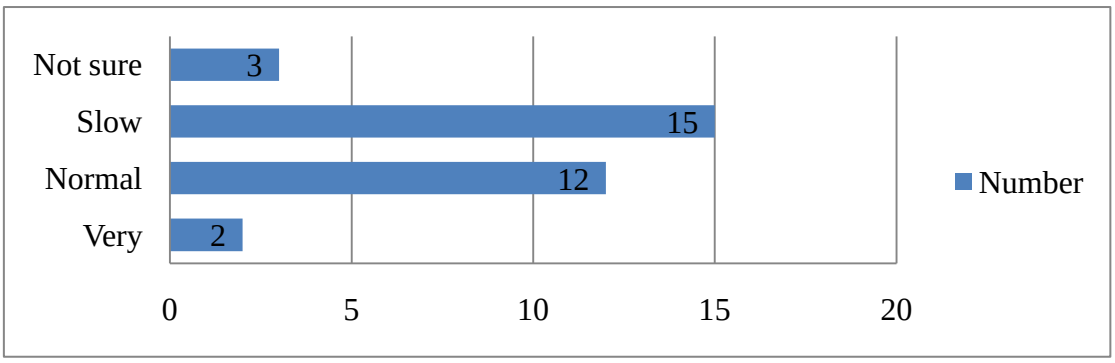


Figure 20: Result of SMED

Comments:

I think it was too slow so I must finish others in overtime. (6)

It’s normal, although we have many varieties. So I think we should better have a method to face this situation. (7)

I’m not sure about it, but I think it’s a good way to reduce the lead-time. (2)

Most respondents think their SMED is not quick (figure 20). The main reason to apply SMED is that the variety is high. Therefore, this tool should be used after the other important tools.

7. Is there a standardised manner to ensure that each job is organized?

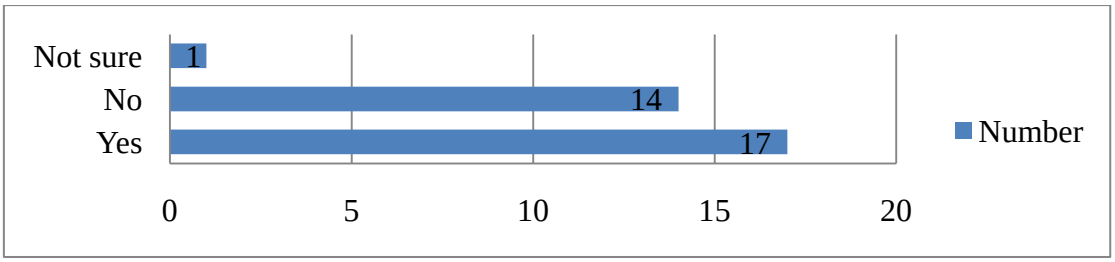


Figure 21: Result of Standardised Work

Comments:

Yes, we have this. But many of them were too old. We need to update. (5)

It's a good idea to help new employees to start working quickly. (8)

No, we work based on experience. Everyone has his own skill. I think set standardised work will be better than now. (7)

As shown in figure 21, more than half the respondents said that they have, although others thought the opposite.. However, all of them espoused the standardised work. This tool should be a basic tool as the 5S in order to improve factory standardization and stability.

8. How do you think about producing a product above customer demand?

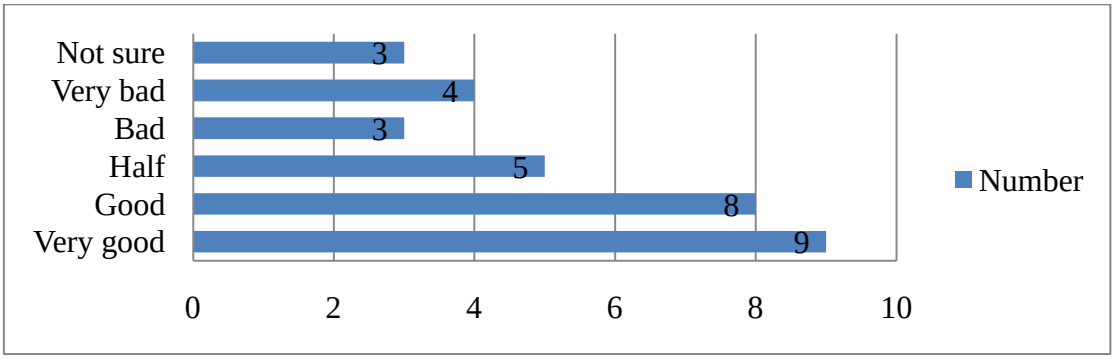


Figure 22: Result of JIT

Comments:

Why would we do that? It's a waste! (3)

We usually produce more goods to compensate for unexpected issues. (5)

If we have the ability to do this, why not? They will be sold sooner or later. (7)

I'm not sure. Maybe the more the better. (2)

These questions' answers are very interesting. More than half think it is a good idea (figure 22). Whereas, produce proper good depend on the customer's demand is better than that. So, training is necessary to transform viewpoints, especially for the managers.

9. Is there a board that controls the production and selling of products?

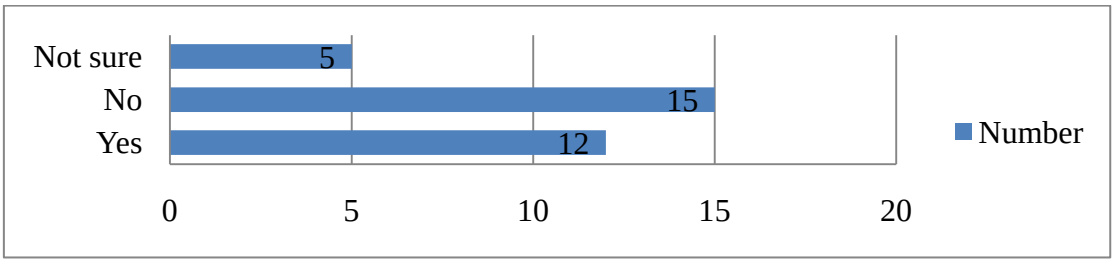


Figure 23: Result of Kanban

Comments:

No, I don't think we have. (7)

Normally, I get the order to produce. But there is not a board to show it. Just some order paper. (6)

Yes, we have a big board. But I don't know how it works. (2)

Kanban is a popular tool. It can control the suppliers and improve flow. But most of the respondents did not have a clear understanding about Kanban, although as figure 23 shows, 12 people selected “Yes”. Hence, this tool should be applied in the middle phase.

10. Is there a mechanism to prevent a mistake or make a mistake obvious at a glance?

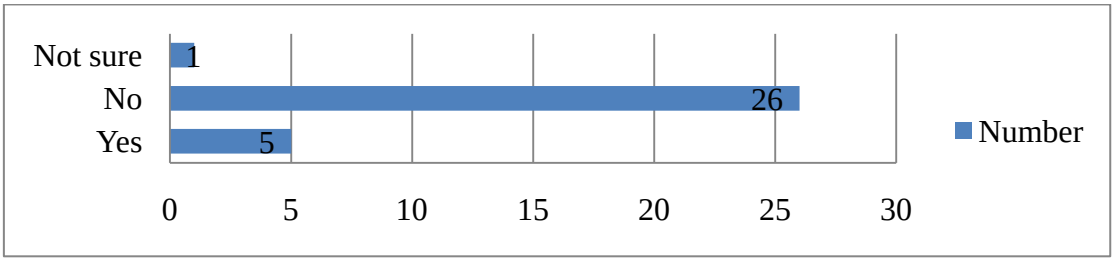


Figure 24: Result of Poka Yoke

Comments:

No, I haven’t ever heard of it. (8)

We usually check after finishing all products. (3)

No, but if do it, I think its better. (7)

Yes, it can prevent some mistakes. But it doesn’t work all the time. (3)

26 respondents chose “No” (figure 24). However, many thought it will bring benefits and wanted to use it in the future. The Poke Yoke can reduce the defects, but it is not the most important tool. Hence, it should be set as a lower priority.

11. Do you think transportation is quick and safe in your company?

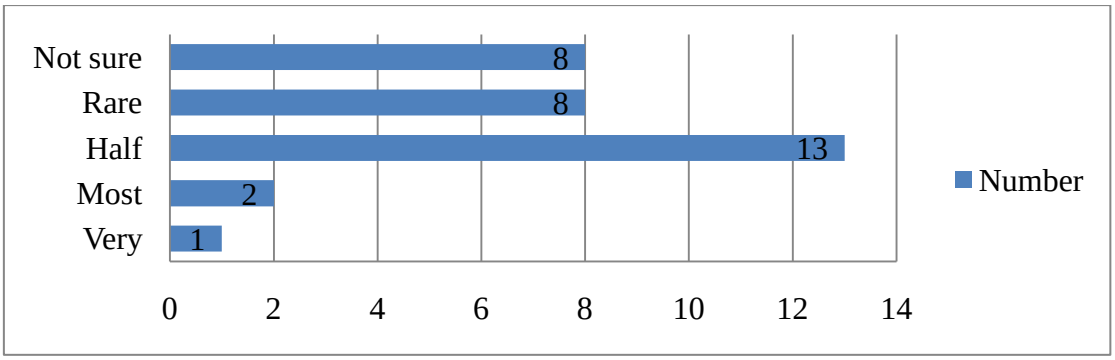


Figure 25: Result of Transportation

Most of them do not think the transportation was quick and safe in their company (figure 25). It means that this waste should be resolved as soon as possible.

12. Are there any actions during working that don't create value?

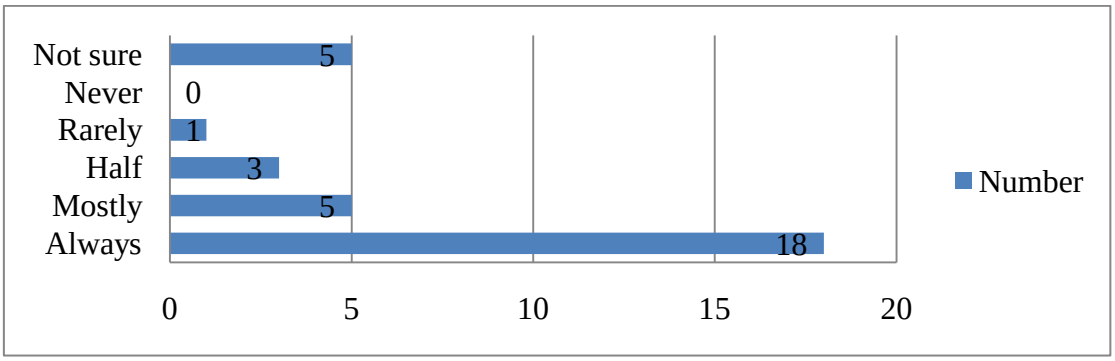


Figure 26: Result of Actions

According to the results in figure 26, many actions were undertaken that didn't add value during working.

13. Do you think all the processes are necessary to produce a product?

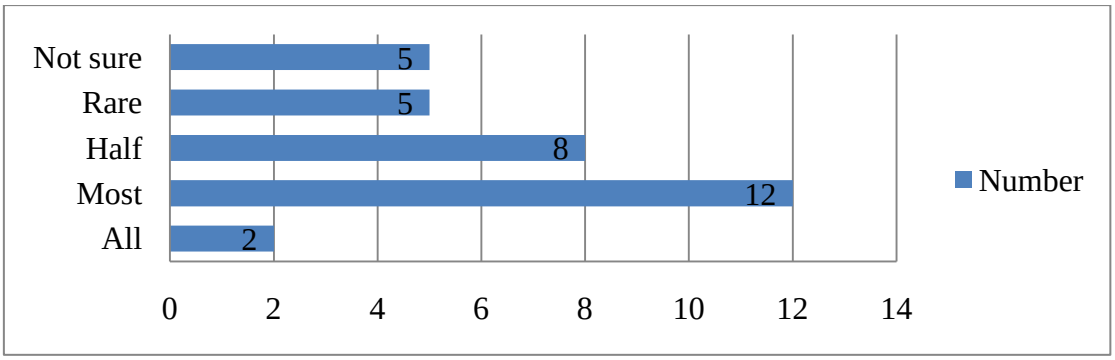


Figure 27: Result of Processes

More than half the respondents think that not all the processes are necessary (figure 27). This will lead to a long time being spent to produce a product.

14. Are there many defects during production?

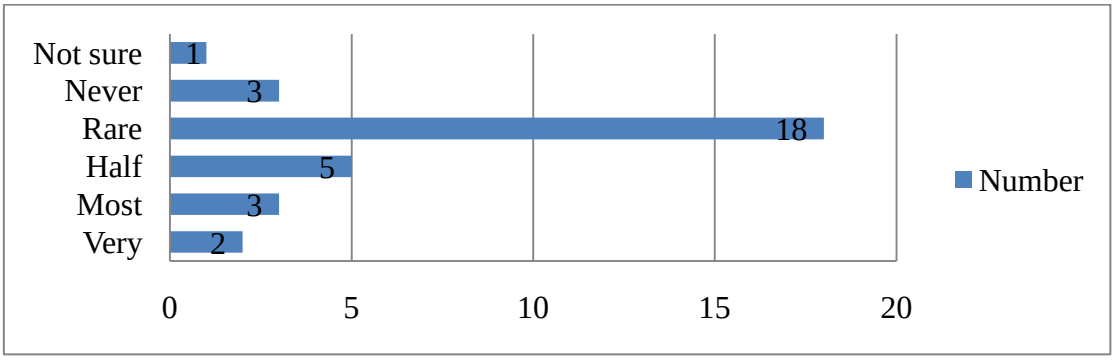


Figure 28: Result of Defects

As shown in figure 28, the defects rate is not very high, but even only one defect is a waste. The aim is to decrease the defects to zero.

15. Do you spend time waiting for people or machines?

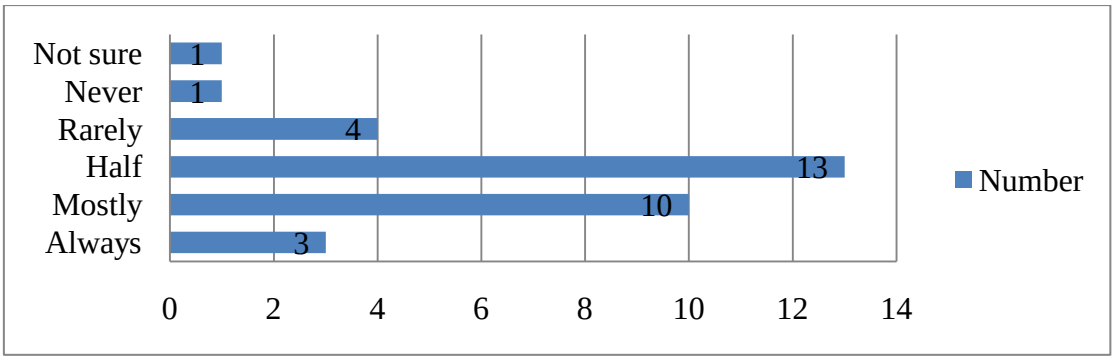


Figure 29: Result of Waiting

As can be seen in figure 29, this is a serious problem for this company. They usually spend significant time waiting for people or machines. It means that they lack an effective method or plan of control.

16. Do you think employees have opportunities in finding solutions and improving process?

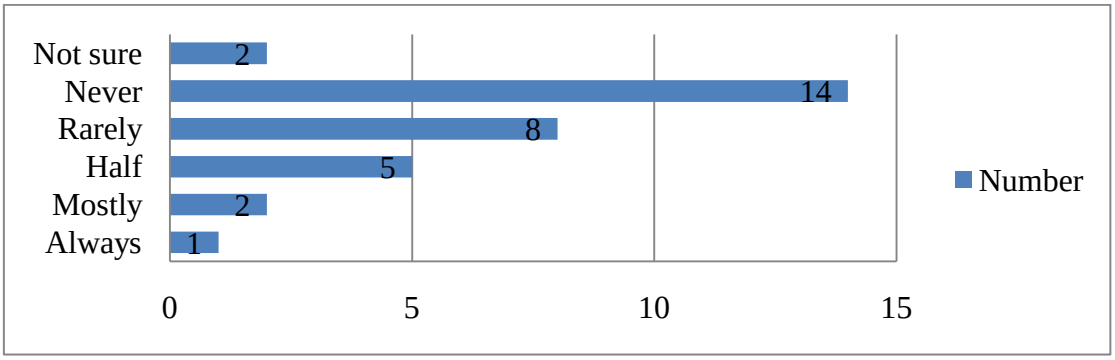


Figure 30: Result of Employees Involvement

The core of continuous improvement is all staff involvement. However, from their answers in figure 30, they did not have opportunity to do this.

17. Is there any other waste that has not been covered above that you wish to tell me about?

Answer:

Many people do something which is not related to the work.

Base on the question 11-17, the waste is serious.

18. Please list the significance of factors in your company in becoming lean. If you do not know what lean is please say and list the significance of these factors in your company. Write number 1 to 8 in the blank squares. 1 is most, 8 is least. If you have other ideas, please add.

This pie chart shows the importance of different factors. Each factor is given a number (1-8). The score of each number is shown in table 2.

Table 2: Score of Numbers

Number	1	2	3	4	5	6	7	8
Score	8	7	6	5	4	3	2	1

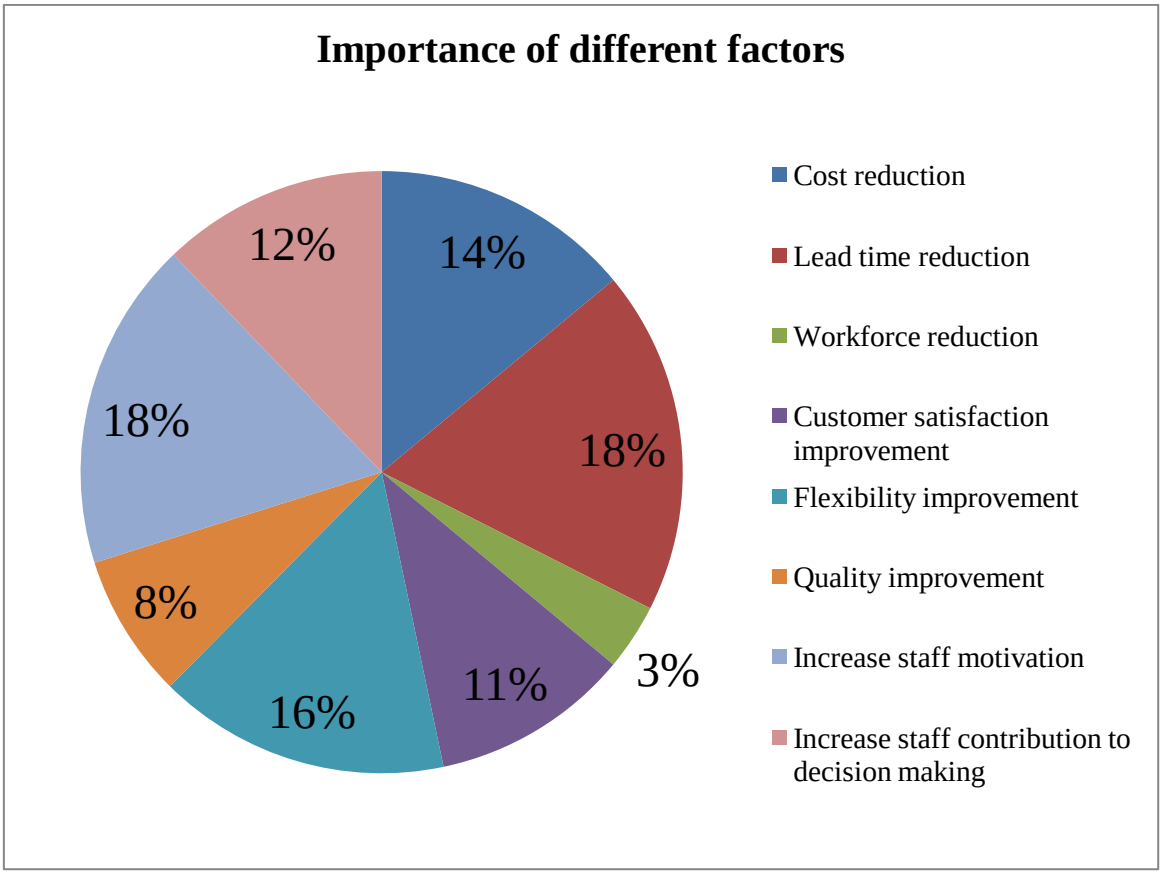


Figure 31: Importance of Different Factors for Becoming Lean

Figure 31 shows that “lead time reduction”, “increase staff motivation”, “flexibility improvement” are the most important factors in this company. Normally, cutting costs is an important outcome of the implementation of Lean. In this figure, the proportion of cost reduction is only 14%. It shows that respondents do not fully understand the role of cost control in manufacturing. The Lean implementation method will reduce costs. Hence, they need to implement lean.

19. Describe your current tasks in as much detail as possible?

Answer:

Receive order → discuss with people who write this order → confirm plan → design → check → submit

Receive order → design process → send to workers

Receive order → get material from suppliers → produce → deliver to customers

From the above answers, Kanban should be applied in their work flow or process.

20. Describe and/or draw a diagram of the process you are involved in.

Answer:

None

This question has no answers. Maybe the respondents thought it was classified information.

21. What are the main problems you encounter?

Answer:

There is no specific manager or department with responsibility for improvement.

The leader cannot give enough support to improve.

Some people didn't have positivity on working.

There is not suitable standard to measure the work.

The work environment is not very good.

It's very hard to have an opportunity to communicate with the manager.

I have no fervour for my work, maybe lack of motivation.

From these answers, the 5S, Standardised Work, Kaizen should be applied to improve their problem. In addition, more managers should be involved in the team meetings.

22. How much volume of product comes through your work area?

Answer:

The volume of product, I think it's low.

The respondents thought the volume is low.

23. How repetitive is the work you do? Are all products the same?

Answer:

I rarely produce the same part in a long time.

There are many different parts in the aircraft. So we must design and produce them, they will not look similar.

The respondents thought the repetitiveness is low.

24. What is driving your company towards becoming "Lean"?

Answer:

To win in the global competition

The successful practices of the other companies

To become a world-class company

The driving reasons are all external. They also need some internal motivation.

25. What will be the barriers to becoming Lean and/or realising success?

Answer:

Bad plan; Low education; High employee turnover; Weak supply chain; Lack of understanding ourselves

I suggest that a comprehensive survey should be done before applying lean in order to identify our status.

The respondents indicated some barriers. All of them should be improved in the lean model.

26. Before filling in the next question, you should read the following short description of Lean Tools first. It will help you to complete the next table. The abbreviation of lean tools is shown in table 3.

Table 3: Abbreviation of Lean Tools

Abbreviation	Tools
5S	5S
VSM	Value stream mapping
VF	Visual Factory
TPM	Total productive maintenance
SMED	Single Minute Exchange of Dies
SW	Standardised Work
JIT	Just in time
CM	Cellular Manufacturing
Kb	Kanban
OPF	One Piece Flow
PY	Poka Yoke
Kz	Kaizen

Figure 32 shows the percentage of lean tools which are currently in use and whether they want to be trained.

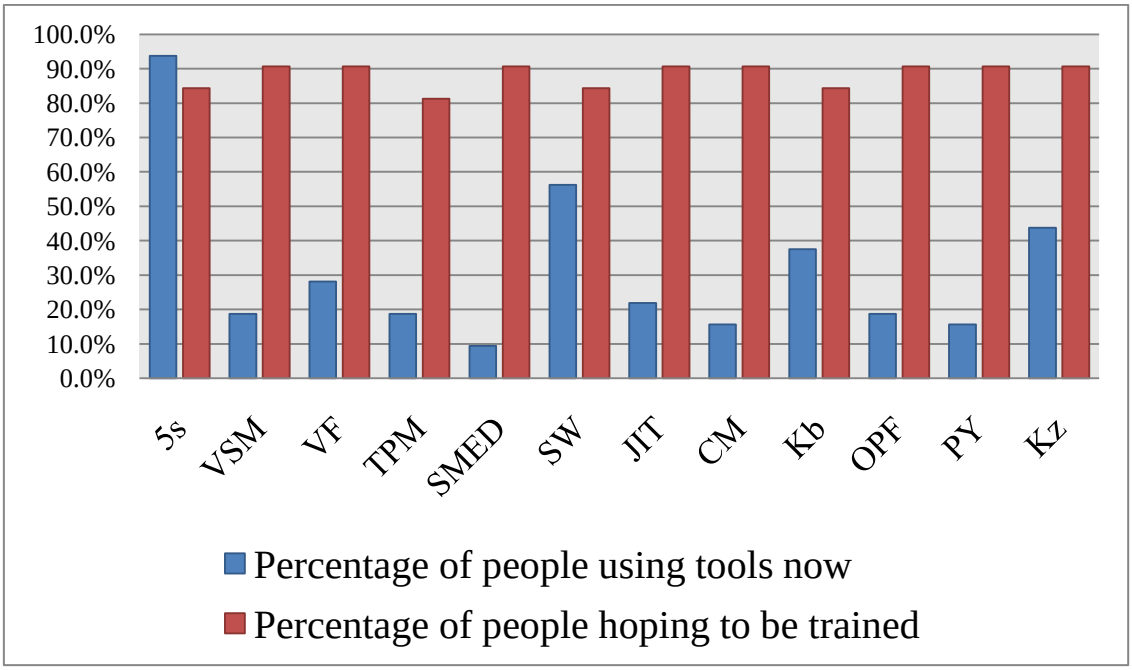


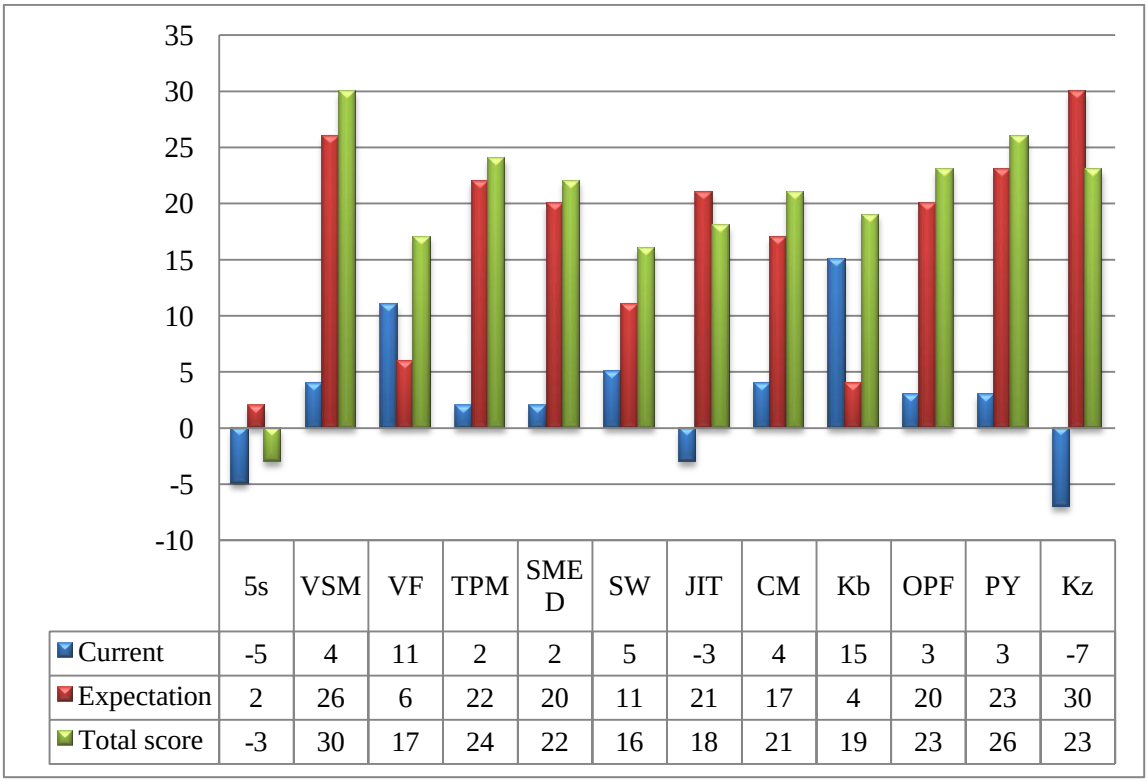
Figure 32: Result of Lean Tools

Clearly, this figure shows that 5s is widely used in COMAC. The Standardised Work is more than 50%, Kaizen is near 50%, and others are too low in use. VSM is less than 20%. But this data is normal for a company. VSM is a professional tool that should be used by the lean expert or manager who has been trained. Hence, the worker maybe does not know this tool. The results nearly show the same percentage, they are all above 80%. Therefore, most of them want to be trained.

For question 26, options were always, mostly, half, rarely, never and not sure. They were marked by different scores, and each tool obtained its score by adding all the responses. The scores are shown in table 4.

Table 4: Score of Options

Option	Always	Mostly	Half	Rarely	Never	Not sure
Score	+2	+1	0	-1	-2	0



	5s	VSM	VF	TPM	SMED	SW	JIT	CM	Kb	OPF	PY	Kz
Current	-5	4	11	2	2	5	-3	4	15	3	3	-7
Expectation	2	26	6	22	20	11	21	17	4	20	23	30
Total score	-3	30	17	24	22	16	18	21	19	23	26	23

Figure 33: Score of Lean Tools

It can be see clearly from figure 33. 5s and Kaizen are not a success in use, but these tools are basic and at the heart of Lean. Therefore, it must be imperative to improve knowledge and train people on how to use them.

4.6 Summary

In this chapter, the results of questionnaire were presented and analyzed. The aim and objectives have been achieved. The author found that this company had numerous problems to resolve. They need to implement lean to improve their current situation. In order to give a clear understanding, some results were summarized in table 5. Table 6 shows the waste level in this company.

Table 5: Questionnaire Summary

Factors	Situation
Goal	World-Class; more competitive in globe market
Lean tools	Some were applied but not successful; most of them had a low level in using
Motivation	None or low
All staff involvement	Very low
Lead time	Not always on time; long
Volume	Low
Repetitiveness	Low
Training	Lack; strong expectation to be trained

Table 6: Wastes Summary

Wastes	Level
Overproduction	High
Inventory	High
Transporting	Normal
Motion	High
Processing	Normal
Defects	Low
Waiting	High
People's Skills	High

5 ASSESSMENT TOOL

5.1 Introduction

This chapter will use an assessment tool to investigate the current situation of manufacturing in COMAC, and identify improvement opportunities..

5.2 Description of Assessment Tool

A spreadsheet-based assessment tool was used to evaluate nine key areas of manufacturing. Appendix B shows the details of this tool. Each response is given a score in the assessment. Scores are calculated for each of the nine areas. The results will show in the score worksheet and a lean performance chart

This tool is an excel spreadsheet developed by Quarterman Lee (2004). There are nine important areas of manufacturing to be investigated:

1. Inventory;
2. Team approach;
3. Processes;
4. Maintenance;
5. Layout;
6. Suppliers;
7. Setups;
8. Quality;
9. Scheduling/Control.

Appendix B presents the details of this tool.

In the first section of the “inventory”, respondents will write the percentage of managers who can express from memory in completive goods, work-in-process (WIP) goods, raw materials and the turnover rate.

In the second area, respondents have to describe the type of their company, compensation type of the plant workers, job security, annual personnel turnover, training and active participation of team work for all personnel.

The third area, investigates the manufacturing process.

The fourth area, maintenance, evaluates the maintenance, the preventive maintenance and the equipment downtime and uptime of the manufacturing system.

The fifth area, layout, measures the space used for the inventory and types of layout.

The sixth area, suppliers, investigates the supply chain, more specifically the average number of suppliers for each raw material, incoming inspection, and where and how often supplies are delivered.

The seventh area, setups, investigates setup time for equipment and efforts in setup time reduction. The quick change is necessary for lean manufacturing.

The eighth section, quality, surveys the statistical process control (SPC) training, and the percentage of operations that are using it.

Finally, the last area is scheduling and control. It evaluates flow of the materials into processes without interruptions and the “Kanban”.

5.3 Data Collection

Some important gaps can be found from the result of the lean assessment tool, and some opportunities to improve also can be identified. This assessment was completed by three directors, as shown in table 7.

Table 7: Department of Director

Department	Assembly Shop	Numerical Control Shop	Tooling Produce Shop
Number	1	1	1

5.4 Data Analysis

After collecting these assessments, the average score for each question was calculated. This data has been analyzed and show as a radar chart (figure 34).

Table 8 presents the score for manufacturing. The highest score, 70 percent, is team, and the lowest score is in maintenance at 35 percent. It is clear that there are significant shortfalls compared with the targets.

Table 8: Assessment

SECTION	SECTION POINTS	# OF QUEST	SECTION AVG	SECTION %	STRATEGIC IMPACT FACTOR	SECTION TARGET
Inventory	5	3	1.67	42%	11.1%	100.0%
Teams	19	6	3.17	79%	11.1%	100.0%
Process	14	6	2.33	58%	11.1%	100.0%
Maintenance	7	5	1.40	35%	11.1%	100.0%
Layout	14	5	2.80	70%	11.1%	100.0%
Supplier	12	5	2.40	60%	11.1%	100.0%
Setup	7	3	2.33	58%	11.1%	100.0%
Quality	7	4	1.75	44%	11.1%	100.0%
Scheduling	7	3	2.33	58%	11.1%	100.0%

The following figure is a radar chart. It is based on the results from the worksheet scores. It shows the lean performance of COMAC. It is a very useful data in presenting the current situation of COMAC. The gap between the actual and the target is clearly visible.

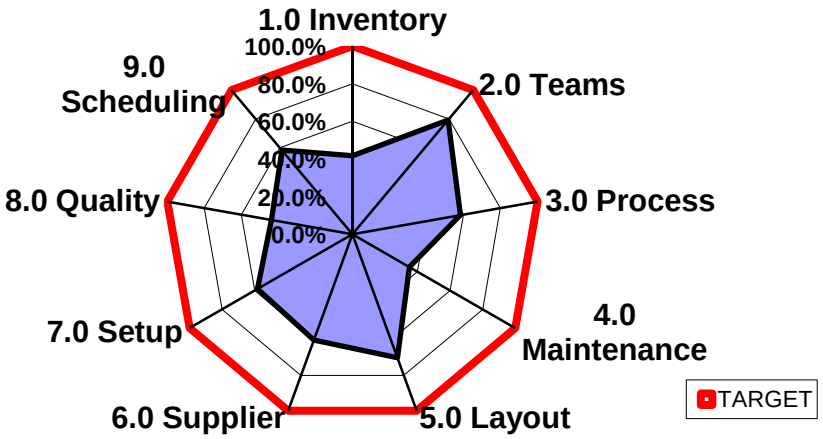


Figure 34: Lean Performance

5.5 Summary

In this chapter, an assessment tool developed by Lee (2004) and applied by Taj (2005) in his research has been used to investigate the lean performance of the customer's company (COMAC).

The result shows the scores for the key areas for lean implementation. The radar chart illustrates that no aspects have reached the goal. Therefore, they require lean improvement. Table 9 shows the assessment scores.

Table 9: Score of Assessment

Area	Score
Inventory	42
Teams	79
Process	58
Maintenance	35
Layout	70
Supplier	60
Setup	58
Quality	44
Scheduling	58

6 DEVELOPMENT OF CUSTOMISED LEAN MODEL

6.1 Introduction

In this chapter, the customised lean manufacturing model will be developed and explained. Firstly, the methodology for the development of the customised Lean model will be introduced. The result of the literature review and survey will then be analyzed. Finally, the customised lean manufacturing model will be presented.

6.2 Methodology for the Development of Customised Lean Model

A flow chart of the customised lean model development is shown in Figure 35. There are two main tasks to developing the lean model. The first one is based on the Literature Review. Lean tools will be initially selected on popularity. Some modules of the lean model will also be identified from other successful lean models. The Chinese barriers of lean implementation will be presented and analyzed to make sure the model will suitable for a Chinese company. The other main task is to investigate the current situation of the customer's company (COMAC). The questionnaire and assessment results will be analyzed to confirm the current situation. The module, barriers and current situation will finally be combined to develop the customised lean model.

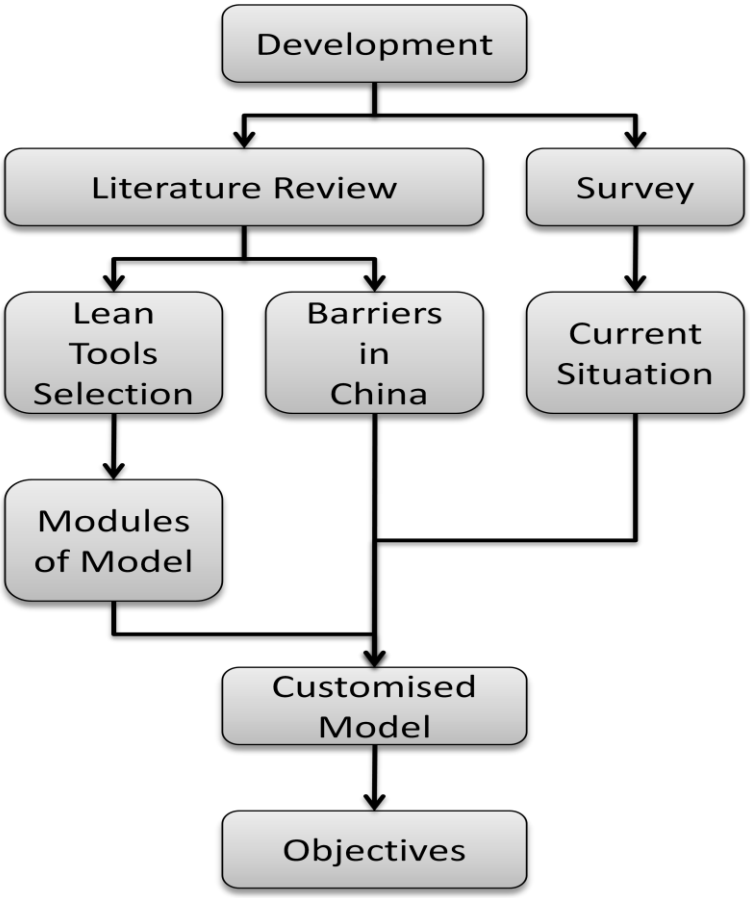


Figure 35: Flow Chart of Model Development

6.3 Lean Tools Selection

To complete this model, the first task is to determine the structure and factors. Lean tools are the most intuitive and widely studied by researchers. Therefore, the author starts working with this aspect.

The first step is the selection of tools. The numbers of lean tools are more than 100 so it is important to choose the most popular and useful tools. Table 10 shows a summary of the data from twelve articles that analyzed the current tools commonly and widely applied in lean manufacturing implementation. Author had summarized this analysis. Twelve tools were selected to apply in the model in table 10. In each book or journal, several tools were reviewed. Researcher picked out these tools that were widely applied in lean manufacturing implementation.

Table 10: Tools Selection

Tools	Reference											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
VSM	√			√	√	√	√	√	√		√	√
5S	√		√		√	√	√	√	√	√	√	√
Poka Yoke	√	√		√	√			√	√	√	√	
Visual Factory			√		√	√	√	√	√	√	√	
SMED	√			√		√		√	√	√	√	√
TPM	√	√	√	√	√			√	√	√	√	√
Cellular Manufacturing	√		√		√			√	√	√	√	
Standard Work	√		√		√		√	√	√	√	√	
Kanban	√	√			√	√		√	√	√	√	√
Once piece flow		√	√	√		√	√			√		√
JIT		√	√	√	√				√	√	√	√
Kaizen	√	√	√	√	√	√	√	√	√	√	√	√

(1: Chen & Meng, 2010; 2: Sohal & Egglestone, 2004; 3: Shah & Ward, 2003; 4: Shah & Ward, 2007; 5: Taj, 2008; 6: Doolen & Hacker, 2005; 7: Panizzolo, 2006; 8: Bicheno, 2004; 9: Dennis, 2002; 10: Feld, 2001; 11: Liker, 2004; 12: Womack & Jones, 2003)

These twelve tools selected for the improvement could bring benefit to the company. Based on the literature review some information can be concluded. The table 11 shows the results.

Numbers in the table show how many sources support each view. For example, nine books thought the VSM can identify the waste, seven of them thought that it can reduce the lead time, six of them thought it can reduce inventory, two deemed it was helpful for layout and setup time, and five believed it was important for continuous improvement.

It can be seen that no any tool has single role only. Each tool can bring several benefits. So it will result in chaos if tools used simultaneously as the benefits and problems of each tool cannot be analyzed and further improvements cannot be sustained. Therefore, the tools will be applied in sequence.

Table 11: Tools Benefits

Benefits	VSM	5S	Poka Yoke	Visual Factory	SMED	TPM	Cellular Manufacturing	Standard Work	Kanban	Once piece flow	JIT	Kaizen
Identify waste	9	7	N/A	4	N/A	3	N/A	5	N/A	N/A	1	7
Employee involvement	N/A	9	N/A	1	N/A	9	4	6	2	N/A	4	12
Standardization	N/A	10	N/A	6	2	8	5	8	2	N/A	2	5
Lead time reduction	7	6	N/A	2	6	5	7	3	9	4	8	6
Inventory reduction	6	5	N/A	1	3	2	2	4	9	7	8	5
Layout adjustments	2	7	N/A	6	7	4	7	3	2	5	1	8
Setup time reduction	2	2	N/A	3	8	5	3	5	3	N/A	N/A	5
Continuous improvement	5	7	1	1	3	8	6	5	6	2	4	12
Reduce defects	N/A	2	8	3	N/A	2	N/A	4	N/A	N/A	N/A	6
Better maintenance	N/A	1	1	1	N/A	10	N/A	3	N/A	N/A	N/A	4

6.4 Modules of Model

However, if implementing lean at tools level only, then, it is likely to lead to failure. In the lean manufacturing model, the tool is just one aspect. There are many other factors to consider, as detailed in Table 12. These seven modules were summarized from other researchers' models reviewed in section 2.11. Initial focus of lean implementation was on the tools and continuous improvement. Next, training was considered necessary. Leadership was also a very significant factor in the research of recent years. Moreover, investigating actual situations, identifying waste and designing implementation plans were equally important. Hence, they were chosen for developing the customised lean manufacturing model.

Table 12: Modules of Model

Module	Model									
	1	2	3	4	5	6	7	8	9	10
Leadership & Strategy			√	√	√		√		√	√
Training		√	√	√	√		√		√	√
Survey				√		√	√			
Indentify Waste (VSM)				√		√	√	√	√	√
Plan		√		√	√	√	√	√		√
Tools Selection (in sequence)	√	√	√	√	√	√	√	√	√	√
Continuous Improvement	√	√	√	√	√	√	√	√	√	√

(1: Dennis, 2002; 2: Gray, 2001; 3: Hines et al, 2008; 4: Wan & Chen, 2009; 5: Aulakh & Gill, 2008; 6: John, 2009; 7: Radnor, 2009; 8: Rivera & Chen, 2007; 9: Hines et al, 2004; 10: Ronald, 2003)

6.5 Barriers of Lean Implementation in China

According to the summary of the literature, the model's structure and composition of elements have been determined. Due to this being a customised model, the company's situation must also be considered.

Firstly, the barriers of lean implementation in Chinese manufacturing were determined according to the literature (Table 13). There are many deficiencies in need of improvement. And this information can also help to design a questionnaire for collecting data.

Table 13: Barriers

Barriers of Lean implementation in China	Reference											
	1	2	3	4	5	6	7	8	9	10	11	12
Apply tools at first without strategy			√		√	√		√		√	√	
Weak leadership contribution	√	√	√			√		√				
Want to quick succeed					√	√					√	
Especial relationships		√	√	√				√		√	√	
High employee turnover	√	√	√	√							√	√
Low skill/education	√		√	√			√		√	√	√	
Weak Supply Chain			√		√			√	√	√	√	√
Inapposite plan	√		√			√	√	√		√	√	
Complete copy			√	√	√	√						
High defect rates	√	√	√						√	√	√	
Weak Inventory Management	√		√					√	√	√		√
Lack of self-initiative		√	√			√	√		√		√	√

(1: Aminpour & Woetzel, 2006; 2: Aoki, 2008; 3: Bollbach, 2010; 4: Brown & O'Rourke, 2007; 5: Brown & Cih, 2008; 6: Chen & Meng, 2010; 7: Chin & Pun,

2002; 8: Comm & Mathaisel, 2005; 9: Lee, 2004; 10: Oliver et al., 1998; 11: Paolini et al., 2005; 12: Taj, 2005)

6.6 Current Situation

Based on the table above and the author's experience, a questionnaire was designed to collect information as well as function as an assessment tool to determine the extent of the company's lean. The details of the questionnaire and assessment were explained in chapter 4 and 5. Figure 36 shows how to combine these issues with the model. It can be seen that the company's current problems can be solved.

There are three parts in this figure:

Current situation: It presents the results of the questionnaire and assessment tool and considers the barriers to lean implementation in China. All of these problems need to be resolved.

Solution: The second part identifies a solution to the current problems identified in the first part. It contains eight keys modules that have been summarized in the section 6.2 and 6.3. They can solve the current problems that identified in the first part.

Objectives: The third part details the benefits to the company of overcoming these problems. These objectives are required to be achieved through lean implementation.

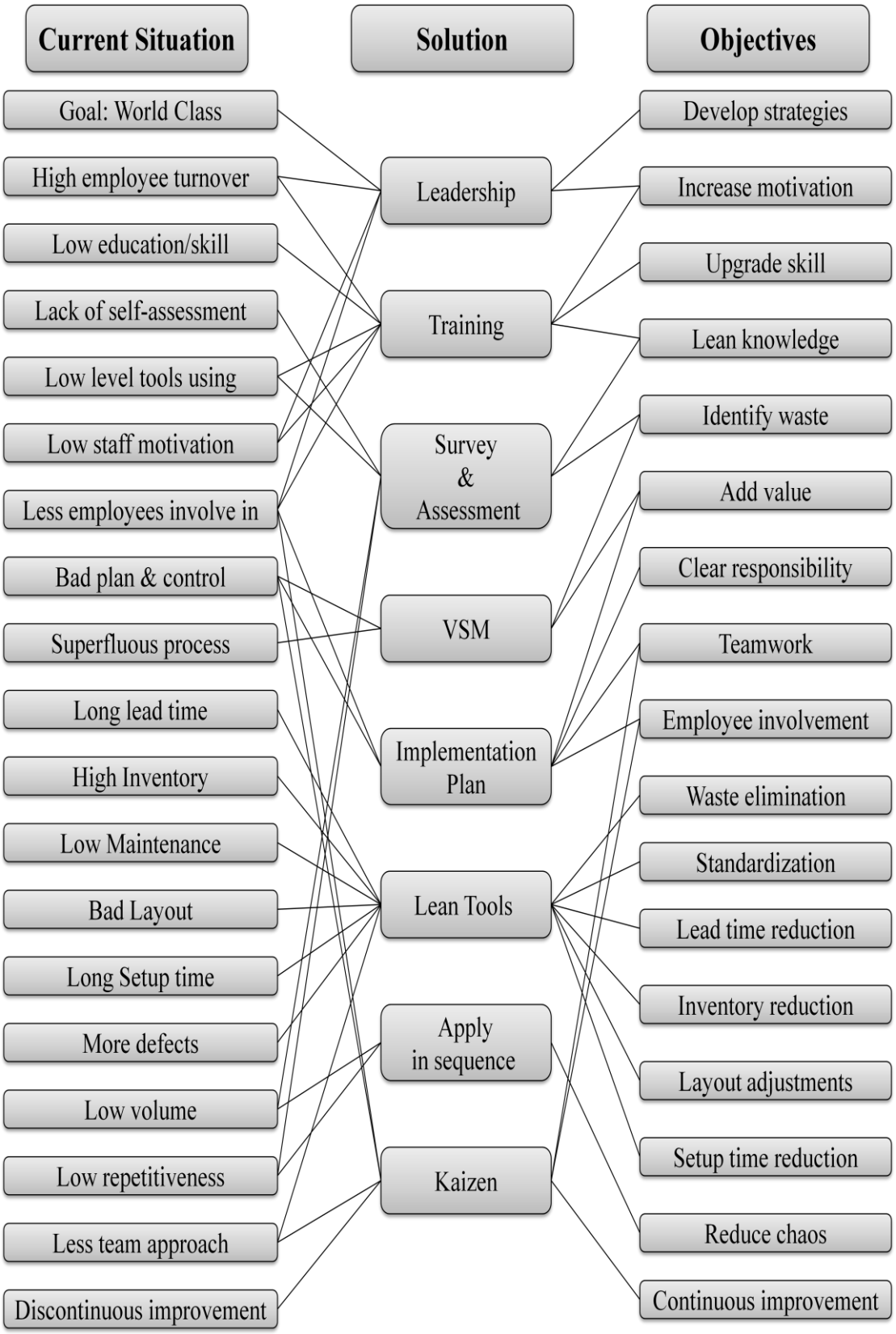


Figure 36: Relationship Map

6.7 Customised Lean Model

The customised lean model was developed following the above steps. There are four stages to run the whole implementation cycle, as shown in figure 37.

Stage I: Support by leadership and confirm business strategy and goals
Stage II: Prepare for implementation
Stage III: Implement Lean Tools
Stage IV: Continue improvement

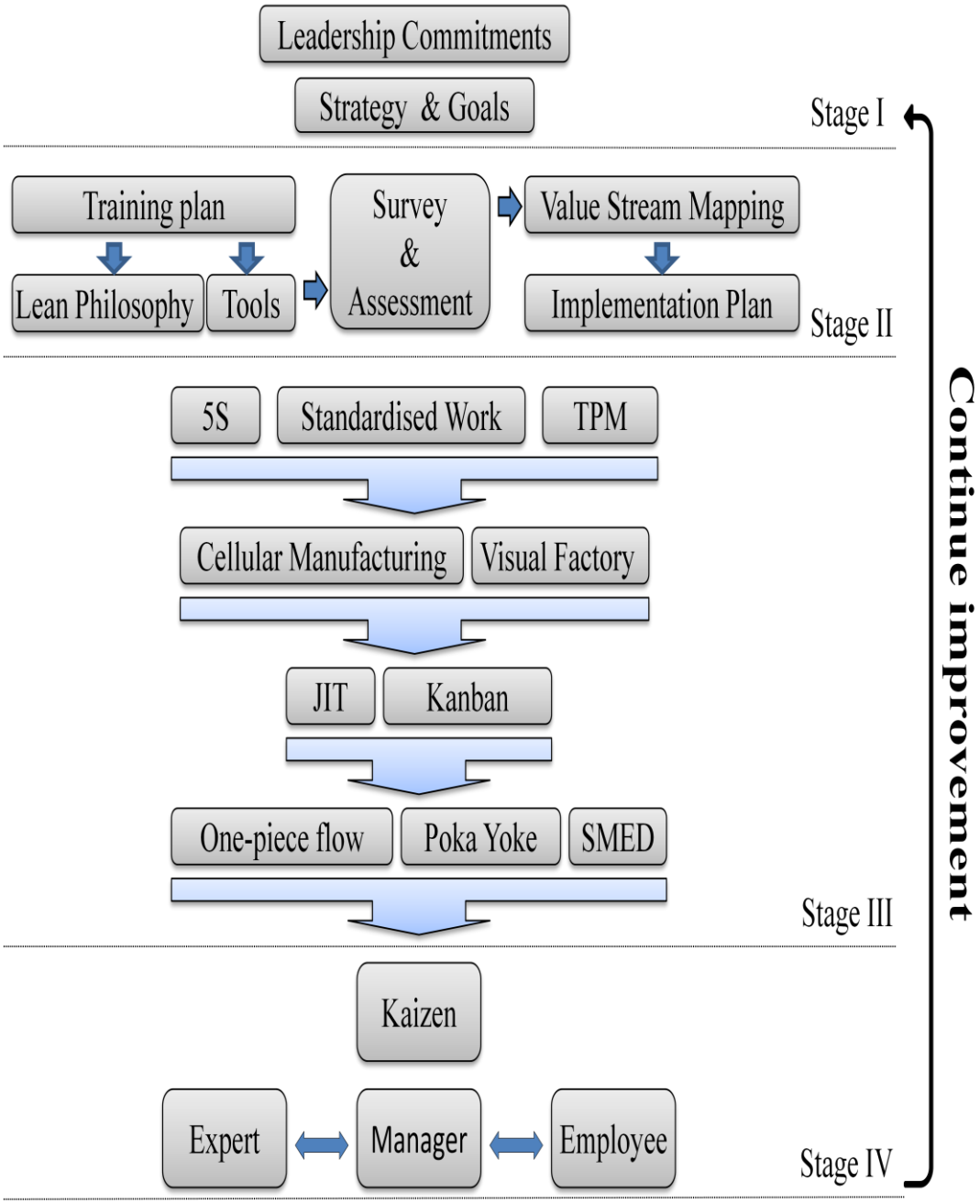


Figure 37: Customised Lean Model

Stage I:

Firstly, it is a good start to bringing together your leadership who will provide the support and resources required.

“Lack of senior management commitment will lead to failed implementation. Top management commitment is a must. The employees must see that management is interested in the changes. Without the commitment, employees will not see the necessity to spend even one minute thinking about the project.” (Scherrer-Rathje et al., 2009)

Therefore, without their commitment, everything will become difficult. In China, the practice was always to start at tool level without an understanding of business strategy. Senior management even didn’t know the aim of what they should achieve. It leads to inefficiency and a blindfold applying to lean (Chen & Meng, 2010). Hence, the aim of the Lean project should be confirmed in the first stage. The employees in COMAC also think that the leadership should pay more attention to the improvement project (see Questionnaire – question 21).

In this stage, leadership is the most important factor. They must understand the reason to become lean. The following aspects should be considered and improved in order to implement the next stage as successfully as possible.

1) Confirm the goals of implementing Lean and link it to the business.
2) Understand lean is not a quick success way: it is a long term project and a continuous process for improvement.
3) Support development of training as this requires time and money.
4) Encourage employees’ involvement, establish method of rewards and increase employees’ motivation.

Stage II:

In this stage, there are four important steps to a successful finish. All of them prepare for implementing Lean.

1. Training: Establish a training plan. Based on the plan, determine the training requirement of the company and the people who will go to attend Lean training. The staff can learn skills and increase motivation from the training (McDowall & Mabey, 2008). The lean expert should also be retained to teach lean philosophy (containing lean thinking and lean principle) and lean tools to the managers and employees as they need to be trained to understand Lean (what can be done and how to do it) and believe in it. The staff showed strong expectation to be trained (see Figure 32).

   Training is a necessary step before applying lean tools (Radnor, 2010). In addition, training is not a separate step, and many other aspects also need to link up in order to achieve continuous improvement (Gunasekaran et al., 2001). Therefore, training and continuous improvement will be done throughout all steps of model.

2. Survey and Assessment: In this step, the retained expert ought to investigate the current situation of the company. A comprehensive survey can show the situation of company which helps to develop a strategic plan for lean deployment (John, 2009). The Lean Assessment can supervise how lean they are now and highlight where is not lean (see Questionnaire – question 25).

3. Value Stream Mapping: VSM is Lean Tools to help companies understand and streamline the process of production. Its aim is to identify and reduce waste in the production process. VSM is often used as a strategic tool for management changing tools (Singh & Sharma, 2009). From the moment raw materials are purchased, VSM begins to work. It

runs through all manufacturing processes and steps, until the end product leaves the warehouse. Hence, VSM should be used prior to developing the implementation plan (Chen & Meng, 2010). From this value stream, waste and value can be easily identified and improvement needs highlighted. However, the VSM is a professional tool that should be used by the lean expert or manager who has been trained. Although it was not used in company, it still had the highest score in the survey. They thought it will bring benefits to the company (see Figure 33). In order to apply VSM, some elements should be noticed:

1). Ensure management support; the logistics manager, production planning manager, production manager, process manager and other departments at least should participate.

2). Ensure that the participants have good lean knowledge and have been trained about VSM.

3). Allow for at least three days full-time involvement for best improvement.

First day: Collect data from raw materials to finished products, all steps should be included.

Second day: Map current value stream, and ensure that all of them are correct.

Third day: Analyze and identify improvements, and map future value stream.

4. Implementation plan: Write down the Lean implementation plan. You should design a plan to ensure the aim can go the right way (Aulakh & Gill, 2008). The responsible department or people should also be confirmed in this step (see Questionnaire – question 21). For applying tools correctly, sponsor for each Lean Tool needs to be arranged (Chen & Meng, 2010). Table 14 shows an example of this.

Table 14: Sponsor of Tools

Tools	Sponsor
5S	Human Resource manager
Value stream mapping	Plant manager
Visual Factory	Plant manager
Total productive maintenance	Maintenance manager
SMED	Production control manager
Standardised Work	Production manager
Just in time	Production manager
Kanban	Plant manager
One Piece Flow	Production control manager
Poka Yoke	Quality manager
Kaizen	Production manager
Cellular Manufacturing	Plant manager

Stage III:

In this stage, Lean tools will be applied in specific sequence (Wan & Chen, 2009; Rivera & Chen, 2007; Grunberg, 2004). Some of the most popular tools were selected to apply in this stage. With further improvement, more tools will be used, but the most basic tools should be applied first. Some best practices of other companies can provide a good example. But they cannot be applied in the same way without adaption. All the tools should be suitable with the actual situation and culture.

1. For a company to achieve stability and standardization is the foundation of Lean manufacturing. Therefore 5S, TPM and Standardized Work should be used first. They also can increase corporate image and employees' morale, and reduce the changeability of the production process.

5S: The role of the implementation of 5S is to establish a basis to apply other tools. 5S can bring many benefits for the company in this stage:

1) Improve corporate image
2) Increase productivity
3) Increase inventory turns
4) Reduce defects
5) Strengthen security, reduce danger risks
6) Develop the habit of saving, reduce costs
7) Shorten the operating cycle, and ensure delivery in time
8) Improve the business spirit, create a good corporate culture

Therefore, 5S should be applied first. Although, COMAC has used it, the results from the questionnaire are on the low level. They need to train to understand why it is necessary. The training is not only for managers to participate, all employees are required to attend regularly. It requires a special organization to be set up to implement 5S. The principal leaders of the company should lead 5S activities and support this tool. The Deputy Director may be responsible for the full implementation of the activities.

TPM: This is a maintenance management system to enhance overall equipment efficiency as the goal, extensive preventive maintenance as the process, and all staff involved as the basis.

This system requires:

1) All personnel to be involved in the TPM, including senior management.

2) Employees to be empowered to self-correct.

3) A longer operating period. This is because that there is TPM's own development process. Hence, implementing the TPM takes about a year or more time.

Standardised Work: Standardization is the best way by recording the current and standard forms of work and to continuously improve. When update the standards, the new standards will be further improved. Improving standardization is a never-ending process. It would focus on the following aspects:

1) Standardization of operating procedures
2) Standardization of operating method
3) Standardization of layout
4) Standardization of material handling
5) Standardization of operating time

2. For the low volume and low repetitiveness manufacturer, Cellular Manufacturing and Visual Factory can effectively solve current problems. They are a quick and obvious method to help the company to become lean.

   Cellular Manufacturing: It refers to a production line, the operation of the production line produces a variety of parts of manufacturing processes. It will bring several advantages as follows:

   1) Eliminate the need for follow-up assembly and manufacturing processes. It will reduce the waste of waiting and walking.
   2) Eliminate production bottlenecks: Cellular manufacturing requires achieve single cell manufacturing. The production equipment or manual operation can adjust the production rate in accordance with the order requirements.
   3) Flexible layout: The traditional linear layout for long production line doesn't allow for workers to turn around and immediately engage in other operations. Hence, cell layout is more flexible.
   4) Multi-task operation: Workers can be used for a variety of special processing in the cell layout. This change can effectively avoid workers repeated fatigue in lengthy single operations and also can save on labour costs.

Visual Factory: It is a management method with the eyes. It reflects the initiative. It can be used in conjunction with a number of tools, such as: 5S, Kanban, Poka Yoke, etc. The purposes of Visual Factory are to:

1) Explicitly inform what to do, to enable early detection of anomalies

2) Prevent human error or mistake, and always maintain the normal state

3) Expose the problem point and waste easily, to prevent and eliminate all risks and wastes in advance

In order to achieve this purpose, the company should use the complete label, logo, colour to manage.

3. JIT and Kanban control system should then be implemented so the materials and information can flow effectively. These will reduce the wastes of inventory, over production and waiting time. They are helpful to realize continuous flow and eliminate wastes.

   JIT: The core of JIT production is pursuit of a non-stock production system, or to minimize the production inventory system. Kanban was developed for this purpose and includes a series of specific methods.

   Kanban: Refers to achieving timely production (JIT) and controlling the production process. Timely production of the pull production system can reduce the flow of information. The material in the production process can flow smoothly with specific containers and table.

4. The final step is implementing some other lean tools, such as One-piece flow, Poka Yoke and SMED. They are not the most important tools for the low volume and low repetitiveness manufacturer. However, they have a useful function to reduce the wastes of transportation, defects and waiting time.

   One-piece flow: It is actually an appropriate amount in order to achieve timely production methods. If it is combined with the use of Kanban, JIT

will be thoroughly implemented. The real one piece flow is based on the order of the customer's demand. Process is driven by order to minimize the batch as the goal, to achieve continuous production and to achieve zero-inventory.

The problem can be solved by:

1). A serious waste of resources, including personnel and equipment;

2). A large inventory;

3). Long delivery time;

The requirements to implement one-piece flow are:

1). Relevant Lean knowledge by the manager.

2).Suitable production line layout - a necessary condition for the implementation.

3). Quick changeover for the different moulds/tooling - this will be introduced below.

SMED: Findings from the questionnaire show that COMAC belongs to a low volume and low repetitiveness manufacturer. It needs to retain a lot of product variety and small batches. It is unavoidable that the factory will be changed frequently in the production between different moulds/tooling. And it causes a large number of machines to stop a long time which leads to a reduced production efficiency, waste and more delivery time. Hence, it needs SMED to improve this problem.

SMED quick changeover is used for external activities instead of internal activities to achieve it. The internal activities can be defined as operations which must be done when the machine is stopped. The external activities can be defined as operations which should be done when the machine is running.

Generally, SMED improvement process can be divided into the following three steps:

1). Map the whole process and divide into internal activities and external activities.

2). Find which internal activities can be exchanged to the external activities and achieve them.
3). Set the evaluation and standardization of all aspects of the process of improving.
These evaluation and standardization works need 5S, Standardized work and Visual Factory as foundation. Therefore, SMED should be applied after them.

Poka Yoke: It means "mistake proofing", that is, Error & Mistake Proofing. It is a tool used to obtain the defect, in order to eventually remove the quality inspection. The principal reason to apply Poka Yoke is to ensure not even a few defective products appear. In order to become a world class enterprise, it not only needs to transform in concept, it must reach "0" defects. Although in reality errors cannot be eliminated completely, the aim must be to discover and immediately correct and prevent errors forming a defect.

Stage IV:

All-staff involvement is critical for a company to successfully implement Lean (Pettersen, 2009; Sim & Rogers, 2009). The manager can link experts and employees together to make sure that continuous improvement is working. Manufacturing cannot be achieved in one action, it is an endless process. Therefore, it would be undertaken as a long-term task with continuous improvements. It embraces every aspect of the lean implementation. It needs flexible, motivated team members continually seeking a better way to finish the aim. Although Kaizen had been applied unsuccessfully, it still had a high score for implementation in the future (see Figure 33).

In order to implement Kaizen well, it is better to set up a group. This Kaizen Improvement Team (KIT) is responsible for the implementation of improved

production systems and improvement activities. The KIT manager of the factory is dominant people of improvement activities.

KIT's main responsibilities are:

1). Overall responsibility for the coordination of Lean continuous improvement;

2). Lean training and skills development;

3). Promotion and communication activities;

4). Internal consultancy work, select and train members of KIT.

Continuous improvements should be divided into three type based on the time.

Five minute meeting: It is a daily Kaizen event for every team. It is better to have a meeting every morning to summarize the previous day's work and plan the current day's work. It is not a big change. The aim of this short meeting is to seek the problem in time. If the problem is found, it should be solved or improved within 2 hours. However, if this problem cannot be solved in a short time, the team should go to the next step – Key Kaizen.

Key Kaizen: This improvement generally lasts one to two days in order to improve the objectives and scope which is relatively difficult. This improvement is also necessary to improve the company's development projects. It needs the support of team leaders and regional sponsors. And it still needs a brief training for the participants involved in it.

Week Kaizen: This improvement is a standard week (five days) continuous improvement projects. This project must meet the long-term development strategy and mission of the company. It needs to be led and monitored by leadership and the Lean expert. Five days to improve the scope and objectives of the project are relatively large. Hence, it must do more towards the preparation and systematic training.

6.8 Summary

In this chapter, a customised lean model has been developed. According to the literature review and company survey, this model is rigorous and understandable. The research objective 3 had been achieved in this chapter.

7 VALIDATION

7.1 Introduction

In this chapter the customised lean model will be validated by the company and some experts in the university. The structure of this chapter is as follows: section 7.2 will introduce the methodology for validation. The validation by the sponsoring company will be written in section 7.3. Section 7.4 and 7.5 will present validation by the academic and industrial experts. Finally, section 7.6 will summarize the chapter.

7.2 Methodology for Validation

In order to validate the customised lean manufacturing model, some experts were interviewed. Questions asked included: (i) How rigorous is this model? (ii) How understandable is this model? (iii) How implementable is this model? (iv) Comment on the benefits or/and drawbacks of this model. (v) How can this model be improved?

The first validation was based on the sponsoring company. The author sent a model description document and followed up with explanations via an internet chat tool. Three directors had a group meeting and gave feedback.

The expert validation was achieved both by industrial and academic experts. In the university, two experts validated this model using their experience and knowledge. Additionally, an expert working in Alstom offered comments from an industrial viewpoint.

7.3 Validation by Company

The first validation was achieved by the customer's company. Three directors were present at this meeting. The researcher used an internet chat tool to explain the model and discuss it with them. This discussion meeting lasted

around two hours. They wrote a summary (see Appendix C) as the feedback for this validation.

Firstly, they thought this model was required for the company at this stage. Leadership was important in China. Especially in this company, they could provide support to start this project. Hence, it was a good start from the leadership. The current situation was that most knew little about lean. Therefore, the training for the whole staff was also necessary. However, they had two questions about training.

1) Who can train the managers and staff?
2) Who will be sent to this training?

For question one, the author suggested the experts who had a wealth of knowledge and experience can teach them first. And then the managers should train employees based on the current company situation. For question two, there would be some different courses for managers and staff. They need not attend every training course. This will be future work for the author to confirm this information.

Secondly, they thought the questionnaire and assessment tool were very useful methods to identify the current situation for their company. They are easy to use for collection of information. Moreover, they thought these tools should be improved and modified in order to make them suitable for more departments.

Next, the VSM was mentioned as a significant tool for becoming lean. However, they rarely applied it before. It was an optimum opportunity to let them use VSM when this model was implemented. The others tools in the implementation stage should be important also; however, they didn’t provide much constructive advice about them.

They had applied the continuous improvement persistently but there was not enough positive effect. Hence, they thought the concept should be changed as this model. For all staff to be involved in the continuous improvement project

was better than the manager only. They can also reward those who propose good ideas. That will bring stronger motivation for staff involvement.

Finally, they thought this model was very rigorous. They could understand this model very clearly and were able to implement it mostly.

7.4 Validation by Academic Experts

The second part of validation was carried out in the university by academic experts. The author had interviewed two experts to explain the model and discuss ways to improve the model. These meetings lasted around two hours. All the content will be presented as follows.

Dr Denyse Julien is the Course Director for the Manufacturing Consultancy course within the Manufacturing Programme. She has great wealth of knowledge and experience on lean manufacturing and six sigma.

Firstly, she thought this model was mostly developed rigorously. There was enough literature to support the build up of this model. The structure was logistical. Moreover, the survey data provided information to develop a customised model.

Secondly, she considered this model clearly understandable. She also believed that this model can be implemented in the company very well.

Finally, she gave a suggestion for future research. She proposed to select a specific project to implement lean tools. It means that several tools will be selected to apply in this area (department, team, process, etc.). This allowed more targeted lean implementation. However, it will require more details about the company. She suggested the author can continue this research after returning to the company.

Dr Andrew Johnstone is piloting 360 degree feedback for students, and using this feedback as a tool to improve students' work and skills.

He believed this model was very rigorous. There are enough details to explain and build up the model. He could understand this model very clearly and it was mostly implementable. However, he thought the model should pay more attention to the function of leadership because they could provide the requirements, encourage employees, support training and communicate to improve. Moreover, he suggested the sequence of the training and survey should be interchanged. The result of the survey can help to decide how to train and who will attend the training.

7.5 Validation by Industrial Expert

Mr Angus Brummitt-Brown is a Project Manager of Cost Excellence in Alstom Power Retrofit. Angus wrote the processes for lean implementation in his previous role at Tarmac National Contracting. The author was very pleased to visit him for validation. We had a meeting which lasted more than two hours. A voice recorder was used to record this meeting to ensure all the data will be written correctly. .

He thought this model was very rigorous. He could understand this model very clearly and it was mostly implementable. However, he had some helpful suggestions to improve this model further.

He thought this model focused on the lean operation system and would be improved if it paid more attention to human behaviour and management. Although this model has referred some aspects of them, he thought the training should be carried out during the whole cycle. The leadership were trained at first to believe lean and support it. The managers and employees were trained following to understand lean and apply it. He presented some factors for change, which are shown in table 15.

Table 15: Factors for Change

Factors						Result
Incentive	Vision	Skill	Communication	Resources	Action Plan	Successful Change
N/A	Vision	Skill	Communication	Resources	Action Plan	Slow Gradual Change
Incentive	N/A	Skill	Communication	Resources	Action Plan	Confusion
Incentive	Vision	N/A	Communication	Resources	Action Plan	Anxiety & Fear
Incentive	Vision	Skill	N/A	Resources	Action Plan	Rejection
Incentive	Vision	Skill	Communication	N/A	Action Plan	Frustration
Incentive	Vision	Skill	Communication	Resources	N/A	False Starts & Chaos

This table shows the influence of every factors during lean change program. If five factors are considered without one, it will lead to failure in one respect. Mr Angus Brummitt-Brown pointed out that all these factors had been referred in the model. Incentive, vision and resources will be confirmed and provided in stage I. Skill will be trained in training step in stage II. And then, the action plan will be determined in stage II. The communication will be performed throughout the whole cycle like the continuous improvement. Therefore, he believed this model could be implemented.

7.6 Summary

This chapter has presented the result of validation. The sponsoring company, academic experts and industrial expert have provided enough comments to validate this model, and have also offered some suggestions for improvement. Therefore, this chapter had achieved objective four – validate this model in the company and university.

8 DISCUSSION AND CONCLUSIONS

8.1 Introduction

This chapter will discuss the harvest and experience during the research project. In section 8.2, the completion of research aim and objectives will be discussed. The development of the model will then be discussed further. It also includes contribution, research limitation and future work in the remaining sections.

8.2 Discussion

The aim of this research is introduce Lean Thinking in a systematic and cost effective way, bring Lean Principles and apply Lean Tools into a new Chinese aerospace company. In particular it means that the research will develop a customised Lean manufacturing model. In order to achieve this aim, several objectives were confirmed. Namely: (i) Investigate the principal features of Lean Thinking, and identify state of the art in Lean manufacturing implementation; (ii) Identify the current situation of a specific Chinese aerospace company and the requirements needed of becoming Lean; (iii) Develop a customised Lean model for applying Lean into a new Chinese aerospace company; (iv) Validate the Lean model by the experts in the company and university.

8.2.1 Achievements of the Set Research Objectives

Four stages have been established to achieve these objectives.

Stage 1:

In this stage, the author focused on the understanding and the investigation of the thesis project. Literature will be reviewed in order to familiarize with the state of art. Extensive journal papers, books and other researchers' theses will be related to the author's research area. The objective one was achieved during this stage. And the research gap was found at the same time.

The literature has reviewed the state of the art. Lean thinking and lean transformation were introduced to give an overview about what lean is. Lean manufacturing, value, wastes and lean tools also were presented. Lean principle and a general method to apply it were explained to know how to achieve lean. Some lean implementation models show the best practices which can support the development of a customised lean model. The barriers of lean implementation in China are defined.

According to the literature review and researcher's knowledge, there is no paper developing a model link to the barriers of lean implementation in Chinese manufacturing. Although these barriers have been reported by many researchers, they did not develop a model containing all of them to solve the problems. From the literature review, most of Chinese company start implementing lean at tool level. There are few managers understanding lean. There are few chances to let all employees involve in the improvement. Therefore, the author had decided to fill up this gap.

Stage 2:

In this stage, the information required was collected. Questionnaire and Assessment Tool were used to collect current situation from the customer's company. The questionnaire was sent to many normal employees and several managers to identify the current problems they faced. The Assessment Tool was used and completed by a few of the directors. That was more exact to understand the lean performance of customer's company. All of these results had been used to identify the current situation of the company.

After collecting all the data, it was analyzed. The result of the questionnaire was presented and analyzed. The author found that this company had many problems to resolve. They needed to implement lean to improve their current situation. The result of the assessment tool showed a score for each area which are the key areas for lean implementation. The radar chart illustrated that no

aspects have reached the goal. Therefore, there was significant improvement potential. Objective two was achieved in this stage.

Stage 3:

In this stage, the customised lean model was developed. Firstly, based on the literature review, some models developed by other researchers were selected for analysis. Many useful and successful examples could be learned from these models. This lean model example collected could support choosing the factors/element of the model. And the result of data analysis helped to modify the model and transform it into the customised lean model. Objective three was achieved in this stage.

Stage 4:

In this final stage, validations were achieved by the experts both in the company and university. The sponsoring company, academic experts and industrial expert had provided enough comments to validate this model, and also shown some suggestions for improvement.

They thought this model was very rigorous. It could be understood very clearly and was mostly implementable. Objective four was achieved in this stage.

8.2.2 Development of Lean Customised Model

This model was developed based on the successful model example and the current situation of customer's company. The Chinese traditional thinking was different from lean think. Therefore, implementing lean in China faced some special barriers. The author made effort to resolve these problems through a customised lean model.

In the process of model development, the author found that successful lean implementation not only required correct application of Lean tools, but a need to understand lean thinking and set a lean implementation plan. These aspects in the period of developing the model need to be taken into account. At the same

time to combine with current situation is the best way to correct and successfully implement Lean.

8.3 Contribution

Lean is not a new technique. It had been studied for a long time. However, in China, most companies implemented lean through copying the example from United States, UK and Western countries without combining their current situation and culture. The contribution of this research is to develop a model combining Chinese barriers and company situation to implement lean. It breaks the barriers of lean implementation in China through customised lean model. For researchers, they can use the result of questionnaire and assessment tool as reference data. For industry, they can use the model to improve their situation.

8.4 Research Limitations

There are some limitations shown as following:

1) The model has not been implemented in the company. Because the lean implementation is a long term task, for a nine month research it was not possible to carry out a case study to prove and test the model.

2) The respondents answering the survey had different levels of understanding of the company situation. If more managers and directors were involved in the survey, the result will be more accurate and convincing.

3) Stage III of the model (Lean Tools implementation stage) lacks more details about how to apply these tools.

8.5 Future Work

Some future work had been highlighted in the validation chapter and discussion section. The following are the key contents for future work.

1) Identify more critical factors for successful Lean implementation in China by reviewing more literature about lean implementation of Chinese aerospace industry, and investigating lean performance and situation of other Chinese aerospace companies.

2) Carry out a case study to proof and test the model.

3) Add more details in the tools implementation stage. Develop some simple manual for each tool. This will help to the staff to apply them quickly.

4) Improve the model continuously. Accumulate the experience and knowledge to summarize the best practice for lean implementation.

8.6 Conclusions

This research has achieved the aim and objectives stated at the beginning of the thesis. After analyzing the results of previous work, this research makes the following conclusions:

1) There are barriers to lean implementation in China; for example, weak leadership, and low skill and education levels. These barriers should be considered to avoid repeating the same mistake.

2) The example Chinese aerospace company had a lot of problems in moving towards lean, including poor leadership and high waste. They need to implement lean to improve their current situation.

3) A proposed customised lean model addresses the barriers to lean implementation in China through linking barriers to the objectives in

becoming lean. It does this through leadership, training, survey, value stream mapping, implementation plan, lean tools in a sequence and kaizen.

4) Leadership is the most significant factor for lean implementation in the new Chinese aerospace company. They can provide adequate support for requirements. Also, they should understand the lean at first in order to start this process.

5) Training is a necessary step before applying lean tools. In addition, training is not a separate step, and many other aspects also need to link up in order to achieve continuous improvement.

6) Lean tool implementation plans are different for different manufacturing systems. It should be designed to make sure the aim can go the right way.

7) Lean is becoming more important for competing in China.

REFERENCES

1. Aase, G. R., Olson, J. R. & Schniederjans, M. J. (2003), "U-shaped assembly line layouts and their impact on labour productivity: an experimental study", European Journal of Operational Research, Vol. 156 No. 3, pp. 689-711.
2. Achanga, P., Shehab, E., Roy, R., & Nelder, G. (2006), “Critical success factors for lean implementation within SMEs”, Journal of Manufacturing Technology Management, Vol. 17, No. 4, pp. 460-471.
3. Agarwal, D., Sahu, S. & Ray, P. K. (2003), “Cell formation in cellular manufacturing: an AHP-based framework for evaluation of various techniques”, International Journal of Manufacturing technology Management, Vol. 5, No. 5-6, pp. 521-535.
4. Al-Najjar, B. & Alsyouf, I. (2003), “Selecting the most efficient maintenance approach using fuzzy multiple criteria decision-making”, International Journal of Production Economics, Vol. 84 No. 1, pp. 85-100.
5. Aminpour, S. & Woetzel, J. R. (2006), “Applying lean manufacturing in China”. McKinsey Quarterly, Vol. 2, No. 1, pp. 106.
6. Aoki, K. (2008), “Transferring japanese kaizen activities to overseas plants in China”, International Journal of Operations and Production Management, Vol. 28, No. 6, pp. 518-539.
7. Aulakh, S.S. & Gill, J.S. (2008), “Lean manufacturing- a practitioner’s perspective”, Industrial Engineering and Engineering Management, **Vol.** 23, No. 11, pp. 1349-1376.
8. Bayo-Moriones, A., Bello-Pintado, A. & Javier, M. (2010), “5S use in manufacturing plants: contextual factors and impact on operating performance”, International Journal of Quality & Reliability Management, Vol. 27, No. 2, pp. 217-230.
9. Betts, J. M. & Johnston, R. B. (2003), "Just-in-time component replenishment decisions for assemble-to-order manufacturing under capital constraints and stochastic demand", International Journal of Production Economics, Vol. 95 No. 1, pp. 51-70.

10. Bicheno, J. (2004), “The New Lean Toolbox: Towards Fast, Flexible Flow”, 3rd ed., PICSIE Books, Buckingham.
11. Bollbach, M. (2010), “Country-specific barriers to implementing lean production systems in China”, PhD thesis, Loughborough University.
12. Boughton, N. J. & Arokiam, I. C. (2000), "The application of cellular manufacturing: a regional small to-medium enterprise perspective", Proceedings of Institutional of Mechanical Engineers, Vol. 214, No. 8, pp. 751-754.
13. Boyer, K.K. (1996), “n assessment of managerial commitment to lean production”, International Journal of Operations & Production Management, Vol. 16, No. 9, pp. 48-59.
14. Brown, G. D. & Cih, D. O. R. (2008), “Lean manufacturing comes to china: A case study of its impact on workplace health and safety”, International Journal of Occupational and Environmental Health, Vol. 13, No. 3, pp249-257.
15. Carreira, B. (2005), “Lean manufacturing that works: powerful tools for dramatically reducing waste and maximizing profits”, American Management Association.
16. Chan, F. T. S, Lau, H. C. W, Ip, R. W. L, Chan, H. K. & Kong, S. (2005), “Implementation of total productive maintenance: a case study”, International Journal of Production Economics, Vol. 95, No. 1, pp. 71-94.
17. Chen, L. & Meng, B. (2010), “Research on the five-stage method for Chinese enterprises to implement lean production”, International Conference on Logistics Systems and Intelligent Management, Vol. 2, No. 3, pp. 1135-1138.
18. Chin, K. S. & Pun, K. F. (2002), “A proposed framework for implementing TQM in Chinese organizations”, International Journal of Quality and Reliability Management, Vol. 19, No. 3, pp. 272-294.
19. Comm, C. L. & Mathaisel, D. F. X. (2005), “An exploratory analysis in applying lean manufacturing to a labor-intensive industry in china”, Asia Pacific Journal of Marketing and Logistics, Vol. 17, No. 4, pp. 63-80.

20. Cook, C. R. & Graser, J. C. (2002), “The effects of lean manufacturing”, Rand Publishers, Santa Monica: CA
21. Crandall, R. & Coffey, B. (2005), “Sailing the seven C’s”, Industrial Engineer, Vol. 37, No. 8, pp. 35-39.
22. Creece, R. C. (2000), “Cost management in lean manufacturing enterprises”, AAAC International Transactions, West Virginia University, Morgan town: MW.
23. Crute, V., Ward, Y., Brown, S. & Graves, A. (2003), “Implementing lean in aerospace: Challenging the assumptions and under- standing the challenges”, Technovation, Vol. 23, No. 12, pp. 917-928.
24. de Treville, S. & Antonakis, J. (2006), “Could lean production job design be intrinsically motivating? Contextual, configurational, and levels-of-analysis issues”, Journal of Operations Management, Vol. 24, No. 2, pp. 99-123.
25. Dennis, P. (2002), “Lean Production Simplified: A Plain Language Guide to the World’s Most Powerful Production System”, Productivity Press, New York, NY.
26. Domingo, R., Alvarez, R., Pena, M. M. and Calvo, R. (2007), “Materials flow improvement in a lean assembly line: a case study”, Assembly Automation, Vol. 27 No. 2, pp. 141-147.
27. Doolen, T.L. & Hacker, M.E. (2005), “A review of Lean Assessment in Organizations: An Exploratory Study of Lean Practices by Electronics Manufacturers,” Journal of Manufacturing System, Vol. 24, No. 1, pp. 55-67.
28. Dossenbach, T. (2006). “Think Visual”, Wood and Wood Products, Vol. 111, No. 1, pp. 25-30.
29. Fawaz, A. & Abdulmalek, J. R. (2007), “Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study”, International Journal of Production Economics, Vol. 107, No. 1, pp. 223-236.
30. Feld, W.M. (2001), “Lean Manufacturing: Tools, Techniques, and How to Use Them”, St Lucie Press, Boca Raton, FL.

31. Gray, C. (2001), “Role of management in a lean manufacturing environment; in: Learning to think lean”, SAE International, http://www.sae.org/manufacturing/lean/column/leanjul01.htm
32. Grunberg, T. (2004), “Performance improvement towards a method for finding and prioritising potential performance improvement areas in manufacturing operations”, International Journal of Productivity and Performance Management, Vol. 53, No. 1, pp. 52–71.
33. Gunasekaran, A., Marri, H.B., McGaughey, R. & Grieve, R.J. (2001), “Implications of organization and human behaviour on the implementation of CIM in SMEs: an empirical analysis”, International Journal of Computer Integrated Manufacturing, Vol. 14, No. 2, pp. 175-85.
34. Herderson, B.A. & Larco, J.L. (2000), “Lean transformation – How to change your business into a lean enterprise”, first edition, The Oaklea Press, Richmond, Virginia, USA.
35. Hemamlini, B. & Rajendran, C. (2000), “Determination of the number of containers, production kanbans and withdrawal kanbans; and scheduling in kanban flowshops”, International Journal of Production Research, Vol. 38, No. 11, pp. 2529-2548.
36. Hines, P., Found, P. & Harrison, R. (2008), “Staying Lean: Thriving, Not Just Surviving”, Lean Enterprise Research Centre, Cardiff University, Cardiff.
37. Hines, P., Holweg, M. & Rich, N. (2004), “Learning to eVolve: a review of contemporary lean thinking”, International Journal of Operations & Production Management, Vol. 24, No. 10, pp. 994-1011.
38. Hopp, W.J. & Spearman, M.L. (2004), “To pull or not to pull: What is the question?”, Manufacturing & Service Operations Management, Vol. 6, No. 2, pp. 133-148.
39. Houshmand, M. & Jamshidnezhad, B. (2006), “An extended model of design process of lean production systems by means of process variables”, Robotics and Computer-Integrated Manufacturing, Vol. 22, No. 1, pp. 1-16.
40. Imai, M. (1997), “Gemba kaizen”, McGraw-Hill Education, New York.

41. John P.T. Mo, (2009), “The role of lean in the application of information technology to manufacturing”, Computers in Industry, Vol. 60, No. 4, pp. 266-276.
42. Kilpatrick, J. (2003). “Lean principles”, Utah Manufacturing Extension Partnership, http://www.mep.org/textfiles/LeanPrinciples.pdf
43. Klein, J. (2004). “True Change”, San Francisco: Jossey-Bass.
44. Lean Advancement Initiative, (2010), “About LAI”, http://lean.mit.edu/about/about-lai
45. Lee, C. Y. (2004), “TQM in small manufacturers: An exploratory study in China”, International Journal of Quality and Reliability Management, Vol. 21, No. 2, pp. 175-197.
46. Lee, Q. (2004), “Lean manufacturing strategy”, Strategy, available at: www.strategosinc.com/
47. Leitner, P. (2005). “The lean journey at the Boeing Company”, ASQ World Conference on Quality and Improvement proceedings, Vol. 59, No. 1, pp. 263-271.
48. Lewis, J. (2000), “It's not easy being ‘Lean’”, Upholstery Design & Management, Vol. 13, No. 9, pp. 30.
49. Liker, J.K. (2004). “The Toyota way: 14management principles from the world’s greatest manufacturer”, New York: McGraw-Hill.
50. Liker, J. K. & Meier, D. (2006), “The Toyota way field book: A practical guide for implementing Toyota’s 4Ps”, New York: McGraw-Hill.
51. McCarron, B. (2006), “Introduction to ‘Lean Thinking’”, CIPFA.
52. McDowall, A. & Mabey, C. (2008), ‘‘Developing a framework for assessing effective development activities’’, Personnel Review, Vol. 37, No. 6, pp. 629.
53. Melton, T. (2005), “The Benefits of Lean Manufacturing: What Lean Thinking has to Offer the Process Industries”, Chemical Engineering Research and Design, Vol. 83, No. 6, pp. 662–673.
54. Michael, L. (2005), “Lean manufacturing beckons low-Volume operations”. Canadian Plastics, Vol. 63, No. 2, pp. 13.
55. Moxham C. & Greatbanks R. (2001), “Prerequisites for the implementation of the SMED methodology: A study in a textile processing environment”,

International Journal of Quality& Reliability Management Vol.18, No. 1, pp. 404-414

56. Narasimhan, R., Swink, M. & Kim, S. W. (2006). “Disentangling leanness and agility: An empirical investigation”, Journal of Operations Management, Vol. 24, No. 5, pp. 440-457.
57. Neese, M. (2007). “Driving Lean Through the Visual Factory”, Circuits Assembly, Vol. 18, No. 9, pp. 56-57.
58. Nicholas J.M. (1998), “Competitive Manufacturing Management: Continues Improvement”, Lean Production, Customer Focused Quality, McGraw-Hill, New York, NY
59. Ohno, T. (1993), “Toyota Production System”, Productivity Press.
60. Oliver, N., Delbridge, R., & Lowe, J. (1998), “Inside the Chinese automotive industry: The third lean enterprise report”, Andersen Consulting, London.
61. Panizzolo R. (2006), “Applying the lessons learned from 27 lean manufacturers. The relevance of relationships management.” International Journal of Production Economics, Vol. 55, No. 1, pp. 223-240.
62. Paolini, A., Leu, B. & Chinn, R. (2005), “Exporting lean to china: Know before you go”, PRTM Insight, Vol. 17, No. 2, pp. 133-139.
63. Pavnascar, S.J., Gershenson, J.K. & Jambekar, A.B. (2003), “Classification scheme for lean manufacturing tools”, International Journal of Production Research, Vol. 41, No. 13, pp. 3075–3090.
64. Pettersen, J. (2009), “Defining lean production: some conceptual and practical issues”, The TQM Journal, Vol. 21, No. 2, pp. 127-142.
65. Price, J. (1994), “Lean production at Suzuki and Toyota: a historical perspective”, Studies in Political Economy, Vol. 45, No. 1, pp. 66-99.
66. Radnor, Z. (2010), “Transferring Lean into government”, Journal of Manufacturing Technology Management, Vol. 21 No. 3, pp. 411-428.
67. Radnor, Z. (2009), “Lean in public services: is it a panacea or paradox?”, Public Executive Journal, Vol. 24, No. 5, pp. 13-20.
68. Rao, P. P. & Mohanty, R. P. (2003), “Impact of cellular manufacturing on supply chain management: exploration of interrelationships between design

issues", International Journal of Manufacturing Technology Management, Vol. 5, No. 6, pp. 507-520.

69. Rivera, L. & Chen, F. F. (2007), "Measuring the impact of Lean tools on the cost–time investment of a product using cost–time profiles", Robotics and Computer-Integrated Manufacturing, Vol. 23, No. 6, pp. 684-689.
70. Ronald, S. J. (2003), "Applying the Lessons of 'Lean Now' To Transform the US Aerospace Enterprise", Research of Massachusetts Institute of Technology.
71. Rother, M. & Shook, J. (1999), "Learning to See: Value Stream Mapping to Add Value and Eliminate Muda", Lean Enterprise Institute, Incorporated.
72. Scherrer-Rathje M., Boyle, T.A. & Deflorin P. (2009), "Lean, take two! Reflections from the second attempt at lean implementation", Business Horizons, Vol. 52, No. 1, pp. 79-88.
73. Shah, R. & Ward, P. T. (2003), "Lean manufacturing: Context, practice bundles, and performance", Journal of Operations Management, Vol. 21, No. 2, pp. 129-149.
74. Shah, R. & Ward, P.T. (2007), "Defining and developing measures of lean production", Journal of Operations Management, Vol. 25, No. 4, pp. 785-805.
75. Sim, K.L. & Rogers, J.W. (2009), "Implementing lean production systems: barriers to change", Management Research News, Vol. 32, No. 1, pp. 37-49.
76. Singh, B & Sharma, S.K. (2009), "Value stream mapping as a versatile tool for lean implementation: an Indian case study of a manufacturing firm", measuring business excellence, Vol. 13, No. 3, pp. 58-68.
77. Sohal A.S. & Egglestone A. (2004), "Lean Production: Experience among Australian Organizations," International Journal of Operations & Production Management, Vol.14, No.11, pp. 35-51.
78. Spear, S. J. (1999), "The Toyota Production System: An Example of Managing Complex Social/Teaching Systems", Harvard Business School.
79. Sullivan, W. G., McDonald, T. N. & van Aken, E. M. (2003), "Equipment replacement decisions and lean manufacturing", Robotics and Computer Integrated Manufacturing, Vol. 18, No. 3, pp. 255-265.

80. Swanson, L. (2001), “Linking maintenance strategies to performance”, International Journal of Production Economics, Vol. 70, No. 3, pp. 237-244.
81. Taj, S. (2005), “Applying lean assessment tools in Chinese hi-tech industries”, Management Decision, Vol. 43, No. 4, pp. 628-643.
82. Taj, S. (2008), “Lean manufacturing performance in China: assessment of 65 manufacturing plants,” Journal of Manufacturing Technology Management, Vol. 19, No. 2, pp. 217-234.
83. Tyson, R. B. & Ralph D. H. (2009), “Reconceptualizing the effects of lean on production costs with evidence from the F-22 program”, Journal of Operations Management, Vol. 27, No. 1, pp. 23-44.
84. University of Bath, (2010), “UKLAI”, http://www.bath.ac.uk/management/aerospace/uklai/
85. Wan, H. & Chen F.F. (2009), “Decision support for lean practitioners: A web-based adaptive assessment approach”, Computers in Industry, Vol. 60, No. 4, pp. 277-283
86. Warwood, S.F. (2004), “An Investigation into Japanese 5S Practice in UK Industry”, The TQM Magazine, Vol.16, No. 5, pp.347 – 353.
87. White, R. E & Pearson, J. N. (1994), "Just-in-time purchasing activities in the beverages bottling industry", *Industrial* Management, Vol. 36, No. 3, pp. 27-32.
88. White, R. E. & Prybutok, V. (2001), “The relationship between JIT practices and type of production system”. Omega, Vol. 29, No. 2, pp. 113.
89. Womack, J.P. & Jones, D.T. (2003), “Lean Thinking: Banish Waste and Create Wealth in Your Corporation”, Free Press, New York, NY.
90. Womack, J.P. Jones, D.T. & Roos, D. (1990), “The Machine That Changed the World”, New York: Harper Collins.

BIBLIOGRAPHY

1. Alukal, G. (2003), “Create a lean, mean machine”, Quality Progress, Vol. 36, No. 4, pp. 29-34.
2. Andrew B, Jr. (2000), “Learning to think lean: Delphi lean engineering initiatives”, Automotive Manufacturing & Production, Vol. 112, No. 5, pp.76-77.
3. Anixter, (2009), “CASE STUDY: Aerospace Manufacturer Achieves Lean Production Goals”, Anixter Inc, http://www.anixter.co.uk/AXECOM/AXEDocLib.nsf/%28UnID%29/129824A546EE9109862575D10055230B/$file/9S0005X0_3PL_Case_Study.pdf
4. Brown, C. B., Collins, T. R. & McCombs, E. L. (2006), “Transforming from batch to lean manufacturing: The performance issues”, Engineering Management Journal, Vol. 18, No. 2, pp. 3-13.
5. Hallam, C. R. A. (2003), “Lean Enterprise Self-Assessment as a Leading Indicator for Accelerating Transformation in the Aerospace Industry”. MIT Thesis.
6. Hines, P. & Rich, N. (1997), "The seven value stream mapping tools", Integrated Journal of Operations and Production Management, Vol. 17, No. 1, pp. 46-64.
7. Mukhopadhyay, S.K. and Shanker, S. (2005), “Kanban implementation at a tyre manufacturing plant: a case study”, Production Planning & Control, Vol. 16 No. 5, pp. 488-99
8. Nash, M. & Poling, S. (2007). “Quality management: Strategic management of lean”. Quality, Vol. 46, No. 4, pp. 46—49.
9. Radnor, Z. & Walley, P. (2008), “Learning to walk before we try to run: adapting Lean for the public sector”, Public Money & Management, Vol. 28, No. 1, pp. 13-20.
10. Samuel K.M. Ho, (2010), “Integrated lean TQM model for global sustainability and competitiveness”, The TQM Journal, Vol. 22, No. 2, pp. 143-158.

11. SaVolainen, T. (2000), “Leadership strategies for gaining business excellence through total quality management: a Finnish case study”, Total Quality Management, Vol. 11, No. 2, pp. 211-216.
12. Shingo, S. (1984), “A Study of the Toyota Production System from an Industrial Engineering Viewpoint”, Productivity Press, Tokyo.
13. Tsang, A.H.C. & Chan, P.K. (2000), “TPM implementation in China: a case study”, International Journal of Quality & Reliability Management, Vol. 17, No. 2, pp. 144-57.

APPENDICES

Appendix A Questionnaire

Cranfield UNIVERSITY

COMAC

Lean Thinking in COMAC Questionnaire

If there are any questions about this questionnaire please contact Chao Li at: Lee.li@cranfield.ac.uk or Dr Paul Baguley at: p.baguley@cranfield.ac.uk

Please fill in the questionnaire and return electronically to: Lee.li@cranfield.ac.uk

Or if you have no e-mail, to:

Paul Baguley, Building 50, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, United Kingdom.

This questionnaire is anonymous. The data is to be used as part of an MSc Research project at Cranfield University entitled "Implementing lean manufacturing in the Chinese aerospace industry". The student is Chao Lee who is also an employee of COMAC. Chao is spending a year at Cranfield University to learn about lean and then pass on his knowledge.

You will receive a report on the results of this questionnaire.

Background

The Chinese aerospace industry is implementing lean manufacturing as part of its move to be more competitive in a global marketplace. As part of this move COMAC aims to improve its understanding of lean thinking. This MSc project will provide state of the art knowledge in lean thinking and how this affects COMAC.

Aim of the Questionnaire

This questionnaire is used to collect information on how lean methods are currently being used in the company. It also aims to collect information about what the current problems are in your area of the company. The information you give will form the basis for providing recommendations for the implementation of lean tools in your work. Hence the questionnaire will form the basis for lean improvements within the company.

Objectives of the Questionnaire

1. Determine what is the current use of lean tools and methods
2. Identify what the current problems are in the company and whether lean tools can help
3. What are the important factors in the company and how lean methods and tools can help
4. Collect the requirement for the use of new lean tools and methods
5. To be able to provide recommendations on becoming lean

Respondent's details

Department:

Role and Position:

Description of Responsibilities:

E-mail:

Telephone:

Cranfield UNIVERSITY

COMAC

1. Do you do the housekeeping on your shop floor and/or the office?

○ Always ○ Mostly ○ Half ○ Rarely ○ Never ○ Not sure

Please comment on housekeeping:

2. How often do you have team meeting?

○ Every day ○ Twice a week ○ Every week ○ More than a week ○ Never

Please comment on team meetings:

3. Is there a picture mapping the material and information flow?

○ Yes ○ No ○ Not sure

Please comment on value stream:

4. Is there a measure to fix machine sudden breakdown?

○ Yes ○ No ○ Not sure

Please comment on quick maintenance:

5. Is there visual display to present information or control the act?

○ Yes ○ No ○ Not sure

Please comment on visual factory:

6. How quickly and efficiently change from one product to another?

○ Very ○ Normal ○ Slow ○ Not sure

Please comment on flow:

7. Is there a Standardised manner to ensure that each job is organized?

○ Yes ○ No ○ Not sure

Please comment on standardization work:

8. How do you think produce product more than customer demand.

○ Very good ○ Good ○ Half ○ Bad ○ Very bad ○ Not sure

Please comment on pull system:

9. Is there a system that creates product that is then sold after it is produced?

○ Yes ○ No ○ Not sure

10. Is there a mechanism to prevent a mistake or make a mistake obvious at a glance?

○ Yes ○ No ○ Not sure

11. Do you think transportation is quick and safe in your company?

○ Very ○ Most ○ Half ○ Rare ○ Not sure

12. Is there some actions during working not create value?

○ Very ○ Most ○ Half ○ Rare ○ Never ○ Not sure

Cranfield UNIVERSITY

COMAC

13. Do you think all the process is necessary to produce a product?

○ All ○ Most ○ Half ○ Rare ○ Not sure

14. Are there many defects during producing?

○ Very ○ Most ○ Half ○ Rare ○ Never ○ Not sure

15. Do you spend time to wait people or machine?

○ Always ○ Most ○ Half ○ Rare ○ Never ○ Not sure

16. Do you think employees have opportunities involved in finding solutions and improved process?

○ Always ○ Most ○ Half ○ Rare ○ Never ○ Not sure

17. Is there any other waste that has not been covered above that you wish to tell me about?

18. Please list the significance of factors in your company in becoming lean. If you do not know what lean is please say and list the significance of these factors in your company. Write number 1 to 8 in the blank. 1 is most, 8 is least. If you have other ideas, please add.

Cost reduction	
Lead time reduction	
Workforce reduction	
Customer satisfaction improvement	
Flexibility improvement	
Quality improvement	
Increase staff motivation	
Increase staff contribution to decision making	
Others A:	
Others B:	

These questions are open questions and are designed so that we can obtain as much information as possible about what you and your department does.

19. Describe your current tasks in as much detail as possible?

20. Describe and/or draw a diagram of the process you are involved in.

21. What are the main problems you encounter?

22. How much volume of product comes through your work area?

23. How repetitive is the work you do? Are all products the same?

24. What is driving your company towards becoming "Lean"?

25. What will be the barriers to becoming Lean and/or realising success?

26. Before you fill in the next question, you should read the following short description of Lean Tools first. It will help you to finish next table.

5s(or 6s): It offers a basic housekeeping discipline for the shop floor and the office.

VSM: Value stream mapping, or material and information flow, should play a very productive role in the entire Lean process since practitioners depict current and future conditions when they develop plans to install Lean systems. Infinite attention should be given to establishing flow, eliminating waste, and adding value.

Visual Factory: It can address both visual display and control. Visual displays present information, while visual control focuses on a need to act. It can highlight problems.

TPM: Total productive maintenance is an important tool to account for sudden machine breakdown.

QCO: Quick Change Over (SMED: single minute exchange of dies) referred to as Setup Reduction, eliminates or reduces non-value added activities in the setup and teardown processes of manufacturing, allowing companies to quickly and efficiently change from one product to another.

Standardised Work: It basically ensures that each job is organized and is carried out in the most effective manner.

JIT: Just in time is a pull system where a customer initiates the demand, and then the demand is transmitted backward from the final assembly all the way to raw material.

Takt Time: It refers to how often a part should be produced in a product family based on the actual customer demand.

Kanban: It is a system that creates product that is then sold after it is produced is called a push system.

One Piece Flow: It describes the sequence of product or of transactional activities through a process one unit at a time. It can reduce customer order to shipment times

Poka Yoke (Error Proofing): A poka-yoke is a mechanism that works with autonomation to either prevent a mistake or make a mistake obvious at a glance. It can detect and correct the defects.

Kaizen: It is a continuous improvement process that empowers people to use their creativity, Kaizen can be used to fix specific problems, workflow issues, or a particular aspect of a business.

Questions / Tools	Do you use these tools before?	If yes, how successful of this tool in reaching the goals.	If no, do you think this tool will bring benefits within your company?	Do you want to be trained for this tool?	Please write some general comments about these tools here.
5s(or 6s)					
VSM					
Visual Factory					
TPM					
QCO					
Standardised Work					
JIT					
Takt Time					
Kanban					
One Piece Flow					
Poka Yoke					
Kaizen					
Others:					

Appendix B Assessment Tool

1.0	Inventory	Response	X
1.1	For the categories of Finished Goods, Work-In-Process (WIP) and Purchased/Raw Materials, what portion of middle and upper managers can state from memory the current turnover and the purpose of each type?	0%-6%	
		7%-55%	
		56%-80%	
		81%-93%	
		94%-100%	
1.2	What is the overall inventory turnover, including Finished Goods, WIP and Purchased/Raw material?	0-3	
		4-6	
		7-12	
		13-24	
		25+	
1.3	What is the ratio of Inventory Turnover to the industry average?	<=1.0	
		1.1-2.0	
		2.1-4.0	
		4.1-8.0	
		8.1+	

2.0	The Team Approach	Response	X
2.1	What is the organization type?	Exploitive	
		Bureaucratic	
		Consultive	
		Participative	
		Highly Participative	
2.2	How are workers on the factory floor compensated?	Individual Incentive	
		Hourly Wage	
		Group Incentive	
		Salary	
		Salary+Annual Bonus	
2.3	To what extent do people have job security?	Layoffs Every Year	
		Transfers & Retraining Reduce Layoffs	
		Layoffs Are Rare	
2.4	What is the annual personnel turnover	31%+	
		14%-30%	
		7%-11%	
		3%-6%	
		0%-2%	
2.5	What percentage of personnel (ALL Personnel) have received at least eight hours of teambuilding training?	<5%	
		6%-10%	
		11%-30%	
		31%-90%	
		91%-100%	
2.6	What percentage of personnel are active members of formal work teams, quality teams, or problem-solving teams?	<5%	
		6%-10%	
		11%-30%	

3.0	Processes	Response	X
3.1	How many large-scale machines or single-process areas are in the plant through which 50% or more of different products must pass?	4+	
		3	
		2	
		1	
		0	
3.2	How would you rate the overall bias of the plant's process selection with respect to scale?	Large Scale	
		Medium/Mixed	
		Small Scale	
3.3	How easy is it to shift output when the product mix changes?	Very Difficult	
		Moderately Difficult	
		Easy	
3.4	How easy is it to alter the total production rate by +/-15%?	Very Difficult	
		Moderately Difficult	
		Easy	
3.5	What is management's target operating capacity for individual departments or machines?	96%-100%	
		91%-95%	
		86%-90%	
		76%-85%	
		50%-75%	
3.6	How would you rate the overall bias of the plant's process selection with respect to technology level?	Complex Technologies	
		Moderate/Mixed	
		Simple Technologies	

4.0	Maintenance	Response	X
4.1	Describe equipment records and data. Include records of uptime, repair history, and spare parts. Include repair and parts manuals.	Non-Existent	
		Substantially Complete	
		Complete & Accurate	
4.2	Excluding new installations and construction projects, what percentage of maintenance hours is unplanned, unexpected, or emergency?	71%-90%	
		51%-70%	
		26%-50%	
		11%-25%	
		0%-10%	
4.3	Does maintenance have and follow a defined preventive schedule?	No PM	
		1%-10% Coverage	
		11%-30% Coverage	
		31%-90% Coverage	
		91%+ Coverage	
4.4	Do equipment breakdowns limit or interrupt production?	Frequently	
		Occasionally	
		Rarely	
4.5	What is the overall average availability of plant equipment?	Unknown	

5.0	Layout & Handling	Response	X
5.1	What portion of total space is used for storage and material handling?	71%-100%	
		46%70%	
		30%-45%	
		16%-30%	
		0%-15%	
5.2	What portion of the plant space is organized by function or process type?	71%-100%	
		46%70%	
		30%-45%	
		16%-30%	
		0%-15%	
5.3	How would you characterize material movement?	Pallet-size (or larger) loads, long distances (>100'),complex flow patterns, confusion, & lost material	
		Mostly tote-size loads, bus-route transport, & intermediate distances	
		Tote-size or smaller loads, short distances (<25'), simple & direct flow pattern	
5.4	How would you rate overall housekeeping and appearance of the plant?	Messy, Filthy, Confused	
		Some dirt, Occasional Mess	
		Spotless , Neat, & Tidy	
5.5	How well could a stranger walking through your plant identify the processes and their sequence?	Impossible to see any logic or flow sequence.	
		Most processes are apparent with some study. Most sequences are visible.	
		Processes and their sequences are immediately visible.	

6.0	Suppliers	Response	X
6.1	What is the average number of suppliers for each raw material or purchased item?	2.5+	
		1.6-2.4	
		1.3-1.7	
		1.2-1.4	
		1.0-1.1	
6.2	On average, how often, in months, are items put up for re-sourcing?	1-11	
		12-17	
		18-23	
		24-36	
		36+	
6.3	What portion of raw material & purchased parts comes from qualified suppliers with no need for incoming inspection?	0%	
		1%-10%	
		11%-30%	
		31%-70%	
		70%-100%	
6.4	What portion of raw material and purchased items is delivered directly to the point of use without incoming inspection or storage?	0%	
		1%-10%	
		11%-30%	
		31%-70%	
		70%-100%	
6.5	What portion of raw materials and purchased parts is delivered more than once per week?	0%	
		1%-10%	
		11%-30%	
		31%-70%	
		70%-100%	

7.0	Setups	Response	X
7.1	What is the average overall setup time (in minutes) for major equipment?	61+	
		29-60	
		16-30	
		10-15	
		0-9	
7.2	What portion of machine operators have had formal training in Rapid Setup techniques?	0%	
		1%-6%	
		7%-18%	
		19%-42%	
		43%-100%	
7.3	To what extent are managers and workers measured and judged on setup performance?	Not at All	
		Informal Tracking & Review	

8.0	Quality	Response	X
8.1	What portion of total employees have had basic SPC training?	0%-6%	
		7%-55%	
		56%-80%	
		81%-93%	
		94%-100%	
8.2	What portion of operations are controlled with Statistical Process Control (SPC)	0%	
		1%-10%	
		11%-30%	
		31%-70%	
		71%-100%	
8.3	What portion of the SPC that is done is accomplished by operators as opposed to Quality or Engineering specialists?	0%	
		1%-10%	
		11%-30%	
		31%-70%	
		71%-100%	
8.4	What is the overall defect rate?	0%	
		1%-10%	
		11%-30%	
		31%-70%	
		71%-100%	

9.0	Scheduling/Control	Response	X
9.1	What portion of work-in-process flows directly from one operation to the next without intermediate storage?	0%	
		1%-10%	
		11%-35%	
		36%-85%	
		86%-100%	
9.2	What portion of work-in-process is under Kanban or Broadcast control	0%	
		1%-10%	
		11%-35%	
		36%-85%	
		86%-100%	
9.3	What is the on-time delivery performance?	0%-50%	
		51%-70%	
		71%-80%	
		81%-95%	
		95%-100%	

Appendix C Comment for customised Lean model

Firstly, it's what we need at this stage. There is a good start from leadership. The current situation is that most of us know less about lean. Hence, the training for the all staff is also necessary. But, there is a question in here. You said that the training must be taught by expert. What expert can do this task? The manager who will be sent to accept training in our company or some people retained by us, it should be expressed clearly.

Secondly, the questionnaire and assessment tool are very useful method to identify the current situation for our company. They are easily to use for collection of information. And if possibly, you can modify these tools when you come back in order to make them suitable for more departments. Such as the IT, archives…

Next, the VSM is a significant tool for becoming lean. However, we rarely applied it before. We think it is an optimum opportunity to let us use VSM when this model is implemented. And the others tools in the implementation stage should be important also, nevertheless we cannot give enough constructive advice about them. Maybe you can get more useful feedback from university.

Finally, we were doing the continuous improvement persistently. But there was not enough positive effect. Hence, we should change concept just like you said. The all staff involve in the continuous improvement project is better than manager only. We can also rewards who propose good idea. That will bring stronger the motivation to involve in. A short conclusion of us:

(1) The right start from leadership; (2) A good idea for training staff to learn lean before they apply it; (3) Applying lean tools in sequence to avoid chaos; (4) Cycle the whole model by continuous improvement.

By Director Wang, Director Li, Director Xu