

CRANFIELD UNIVERSITY

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**LEAN MANUFACTURING STRATEGY FOR THE IMPLEMENTATION IN
MANUFACTURING ENTERPRISES IN DEVELOPING COUNTRIES**

SCHOOL OF AEROSPACE, TRANSPORT AND MANUFACTURING

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ABSTRACT

Manufacturing organisations all over the world are constantly seeking continuous improvement initiatives to enhance performance and meet customer requirements. In this regard, many manufacturing initiatives have been introduced, one of the most successful and famous process improvement initiatives is Lean Manufacturing based on Toyota Production System (TPS). Lean manufacturing has internationally been proven as an effective approach for reducing many types of waste and creating value for customers. Although many organisations have realised the benefits of lean, many attempts have not been successful to adopt it effectively. Lean manufacturing can lead to improve an organisation's performance, yet implementation's challenges do exist. Implementing lean in a systematic way is not a simple job and becomes difficult to sustain. While some organisations stumble through with trial and error to achieve a level of leanness, others rely on repeated Kaizen (continuous improvement).

The aim of this study was to develop a customised strategy to introduce lean to manufacturing enterprises in developing countries. The developed lean manufacturing transformation strategy (LMTS) encompasses all lean human and technical-related critical success factors. Several research methods have been employed in this research. It included structured questionnaire, semi-structured interviews, and plant observations conducted within three companies in the automotive sector in Libya. The Libyan automotive industry has been used in this research as a representation of the situation in the manufacturing enterprises in similar developing countries.

The findings of this study indicated that the managerial and operational practices within Libyan companies are not supportive toward adopting lean manufacturing successfully. Libyan companies lack the infrastructure for lean and their readiness level is comparatively low. The proposed LMTS is aimed to assist organisations in developing countries view lean strategically as a management philosophy rather than as a set of tools and thus guides those organisations toward the initiative's successful adoption. The LMTS will work as a guide for manufacturing organisations in Libya and other

relevant developing countries as they proceed toward high impact adoption of lean manufacturing practices.

Keywords: Lean Manufacturing, Developed Countries, Developing Countries, Critical Success Factors (CSF), Leanness, Measurement, Strategy

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Finally, I would like to dedicate this thesis to my brother's soul. Dear Zargoon (Abu Musab); may your soul rest in peace.

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Chapter 1 Introduction

1.1 Lean Historical Background

The term lean was first coined by Krafcik (1988) and was popularised in *The Machine that Changed the World* (Womack *et al.*, 1990) by the researchers of International Motor Vehicle Programme (IMVP) which was pivoted from the Massachusetts Institute of Technology Boston, Massachusetts. IMVP researchers have meticulously studied the significant performance gap between Western and Japanese automotive industries. According to Womack *et al.* (1990), lean manufacturing uses less of everything compared to mass production - half the human effort in the factory, half the manufacturing space, half the investment in tools and half the engineering hours to develop a new product in half the time. Lean manufacturing is a production philosophy, a fundamentally different way of thinking about manufacturing. It is a different way of conceptualising the entire production stream from raw material to finished goods and from product design to customer service. It is a philosophy of manufacturing that seeks to minimise unnecessary time, materials, and effort in the production process (Standard and Davis, 1999). From this definition, it can be understood that lean manufacturing has both strategic and operational dimensions (Hines *et al.*, 2011). In addition, lean can be seen as having both a philosophical as well as a practical orientation (Shah and Ward, 2003). According to Billesbach (1994), the interest on lean manufacturing is generally based on the empirical evidence that it improves the company's competitiveness. The primary aim to introduce any lean manufacturing programme is to increase productivity, reduce lead times and costs, improve quality, utilize less floor space, reduce human effort, require smaller investment in capital equipment and tooling, minimise the engineering time required to develop a new product, etc. (Sriparavastu and Gupta, 1997). At present, the lean manufacturing is widely used by different manufacturing companies worldwide. Principles of lean are universal as they are broadly accepted by many manufacturing operations and have been applied successfully across many disciplines. It has become an integrated system composed of highly inter-related elements and a wide variety of

management practices including Just-in-time, quality system, collaboration in teams, cellular manufacturing, etc (Womack and Jones, 1996).

Despite this acceptance, there are very little evidences of successfully lean manufacturing applications in the developing countries which is the interest of this PhD research.

1.2 Rationale of This Research

Libyan economy used to be closed and protected by the government interventions. After the recent market liberalisation, emerging economies, such as the case in Libya and similar developing countries need to cope with the intensive competition from international organisations operating overseas. Changing from traditional economy pattern to a demand-driven market, has brought those countries' attention to the importance of enhancing quality, and improving manufacturing systems to be more efficient to play an important role in enhancing the national economy overall. However, the Libyan manufacturing organisations face challenges in introducing effective quality management initiatives (Youssef, 2006). This seems to be a widespread issue in the Arab world countries (developing countries) as it has been highlighted by Alhaqbani (2013). This might be attributed to the fact that some Arab oil & gas-based economies heavily base their efforts and supports towards this sector, neglecting other sectors such as manufacturing and operations management.

Libyan manufacturing organisations need to find a path to improve productivity and their general performance in order to positively contribute to the country's economy growth and cope with the intensively market change. Embracing quality building and continuous improvement initiatives such as lean manufacturing could be a good option to restructuring and enhancing the role of the manufacturing sector in Libya which will have a positive impact on the overall economy in the country. Lean manufacturing has been proven as an effective approach by which organisations have reported benefits in terms of increasing productivity and enhancing customer value (Timans *et al.* 2012).

Although lean manufacturing has been adopted worldwide and becoming a popular approach to enhance productivity, Libyan manufacturing companies are still not certain of the cost of its implementation and the likely tangible benefits they may achieve from. By successfully adopting lean manufacturing principles and practices, an organisation becomes more able to trim the wastes from its operations and increases its productivity. In fact, lean has been widely accepted as the most reliable approach for manufacturing companies all over the world (Forrester *et al.* 2010). Nevertheless, very few studies have addressed lean manufacturing in Libya.

For instance, Hokoma (*et al.*, 2010) have assessed the status of using just-in-time technique in a manufacturing company in the country. Although just-in-time is an important component of lean, it is not suffice to represent the entire concept. Also, that study (Hokoma *et al.*, 2010) was not pure-lean oriented as it has also investigated other management initiatives such as total quality management, and MRPII. Hokoma, (2007) has showed that the vast majority of Libyan manufacturing sectors are not familiar with the concept of lean manufacturing and its implementation. The same author has advised researchers to conduct further investigations to help Libyan manufacturing sectors to practice lean and its associated tools and techniques.

Tourki, (2010) partially addressed lean manufacturing in Libya. However, this study was meant to empirically investigate the adaptation of lean to cement industry at the operational level by developing a simulation model. Tourki, (2010) was merely focused on certain internal lean practices (shop floor tools). Other lean strategic and external practices (e.g. supplier and customer relationships) have been ignored in Tourki, (2010).

By contrast, a huge number of studies have investigated lean manufacturing transformation in a broad list of industrialised developed countries, and many of cases studies have been reported (Achanga *et al.* 2006; Bakås *et al.* 2011; Czapke *et al.*, 2008 Crute *et al.* 2003; Hofer *et al.* 2011; Timans *et al.* 2012). This research is meant to fill this gap in the existing literature by exploring the current practices in a selected sample of Libyan manufacturing companies; more specifically the automotive sector in Libya will be the target of this study. It might be important to mention that the Libyan

automotive industry has been used in this study as a representative of the situation in the manufacturing enterprises in similar developing countries.

Implementing lean manufacturing in a systematic way is not a simple job and becomes difficult to sustain. While some organisations stumble through with trial and error to achieve a level of leanness, others rely on repeated *Kaizen* (continuous improvement) activities. However, not all organisations can afford sufficient financial resources and dedicate enough time to practice trial and error (Saurin, *et al.*, 2011; Singh *et al.*, 2010a). Also, sustaining the achieved gains on long term basis is one of the challenges companies are facing in implementing lean manufacturing effectively. It is quite usual that the achieved short term improvements would eventually be degraded due to the improper adoption of lean. Therefore companies tend to gradually lose impulse and over time regress to pre-lean conditions once the Kaizen activities are over. That is not surprising as the methodology and culture of lean have not been instilled into the companies' day-to day activities.

Although lean manufacturing can lead to improve an organisation's performance, challenges do exist. In many cases, implementing lean successfully can be seen as a difficult task to carry out. There are many studies that have reported lean implementation failures due to several reasons (Browning and Heath, 2009; Emiliani, 2006, Tiwari *et al.*, 2007). Attributing it to different grounds, financial; technological; and / or sociocultural, companies may fail in their attempts to transform towards lean manufacturing (Stone, 2012; Nordin *et al.*, 2010; Herron and Braiden, 2007).

Building on the above facts, the need is arising for a comprehensive transformation strategy to function as a directive tool guiding companies towards becoming successful lean manufacturing implementers. Therefore, there is a need for conducting a research project to develop a lean manufacturing strategy proper for developing countries such as Libya, which is the main goal of this research.

This study is not justifying the values of lean best practices such as improving quality, enhancing performance, minimising resources, and reducing costs. Instead, this study is an attempt to understand certain contextual conditions under which lean best

practices are effective in enhancing manufacturing productivity in a developing country such as Libya.

The main outcome of this research project is hoped to help organisations to view lean strategically, as a philosophy rather than tactically as a set of tools. The lessened benefits resulting from tactical implementations are behind the rational to develop a strategic comprehensive approach towards lean manufacturing transformation, in order to sustain the benefits of lean. In other words, is to develop a lean manufacturing strategy, which is the main target of conducting this study. The transformation strategy will work as a guide for manufacturing organisations in Libya and other relevant developing countries as they proceed towards high impact adoption of lean manufacturing practices.

1.3 Research Aim and Objectives

The aim of this research is to develop a lean thinking strategy that is customised to the need of the manufacturing enterprises in developing countries. This is to help identifying the opportunities of improvement and a smooth lean manufacturing adoption and implementation in the business under consideration.

Towards meeting the research's aim, the following objectives have been set out:

1. Identify the critical factors that led to successful lean manufacturing application via extensive literature review and industrial applications.
2. Synthesis lean manufacturing models and frameworks to identify the steps required to transfer organisations to lean environment.
3. Capture the AS-IS practices in Libyan automotive manufacturing sector via a field study in order to identify opportunities of improvement.
4. Develop a lean manufacturing strategy and its associated tools and techniques that will be customised to the manufacturing enterprises in developing countries.

5. Validate the developed strategy through an industrial case study in the automotive sector in Libya. Moreover, judgement will be sought from an expert in the field for validation purpose.

1.4 Research Questions

In order to achieve the research aim and objectives, the following research questions were compiled:

RQ1: What is the current state of lean manufacturing related practices within developing-world manufacturing organisation?

RQ2: What managerial and operational related factors might inhibit developing-world companies from adopting lean?

RQ3: Is there a compelling need for developing-world companies to adopt lean?

RQ4: Could lean successful factors in developed countries be adopted to make the implementation successful in developing-world as well?

RQ5: Is a strategy needed for introducing lean manufacturing to the Libyan companies?

It might be worth to mention that the Libyan automotive industry is to be used as a representation of the situation in the manufacturing enterprises in similar developing countries. Developing countries in the Middle East and North Africa region share similar characteristics of culture and other organisational features. Therefore, the automotive sector in Libya is suitable to be representative of the rest of the manufacturing sectors in Libya and in other similar developing countries. According to Industrial Development Report 2016, issued by UNIDO (United Nations Industrial Development Organisation), Libya and other developing countries (e.g., Egypt, Tunisia, Algeria, Morocco, Sudan, Saudi Arabia, etc.) are grouped within the *Industrialising Countries and Economies*. It has been mentioned that the contribution of

manufacturing output to total national income is very low in the countries within that group. Therefore, the researcher assumes that all manufacturing companies in Libya (and in those relevant developing countries) are similar in terms of their way of creating and delivering value to their customers. Hence, the findings of this research are likely to be generalisable to other manufacturing sectors in Libya and in other relevant countries.

1.5 Research Plan

The research plan for developing a lean manufacturing transformation strategy (LMTS) for introducing lean to the developing countries is shown in Table 1-1. The plan for this research has been divided into six phases based on research objectives, and each phase comprising various tasks. The main six basic research phases are as follow:

1. Background Theory
2. Identifying Lean Manufacturing Critical Success Factors
3. Industrial Field Study
4. Data Analysis
5. Developing Lean Manufacturing Strategy
6. Validation

Phase 1: Background Theory

The first phase of the research plan is an exploratory phase in which two sub-tasks have been addressed as follow:

Task 1.1: The aim of the first task (Task 1.1) within Phase one is to extensively analyse the literature as to the research topic (lean manufacturing). An extensive review of literature pertaining to lean manufacturing principle and tools is to be performed. The results of the literature review are to be presented in Chapter 2.

Table 1-1 Phases of research plan

Research Phases	Tasks	Deliverables
1. Background Theory	1.1 State of the art review on lean manufacturing (LM) principles and best practices. 1.2 Understanding the key elements of the formation of lean manufacturing strategy.	Sate of the Art
2. Identifying LM critical success factors (CSFs)	2.1 CSFs in developed world: identification, filtration and classification. 2.2 Identifying CSFs in developing world from published literature. 2.3 Propose and define a list of CSFs to deploy LM strategy after mapping the captured factors in 2.1 and 2.2	Proposed CSFs for developing countries
3. Industrial Field Study	3.1 Developing a structured questionnaire. 3.2 Performing semi-structured face-to-Face interviews. 3.3 Plant tours and shop-floor observations.	As-Is practices and the need for LM strategy
4. Data Analysis	4.1 Identifying the influential factors related to LM applications in Libya. 4.2 Identifying suitable area for implementing LM in shop floor.	Opportunities for improvement
5. Develop Lean Manufacturing Transformation Strategy (LMTS)	5.1 Define the main elements of the lean manufacturing strategy 5.2 Developing a customised lean manufacturing transformation strategy (LMTS) covering managerial and operational aspects that is suitable for developing countries such as Libya. 5.3 Developing a user guide for implementing LMS.	Lean manufacturing strategy
6. Validation	6.1 Case studies validation in Libyan manufacturing companies and measuring its impact. 6.2 Expert judgment validation of the results.	Validated LMS

Task 1.2: The aim of the second task (Task 1.2) within Phase one is to synthesise the best practices of lean manufacturing adoption strategies. In this vein, models and frameworks for lean implementation in addition to successful implementation case

studies have been explored to provide the researcher with an overview of the most common methodologies for introducing lean manufacturing which includes the mechanism and steps towards lean and its common sequence. The results and details related to Task 1.2 are presented in Chapter 2.

Phase 2: Identification of Lean Manufacturing Critical Success Factors

The second phase of the research plan consists of three main tasks - that is - Task 2.1; Task 2.2; and Task 2.3. The overall aim of Phase 2 is to propose a list of critical success factors that should be appropriate to introduce lean manufacturing to the developing countries. Figure 1-1 presents the general approach that has been developed by the researcher to carry out the flow of these three tasks (Task 2.1, Task 2.2, and Task 2.3).

Task 2.1: Identifying Lean Success Factors in Developed Countries

The aim of task 2.1 is to identify the factors deemed critical for successful lean adoption in the developed countries. The task 2.1 has been performed and presented in Chapter 3, section 3.2. The first step of task 2.1 has been performed through extensive literature review and investigating successful case studies that had been carried out in manufacturing organisations in developed countries. The next step of task 2.1 is to filter and classify the identified lean success factors. The filtration and then the classification of the lean success factors have been performed according to the theory that lean is a social-technical system. Furthermore, the success factors have been distributed into the four sub-groups that form the general structure of a social technical system. Finally, the results of the filtration and classification of the identified factors have been presented and discussed in Chapter 3, section 3.3.

Task 2.2: Investigating Lean Manufacturing Practices in Developing Countries

The second task in Phase 2 (Task 2.2) is to investigate the practices of lean manufacturing within manufacturing organisations in the developing countries that

have already made efforts to adopt lean concept. The aim of addressing lean attempts in the developing countries is to explore the operational and managerial practices within those organisations in terms of their approaches to lean and also to investigate which factors those organisations have considered when embracing lean initiatives. The results of that exploration and investigation will be helpful in determining whether or not lean success factors have the same validity and importance for developing countries as in the context of developed countries or if there is any other lean way that is suitable for the developing countries. This should lead to an understanding of the barriers

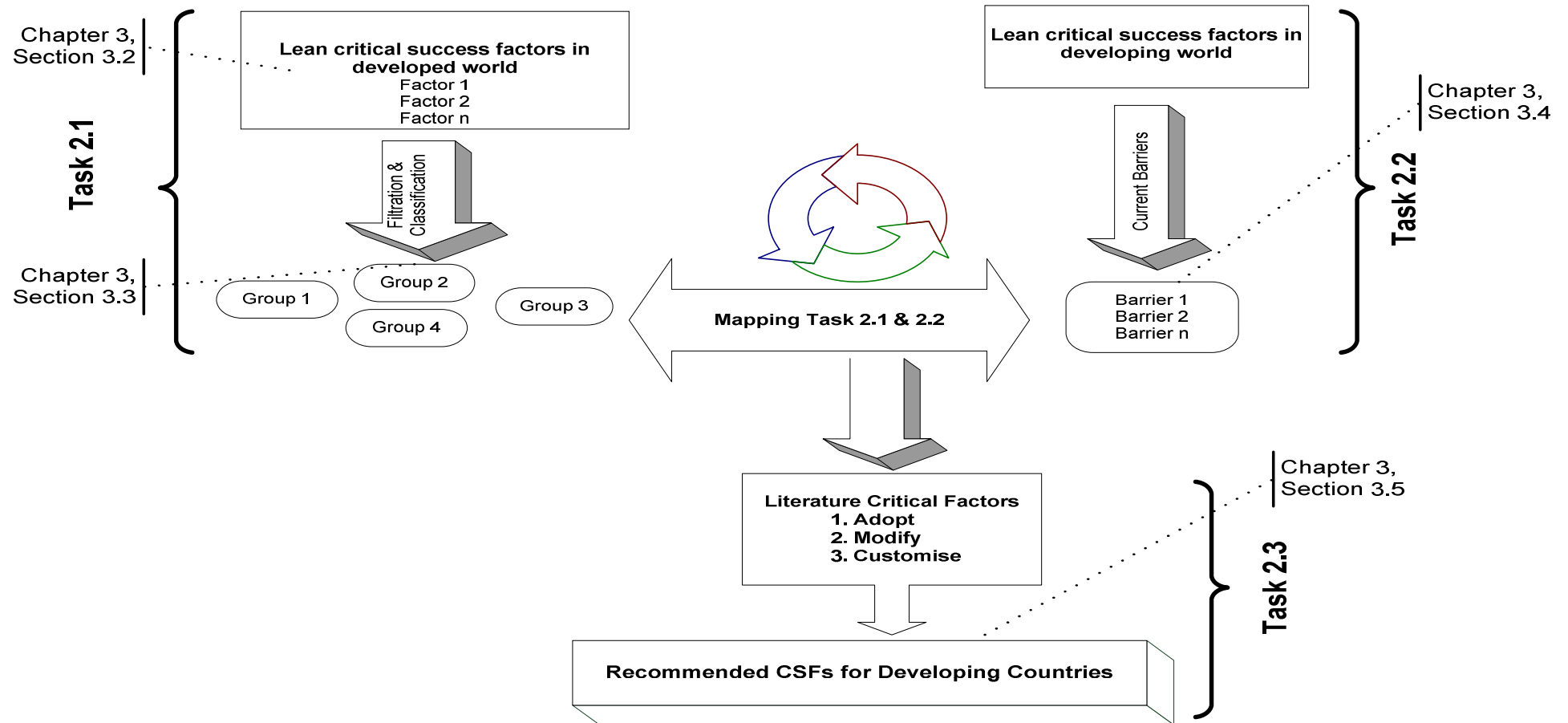


Figure 1-1 Approach for proposing lean manufacturing success factors for developing countries

and the current issues that manufacturing organisations in developing countries usually face while attempting to transfer to lean. Thus, the results of analysing the lean barriers in developing countries should allow the researcher to understand the risk of failure associated with these lean attempts. Thereby, countermeasures could be recommended to avoid failure when introducing lean to a developing country. The results of Task 2.2 is presented and discussed in more details in Chapter 3, section 3.4 in this study.

Task 2.3: Recommending Lean Success Factors for Developing Countries

The third task in the Phase 2 of the research plan (Task 2.3) is aimed to come up with a based literature list of lean critical success factors that should be suitable for developing countries. The task 2.3 has been carried out by mapping the results of task 2.1 and task 2.2. By comparing different results, this mapping should enable the researcher to propose a bundle of lean manufacturing success factors that should be useful in avoiding the risk of possible failure associated with the process of lean transformation to developing countries. The result of mapping Task 2.1 and Task 2.2 has been presented in Chapter 3, section 3.5.

In conclusion, this approach (Figure 1-1) is an attempt to answer the question: Whether or not the lean factors that have been considered in developed countries are transferable and can be adopted in developing countries just as they have been adopted in developed world or modification and customisation need to be done. This comparison will shed new light on the transferability of lean manufacturing in the developing countries.

Phase 3: Industrial Field Study in Libya

Task 3.1 Structured Questionnaire

Based on the results of Phase 2, a structured questionnaire has been designed and used as a main research tool to meet the objectives and achieve the research's main aim (Chapter 4). The proposed list of lean success factors (results of Task 2.3) have

been embedded in the questionnaire. After administering the questionnaire to the targeted companies, and once the collected data has been analysed, the researcher will be able to find out if the proposed lean success factors are useful as well for Libyan companies (as an example of other similar developing countries). This is to figure out whether or not the Libyan context is similar to the Western context or customisation must be done in order to embrace lean manufacturing successfully. The questionnaire has been employed to elicit the respondents' (various levels of employees) point of views, ideas, their level of knowledge, and commitment towards implementing lean manufacturing in their organisations. More details about the questionnaire design and administration is presented in Chapter 4.

Task 3.2 Semi-structured Face to Face Interviews

In order to have a clear picture of the realities of lean status in the targeted companies, the structured questionnaire has been complemented by semi- structured face to face interviews. These interviews have been conducted with employees from senior management levels, in order to gauge and have insights into the current manufacturing and managerial practices related to lean manufacturing practices. All interviews have been recorded to facilitate the transcription process and hence, maximise the credibility and validity of the collected data. The interviews protocol is presented in more details in Chapter 5, section 5.4 and the results are presented in section 5.4.2.

Task 3.3 Observations

In this study, direct observations (non-participant) have been conducted to allow the researcher to have first-hand information of the operational practices within the investigated companies. This direct observation should be helpful in determining how the investigated companies run their daily operations and therefore identifying the barriers that hinder the readiness of lean manufacturing. The direct observation provided the researcher with opportunity to validate the information obtained by the questionnaire, therefore ensure the results' reliability and validity.

Research Phase 4: Data Analysis

Once the data has been collected, the responses have been entered into SPSS software (Statistical Package for the Social Sciences) to perform several analyses. The performed analyses include Cronbach's alpha and descriptive analysis.

Cronbach's alpha (α): The purpose of performing Cronbach's alpha test is to estimate the reliability and internal consistency of the collected responses. The internal consistency is very important to be identified, as the further data analysis will be relay on. According to Pallant, 2010 the value of alpha (α) is acceptable if α is above 0.7.

Descriptive Analysis: This test helps to organise respondents' answers into statistical data to see the frequency of answers.

Chapter 2 Lean Manufacturing Principles, Tools, and Techniques

2.1 Introduction

The purpose of this chapter is to develop a theoretical understanding of lean manufacturing implementation by describing the different principles, tools and associated techniques and by examining the academic state of the art on lean manufacturing implementation procedures, which would be helpful in describing the phases when implementing lean manufacturing. Thus, in order to have a full picture of the topic to support the aim of this research the following are needed to be considered as shown in Figure 2-1: Lean manufacturing principles, lean manufacturing tools and techniques, the origin and the elements of manufacturing strategy, and lean manufacturing models & frameworks.

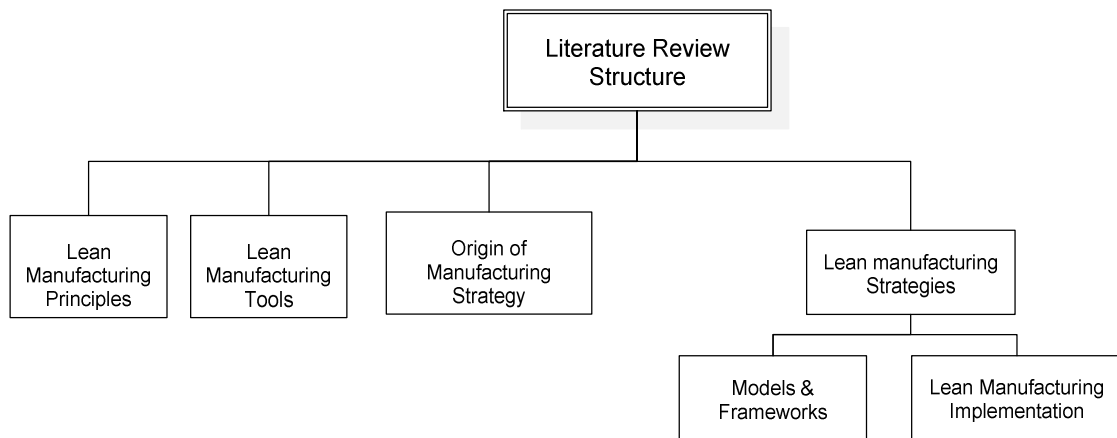


Figure 2-1 Literature review layout

2.2 Lean Manufacturing Principles

The five basic principles of lean manufacturing that have been described by Krafcik (1988); Womack *et al.*, (1990) and Womack and Jones (1996) as shown in **Error! Reference source not found.** are: value, value stream, create flow, pull, perfection.

According to Womack and Jones, (1996) lean manufacturing is commonly described from two perspectives, either from a philosophical point of view related to guiding principles or from the practical point of view (Shah and Ward, 2003). However, the semantic differences between the various lean manufacturing components widely exist in the literature. For instance, Bicheno and Holweg, (2009) regarded all elements of lean manufacturing as tools; however, Cochran *et al.* (2000) regarded elements such as kanban, pull system, Takt time, one piece flow, and Poka Yoke as principles.

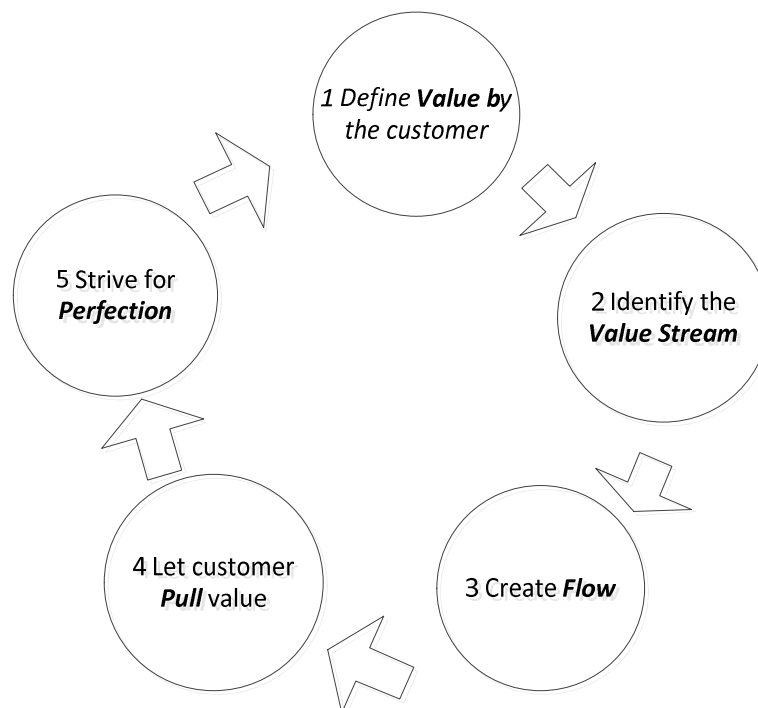


Figure 2-2 Five basic principles of lean manufacturing (Womack and Jones, 1996)

Åhlström and Karlsson, (2000) identified eight lean manufacturing principles: elimination of waste, zero defects, pull scheduling, multifunctional teamwork, layering (reductions in hierarchy levels) team leader, vertical information system, and continuous improvement. Shah and Ward, (2007) attempted to clarify that confusion and inconsistency associated with the content of lean manufacturing. Empirically, they traced the main lean manufacturing components and identified ten key factors related to the subject as shown in Figure 2-3.

Anand and Kodali, (2009a) argued that lean manufacturing principles are those which establish lean manufacturing as a fundamentally different manufacturing system. They developed a detailed conceptual lean manufacturing model with a 56 element and argued that the core principles of lean manufacturing are:

- Customer-driven production
- Defect free products
- Elimination of wastes
- on-going activity focusing on continuous incremental improvements
- Respect people
- Visual management system
- Focus on customer
- Supplier partnership

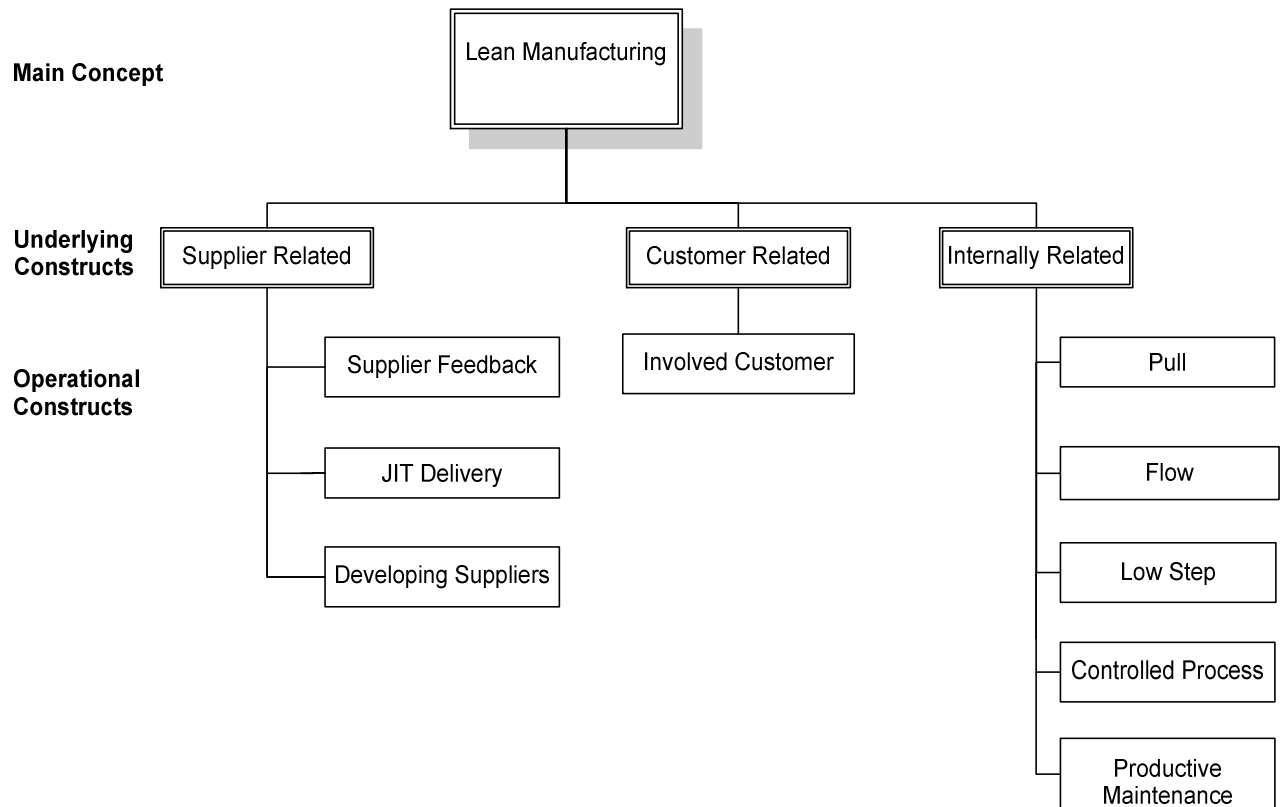


Figure 2-3 Conceptual and empirical mapping of key aspects related to lean manufacturing (Shah and Ward, 2007)

Since this research is focusing on lean strategic activities (ex. decentralised responsibilities) to improve the operational activities (ex. reduce lead time), the linguistic and semantic confusion associated with the lean various historical facets fall outside the scope of this research. Many researchers have gone into the different constituents of lean manufacturing in more detail, which resulted in setting prerequisites for successful lean adoption. Table 2-1 summarises the researchers' diverse perspectives on lean manufacturing.

An extensive search through the literature of lean manufacturing principles and concepts led the researcher to conclude the following lean thinking concepts as shown in Figure 2-4, which are applicable to any type of industry.

Table 2-1: Researchers' views on the constituent elements of lean concepts

Constituent of Lean Manufacturing	Authors
Specify value, Identify the value Stream	Soriano-Meier and Forrester, (2002); Suzuki, (2004)
Just-in-time (JIT) and zero inventories	Hall, (1983)
JIT, Quality and Work improvement	Schonberger, (1982b)
JIT and strategic Human resource management	Shimada and MacDuffie, (1986)
JIT, Quality, Flexibility and respect for people	Krafcik, 1988; Holweg, (2007)
Excellent process flow, Pull system, Continuous improvement, Visual Control, Culture of learning, Teamwork	Liker and Hoseus, (2008)
Involve supply chain management	Shah and Ward, (2007)
JIT, respect for people	Emiliani, (2007); Ohno, (1988)

Instead of each function individually and independently working on reducing its own costs, lean manufacturing aims to aligning all functions with the common goal of reducing the overall costs of the organisation operations. For a company to successfully transform into lean, all functions are required to understand the application of tools and techniques associated with lean manufacturing and then aim to eliminate waste within processes. Once the wasteful activities are eliminated, the root causes of the problems become visible and then must be solved to fully eliminate the problems, which results in a more consistent manufacturing system. After that, work standards can be created and then the Kaizen (continuous improvements) can be strived for by continuously challenge the standards in attempt to make further improvements. Kaizen requires continuous, gradual, and persistent improvement which should be done by people at all levels in the organisation. Therefore, any non-value added activities would be identified and eliminated as quickly as possible at the lowest possible cost.

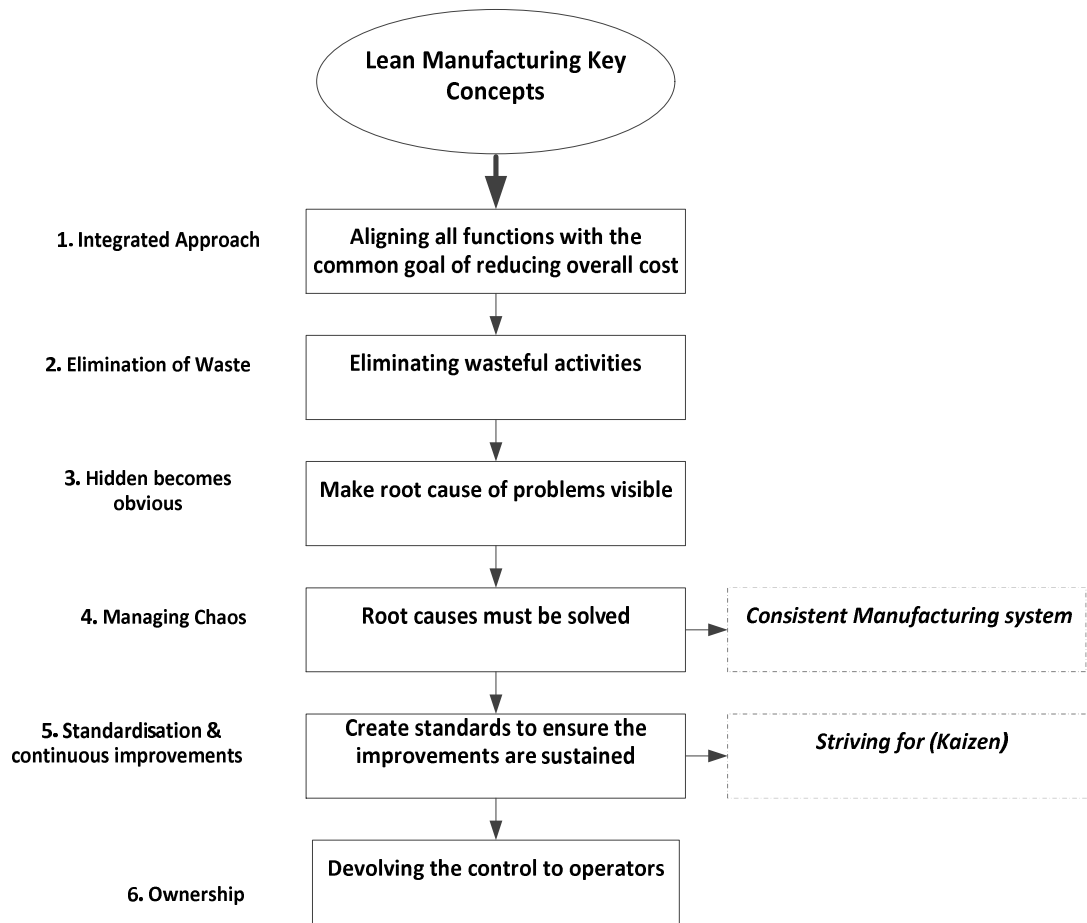


Figure 2-4 Lean manufacturing key concepts

Finally, once standards are set, and to ensure a successful embarking on a lean manufacturing journey, the ownership and the control of the manufacturing process should be placed into the hands of people who actually operate it.

2.3 Lean Manufacturing Techniques and Tools

Once an organisation pinpoint the root cause of waste, tools and techniques such as Kaizen, JIT, Poka Yoke, Takt Time, 5S (*Sorting, Straightening, Shining, Standardising, Sustaining*) and many others will help the organisation through corrective actions in order to eliminate waste. Any activities that consume resources but create no redeeming value to the customers are considered wastes that must be properly eliminated (Womack and Jones 1996). The basic building blocks of lean manufacturing

are shown in Figure 2-5. The roof of the house - the objective of lean manufacturing - represents what the customer wants, that is highest quality, lowest cost and shortest lead time. The house's roof is supported by the two pillars of JIT and JIDOKA. These pillars rest upon a solid foundation of HEIJUNKA, standard work and KAIZEN, which itself rests upon a foundation of stability.

The following subsections present the lean manufacturing house in some detail.

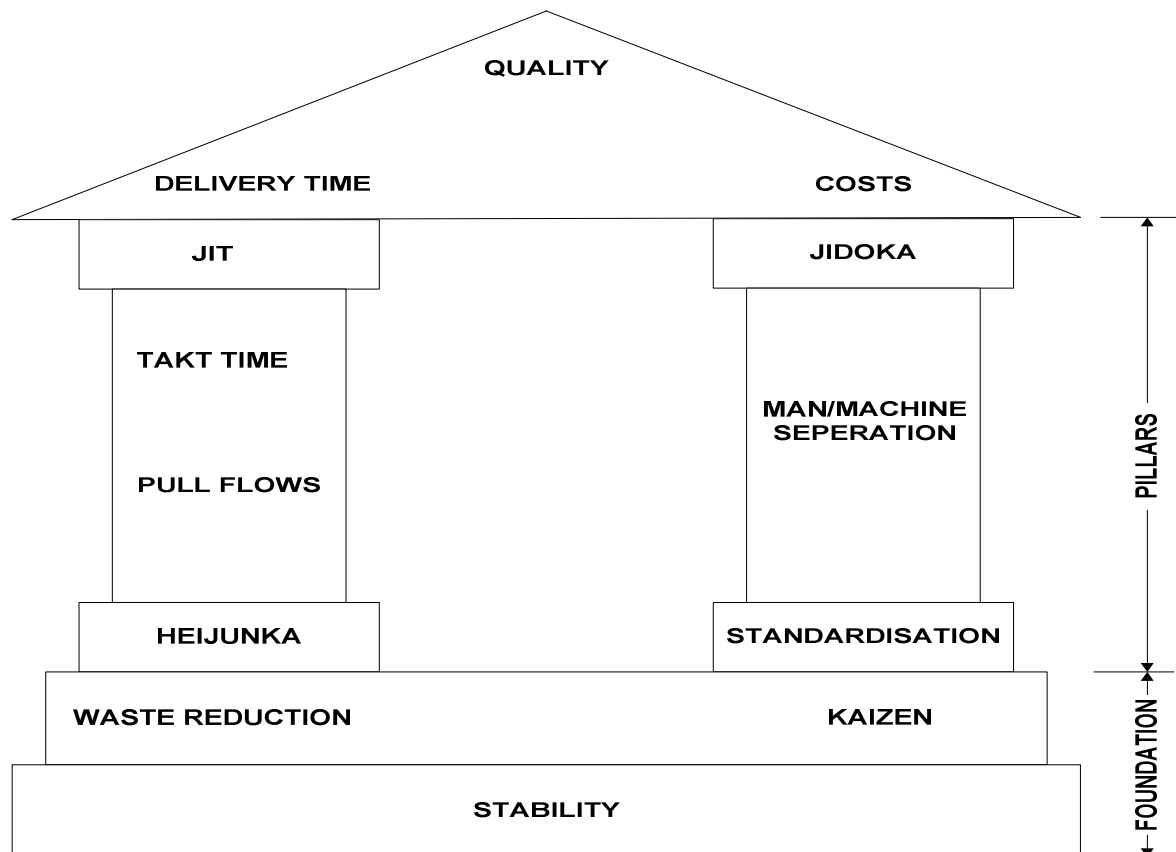


Figure 2-5 Lean manufacturing house (Stump and Badurdeen, 2012)

2.3.1 The Foundation

The base of the house, on which all the rest is built, has two elements: Kaizen and elimination of MUDA (waste). One of lean manufacturing features is the search for Kaizen (continuous improvement) in products and processes (Godinho Filho and Uzsoy, 2011). This ensures that employees are involved and also need the top management support (Sánchez and Pérez, 2001). The aim of Kaizen is to create an atmosphere, a

culture of continuous improvement, by focusing people on problems. People must be trained to see waste and solve problems at the root cause by repeatedly asking why the problem really occurs. Another important element is waste elimination; waste (non-value added activities) is a symptom rather than a root cause of the problem. For organisations to perfectly eliminate the waste in their processes, they should understand that the methodical attack on waste is a systematic assault on the factors behind poor quality; that is the seven different kinds of waste. The seven basic forms of muda (waste) that developed by Ohno, (1988) are: defects in production, overproduction, inventories, unnecessary processing, unnecessary movement of people, unnecessary transport of good, and waiting by employees. Womack and Jones (1996) added to those forms of waste goods and services that fail to meet the needs of customers. Dennis and Shook, (2007) considered knowledge disconnection as a kind of waste. In addition to Kaizen and waste reduction, stability starts with visual management and the 5S tool. 5S supports standardised work and total productive maintenance (TPM), which are the key to method and machine stability respectively. Finally, 5S supports just-in-time (JIT) technique by providing point-of-use information that eases decision making process.

Moreover, the foundation of lean manufacturing includes the following tools that must be taken into consideration when addressing lean manufacturing:

- I. Visual factory (5s)
- II. Standardisation
- III. Total Productive Maintenance (TPM)
- IV. Quick change over (QCO) or Single Minute Exchange of Dies (SMED)

I. Visual factory (5s):

The 5s is a simple and not expensive improvement tool yet can bring about clever solutions; therefore it must be taken into consideration when lean manufacturing transformation is the subject. It is a systematic method for keeping workplace organised by performing a series of steps. The activities of 5s can enhance process

owners' responsibilities and self-discipline towards maintaining and further developing working practices.

The improvements that could be brought about by the implementation of 5S include, but are not limited to:

- Enhance safety and work environment conditions
- Enhance machine downtime
- Enhance quality
- Enhance productivity
- Enhance workers' morale and teamwork
- Enhance visibility and thus control is developed
- Find and then remove waste quickly
- Enhance defect rate
- Enhance processing time and thus reduce delivery time

For the above reasons the 5S is considered as a “Must Tool” and hence should be addressed early when transforming a company into lean manufacturing environment.

II. Standardization:

The purpose of standardisation is to improve the effectiveness of workers by setting a regular and normal way (which includes Takt time, work sequence, and standard WIP) in which work is performed on the shop floor. The standardisation is also to set up and define the guidelines for quality, manufacturing, human, safety, and inventory.

III. Total Productive Maintenance (TPM)

Total productive maintenance (TPM) is regarded as one of important components of lean manufacturing; therefore companies must build interest and awareness of its importance if they address the transformation to lean manufacturing. It is a management system with the aim of enhancing the overall machines efficiency by performing preventive maintenance activities with all workers being involved in the process. When adopted effectively, the TPM programmes could positively contribute

to reducing waste, saving financial resources, and enhancing the workplace environment. Moreover, the participating operators in TPM programmes can acquire the confidence and the necessary know-how for managing their own equipment. The benefits of TPM could be summarised as follows:

- TPM reduces the idea that equipment's failure is inevitable
- TPM decreases the total expenses related to equipment's working life
- TPM enables us to prevent machines error to become real fails
- TPM enables operators to gradually become maintainers

In order to realise the benefits of TPM programmes, there are certain activities that should be taken into consideration. Autonomous maintenance is one of the important activities that should be addressed when lean manufacturing transformation is being addressed. Autonomous maintenance (AM) is aimed to help operators to quickly identify and solve equipment related issues before deterioration into failure. Therefore, autonomous maintenance could positively contribute to the stabilisation of machines conditions.

IV. Quick change over (QCO) or Single Minute Exchange of Dies (SMED)

The principle of the single minute exchange of dies (SMED) or the quick change over (QCO) is to reduce machine idle time by converting the internal setup activities to external ones while a machine is still operating. The benefits of reducing the changeover time include the following:

- lowering batch size
- reducing work in process (WIP) stock
- improving capacity
- improving quality
- reducing waste
- lowering lead times
- improving flexibility

2.3.2 The Pillars

The two pillars of the Lean house are just-in-time (JIT) and Jidoka - automation with human mind (Black and Hunter 2003), JIT is based on Heijunka whereas Jidoka is based on standard work. In the left pillar which represents JIT, we look at how to make things flow (the ideal is one piece flow) using principles like TAKT time (the rate at which customers require the product). The mechanism of JIT tool is shown in Figure 2-6. The idea is, if you do not need an item or part now, do not make it now. Produce each day only what is sold each day (theoretically). In this way, market demand pulls production. JIT requires only necessary units to be provided in necessary quantities at necessary times. Producing one unit extra is as bad as being one unit short. Furthermore, suppliers deliver small batches of raw materials, sometimes directly to the appropriate department just- in- time, or right –on- time, to meet production demands. JIT delivery has been a key element in the development of lean manufacturing in many companies.

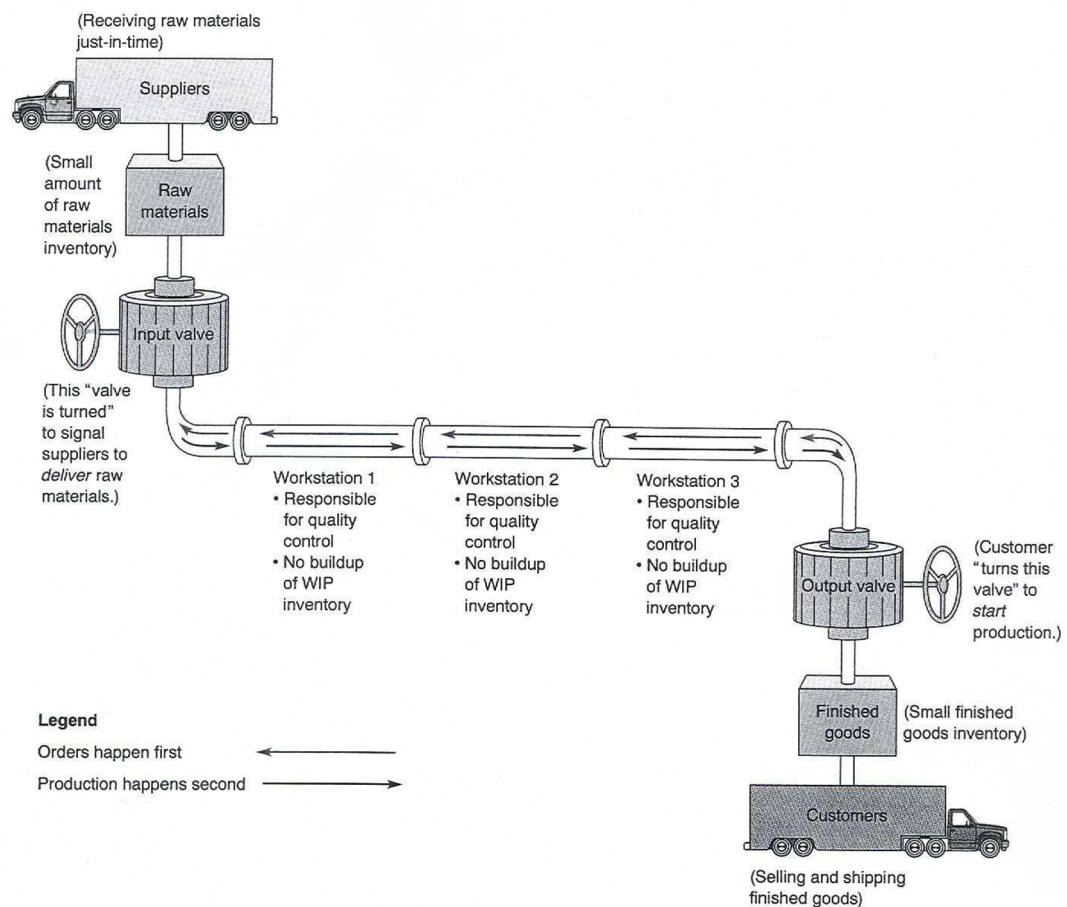


Figure 2-6 Just-in-Time technique mechanism (Burch, 1994)

In line with that, Heijunka aims to smooth out production in such a way that allows us to better utilise our resources.

Since high defect rates lead to frequent line stoppages, which make flow and pull impossible, the other pillar of lean manufacturing house - Jidoka- is all about ensuring we make a product of quality and eliminate, as much as possible, any opportunity to produce defects (Dennis and Shook, 2007). Besides standardised work, visual management, and 5S; POKA YOKE is another method to improve human reliability. Poka means inadvertent error, and Yoke mean prevention. Poka-Yoke means implementing simple low-cost devices that either detect abnormal situations before they occur, or once they occur, stop the line to prevent defects (Shingō, 1986). Poka-Yoke, or error proofing, is an excellent tool to ensure Jidoka is in place. Once we identify a failure mode, the best control of all is a Poka-Yoke device. The devices that Poka-Yoka uses could be contacting, sensing, or warning devices. Hofer *et al.*, (2011)

have grouped lean practices into three categories: internal-technical, internal-relational, and supply chain lean practices. The first category includes practices that are of technical nature such as Pull, Flow, Setup and Lead time reduction, Total productive maintenance, 5S, and Poka-yoke. The second group includes practices that are of relational nature such as employee involvement and empowerment. The last category includes practices that are implemented in collaboration with supply chain partners such as customer involvement, JIT supplier, supplier development, and supplier feedback. Supply chain lean practices aim to reduce or eliminate the manufacturing process's non-value added activities and variability

A summary of definitions of some common lean practices is provided in Table 2-2.

Table 2-2 Definitions of common lean manufacturing practices

Practice	Brief Definition	Literature Support
5S	Five dimensions of workplace organisation. The focus of 5S activity is to organise the workplace in order to make it more productive. After 5S, it is expected to see a place for everything, and everything in its place.	Manotas <i>et al.</i> , (2008); Upadhye, <i>et al.</i> , (2011)
Value Stream Mapping	A method / tool to graphically describe the flow of material and information through the production system. By graphically portraying the process, the waste becomes visible.	Grewal, (2008); Jiménez <i>et al.</i> , (2011)
Poka-yoke	A method that uses simple, low cost devices that prevents defective parts from being processed or passed into the process.	Pettersen, (2009); Boyle <i>et al.</i> , (2011)
Kaizen	Defined as continuous improvement through incremental improvement. It is an ongoing activity to go for the better towards improving a specific process.	Boyle <i>et al.</i> , (2011); Suárez-Barraza and Ramis-Pujol, (2010)
Pull Production	A system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need	Grewal, (2008); Suárez-Barraza and Ramis-Pujol, (2010)

2.4 Origin and Definition of Manufacturing Strategy

Manufacturing strategy in a company is related to key decisions about the precise role to be played by the manufacturing function towards achieving competitive advantage.

Manufacturing strategy has been interpreted by many academics. Skinner, (1969) was the first to propose the concept of manufacturing strategy, linking the manufacturing function to competitive strategy. Researchers on manufacturing strategy have conventionally distinguished between the content and process of manufacturing strategy for a long time (Brown *et al.*, 2007; Jia and Bai, 2011). Process aspects include development and execution of manufacturing strategy, whereas the content concerns with the choices and plans that set an operation direction. The concept of manufacturing strategy has been defined in a number of ways over the years.

Since the main aim of this research is to come up with “lean *manufacturing strategy*”, it is then important to understand what manufacturing strategy is and how it is formed. Therefore,

Table 2-3 presents few examples of connotations of manufacturing strategy given by some authors

Table 2-3 Some Connotations of Manufacturing Strategy

Author	Manufacturing Strategy Connotation
Amoako-Gyampah and Acquah, (2008)	Manufacturing strategy refers to the competencies that a firm develops around the operations function. Manufacturing strategy is also expected to be one of the components of a firm’s business strategy or strongly integrated with a firm’s business strategies.
Jia and Bai, (2011)	Manufacturing strategy contains the pattern of strategic decisions and actions which set the role, objectives and activities of the manufacturing in a manufacturing company.
Platts and Gregory, (1990)	Manufacturing strategy "defines how the manufacturing function will assist in achieving business goals by providing the appropriate structural items (buildings, plant, equipment, etc.) and appropriate infrastructure (human resources, organisational structure, control policies, etc.) in order to ensure the effectiveness of operations"
Hayes and Wheelwright, (1984)	Manufacturing strategy is defined as a consistent pattern of decision making in the manufacturing function that is linked to the business strategy.

2.5 Lean Manufacturing Strategies

Lean manufacturing practices are becoming increasingly difficult to implement and sustain as supply chains increase in complexity and length. Many organisations have implemented lean successfully, attained and reported great benefits (Dunstan *et al.*, 2006; Panizzolo *et al.*, 2012; Parry and Turner, 2006). However, in the light of a lack of knowledge on its principles and its anticipated benefits, inappropriate planning, lack of a comprehensive adoption strategy, and lack of recognising its critical success factors, a lot of organisations have not been successful in their attempts to obtain the desired results from lean. This is consistent with many studies as has been cited by several researchers (Bhasin, 2008; Green *et al.* 2010; Gorman *et al.* 2009; Meade *et al.*, 2010 Papadopoulou and Ozbayrak, 2005; Taj and Berro 2006; Staats *et al.* 2011).

Bhasin and Burcher, (2006) noted the low rate of successful lean projects. They suggested that only about 10% of the surveyed companies have been successful in implementing TPM and other lean manufacturing practices. In fact, the process of lean manufacturing adoption is an interrelated and a complicated task that is generally encountered with a number of hindrances (Bhasin 2012; Scherrer-Rathje *et al.* 2009).

Mistakes committed during the transformation process and lack of lean detailed implementation plans usually drive organisation to fail (Anvari *et al.*, 2010; Danford, 2007). Manufacturing managers can successfully develop their own lean manufacturing strategies by incorporating lean manufacturing best practices, tools and techniques within more comprehensive frameworks. According to Da Silva *et al.*, (2009) there are two schools for designing and implementing manufacturing strategies, the two traditional methodologies found in the literature are those described by Hill, (2000) and Mills, *et al.*, (1995). The last authors explained that and noted:

“There have been two streams of research on generic manufacturing strategies. The first is predominantly survey or case based, in which results are analysed by cluster techniques to identify sets of companies following similar or generic strategies. From such an analysis performance, differences between the clusters may lead to new perspectives on manufacturing strategy....etc. The second stream of research

emphasises the development of frameworks that should assist in the strategic management of manufacturing.”

Consequently, to secure the success of lean manufacturing implementation, the need arises to understand the models and frameworks to effectively guide the implementation process towards lean.

2.6 Frameworks for Lean Manufacturing Implementation

A vast number of frameworks pertaining to lean manufacturing have been published by academics, experts, and consulting groups. In this research, the focus is on the implementations ones that - to some degree - act as guiding torches that help companies in providing necessary directions during the transition period towards lean manufacturing.

Yusof and Aspinwall, (2000) have distinguished between conceptual models and implantation frameworks. Anand and Kodali, (2009a) stated that conceptual models are about the "what is" questions (descriptive) whereas implementation frameworks are about the "how to" questions (prescriptive set of actions). In other words, conceptual models capture what constitutes lean manufacturing while implementation frameworks describe the sequence for implementing / operationalising lean manufacturing elements (how to put lean elements in practice or in use). However, there are several lean manufacturing models that are neither conceptual nor implementation which only provide general information on lean (Lewis, 2000; Motwani, 2003).

There are two trends in lean manufacturing transformation frameworks, while some focus on the technical aspects of lean manufacturing, (tools and techniques) "hardware aspects", others centre more on the organisational culture, social, and educational aspects "software aspects" (Anvari *et al.*, 2011). In this research, both aspects to leanness will be covered equally.

2.6.1 Anand and Kodali Framework

Anand and Kodali, (2010b) have reviewed 30 lean manufacturing frameworks and have found that none of them describes the steps of the implementation process. In addition, none of the reviewed frameworks clarifies the relationship between the elements of lean manufacturing. It has also been noted that – in terms of roles in implementing lean – the role of an organisation's internal stakeholders (senior management, managers, engineers, and front line workers) have not been addressed. In addition, the relationship between lean manufacturing elements and a company's competitive priorities has not been addressed in those frameworks. To overcome these shortcomings Anand and Kodali, (2010b) proposed a 10 level implementation model as shown in Figure 2-7 below. A brief description of the model's levels is given below.

Level Zero Evaluate: in this stage, the top management in consultation with a lean expert initially assesses the company and identifies the non-value added activities in its processes.

Level 1 Prepare: This is a preparation stage in which the company demonstrates the compelling need for change. Here, the company implement pre-requisites elements that should lead to achieve success in lean implementation. In this early stage, it is vital for the top management to ensure employees job security. The responsibility of lean implementation is given to a cross functional team, proper training should be arranged to all team members and senior management as well as to shop floor workers. In this level, top management needs to implement certain elements such as flat organisation structure, rewards and recognition and employee empowerment.

Level 2 Identify value: The organisation defines value by identifying the product using some tools, such as risk analysis. The plant or the line producing that product can be regarded as the pilot project.

Level 3 Identify the value stream: Once the product is identified, the company should understand the required manufacturing process. Next step is mapping out the current

and future material and information flow. During mapping current state, managers would be able to collect data such as, cycle time, idle time, preceding and subsequent operation, number of operators, maintenance time, setup time, etc. While by mapping future state the team identifies potential areas for improvements and also identifies the lean manufacturing tools to be implemented to achieve those improvements.

Level 4 initiate: in this stage the company starts the actual implementation by applying 5s then defects should be reduced and quality improved by implementing practice such as, work standardisation, defect at source, successive check. Such practices enable the shop floor workers to see wastes in the manufacturing process.

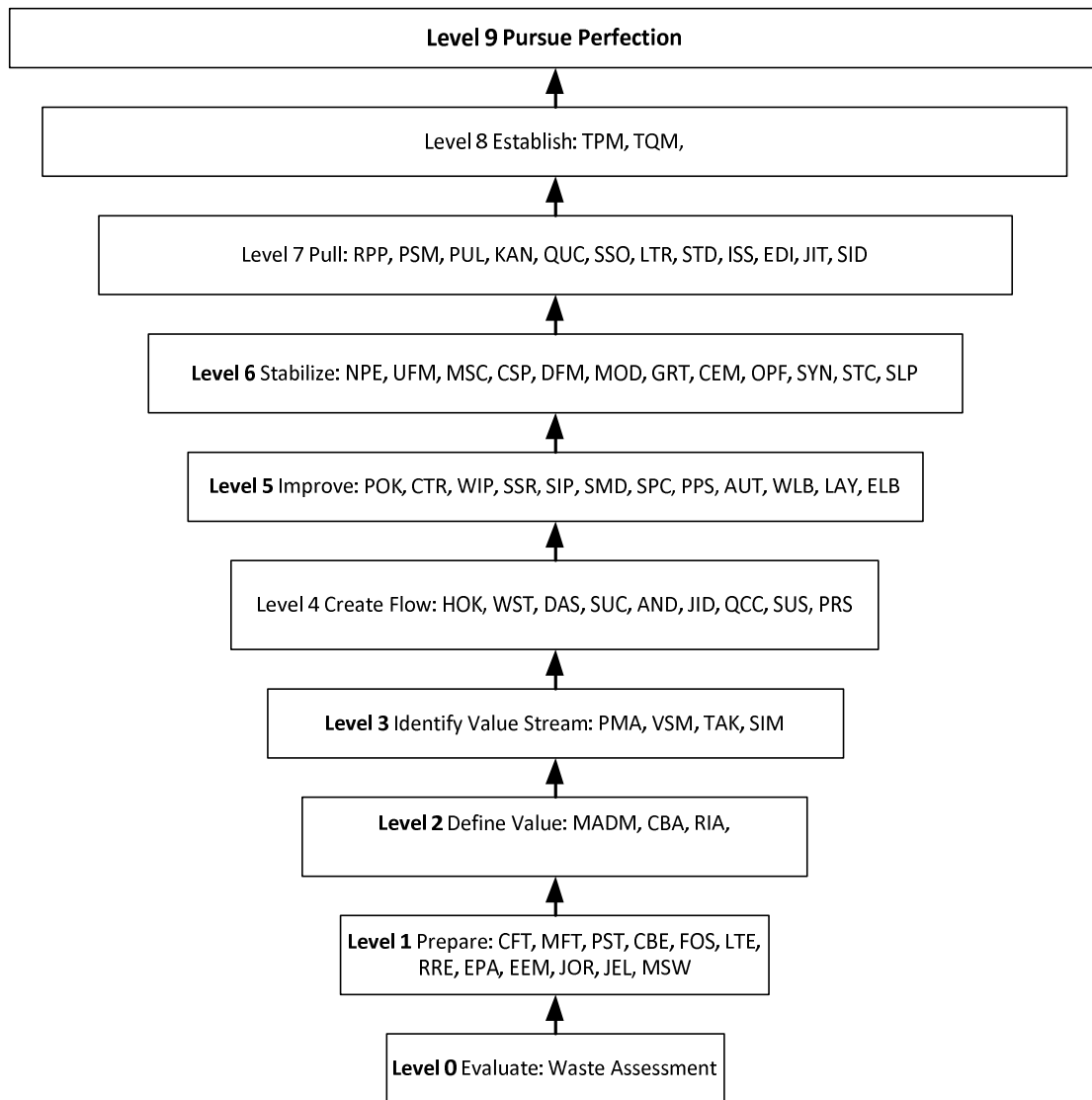


Figure 2-7 Framework for implementation of lean manufacturing programmes (Anand and Kodali, 2010b)

CFT cross functional teams, **MFT** multi-functional training, **PST** problem solving tools, **CBE** communication between employees, **FOS** flat organisation structure, **LTE** long term employment, **RRE** rewards & recognition, **EEM** employee empowerment, **JOR** job rotation, **JEL** job enlargement, **MSW** multi skills workforce, **RIA** risk analysis, **VSM** value stream mapping, **HOK** housekeeping 5S, **WST** work standardisation, **DAS** defects at source, **SUC** successive checking, **AND** andon, **QCC** quality circles, **SUS** suggestion scheme, **PRS** process sharing, **POK**, pokeyok, **CTR** cycle time & lead time reduction, **SSR** storage space reduction, **SIP** safety improvements programs, **SMD** single minute exchange of dies, **SPC** statistical process control, **PPS** product & process simplification, **AUT** automation, **WLB** workload balancing, **LAY** layout change, **ELB** elimination of buffers, **RPP** rolling production plan, **PSM** production smoothing, **PUL** pull production, **KAN** kanban system, **QUC** quality certification, **SSO** supplier reduction, **LTR** long term supplier relationship, **STD** supplier tanning & development, **ISS** information sharing with supplier, **TQM** total quality management, **TPM** total productivity maintenance,

Level 5 Improve: support of engineers with shop floor associates is required to apply more advanced tools such as, poka yoke, single minute exchange of dies, statistical

process control, automation, work levelling, product and process simplification, etc. At the end of this level, the organisation can see a significant reduction in the wastes apart from an increase in the performance related to competitive priorities such as productivity, cost, quality, delivery, flexibility, morale, innovation, etc.

Level 6 Stabilise: improvements that happened in the previous stage are stabilised. In this stage, elements related to other areas must be implemented. For example, communication & standardisation of parts, design for manufacturing, modularity, are related to design and product development area. Similarly, techniques such as group technology and cellular manufacturing that dealing with production engineering have to be implemented.

Level 7 Advanced: this stage refers to one of the most important lean principle (pull value). Advanced lean practices and techniques should be implemented in this stage. For instance, Kanban system and pull system. The success of implementing these practices is dependent on both the internal and external members such as production planning and control and suppliers.

Level 8 Establish: Since, the basic cultural changes among employees are brought out; it will be easier to introduce other management philosophies such as total quality management (TQM) and total productive maintenance (TPM).

Level 9 Continue: Since the process is never perfection, this stage refers to the last tenet of lean manufacturing (pursue perfection). It focuses on continuous improvement of the existing value stream. Once the pilot programme is successful, it can be extended to across the plant. The previous experience of the implementation should be well documented to make the future expansion much easier.

2.6.2 Chakravorty Framework

Chakravorty, (2010) has developed a six-step lean implementation framework. As shown in Figure 2-8. As a first step, the top management analysed the company's current competitive position in the market. The senior managers assessed the current

operational performance by for example, comparing their lead time performance and WIP inventory with key competitors' ones in the market.

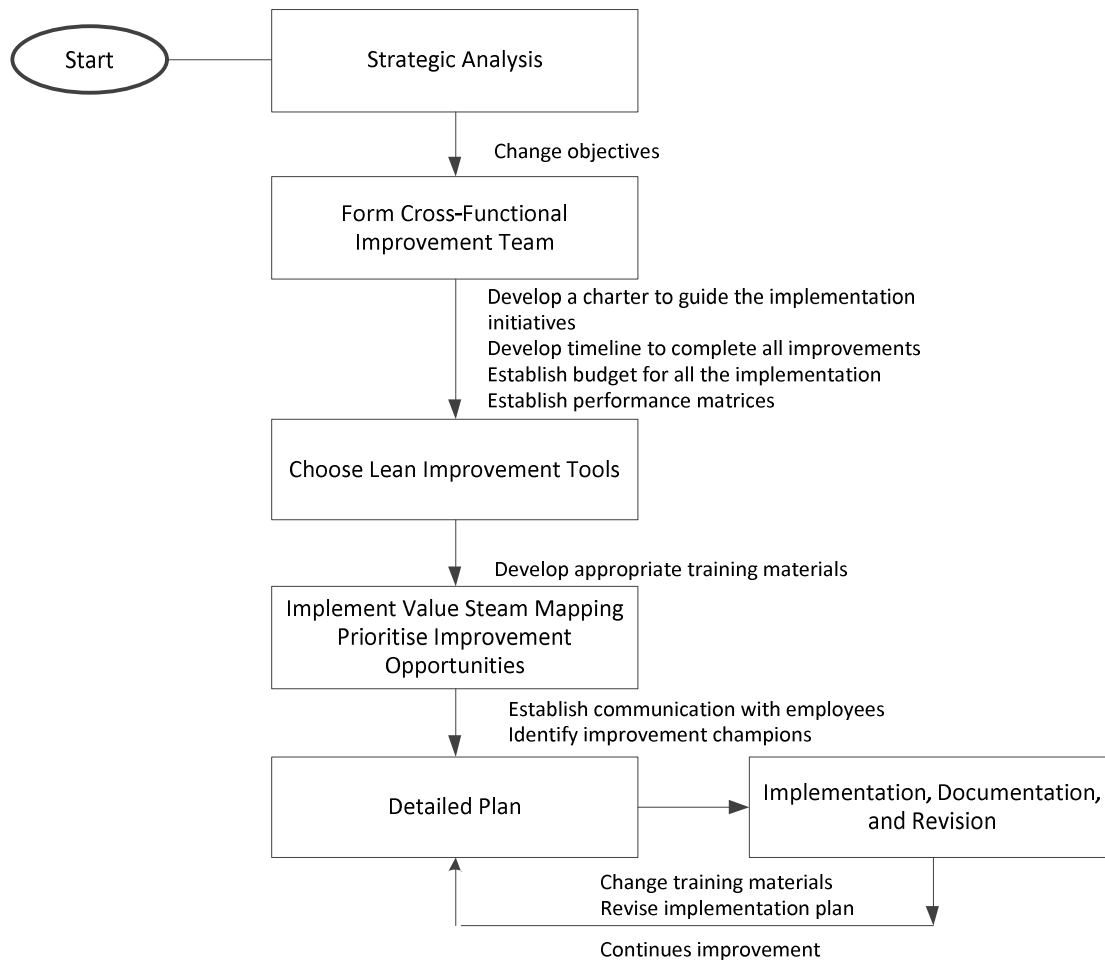


Figure 2-8 Six steps lean manufacturing implementation framework (Chakravorty, 2010)

The focus in this stage is to establish the need for lean by having a clear picture of customer needs and wants. In the second step, the company formed a high level cross functional team consisting of all departments' heads (steering committee) to guide the implementation and the vice president of operations championed the initiative. The team performed several activities to set a solid foundation from which to start off to improve the company operations. For instance, the team developed a charter for all improvement activities, set a timeline for implementation, analysed the existing process, and established lean metrics to measure implementation progress. The next

step was to develop simple improvement tools, which could be easily used by shop floor workers to facilitate improvements; the tools included value stream mapping, problem-solving approach, and the concept of waste. At this stage, the team provided training on process improvement, the content of the training was in the form of interactive simulation games, illustrations, and examples. After that value stream mapping of the company's operations was developed to understand the stages of products / parts flow. Since the team was not able to address all problems simultaneously, it was needed to prioritise improvement opportunities. The steering committee then have taken few steps towards developing a detailed implementation plan. For example, lower-level cross-functional improvement teams have been setup to carry out the implementation from the bottom up and champions to manage the teams during the implementation have been selected. Also, it has been ensured that all team members have been familiar with the product flow and then should be able to "put in words" the possible problem statement. As a final step in the framework and under the supervision of the steering committee, the champions with their improvement teams orchestrated 5S application to enhance workplace and to control inventory. Moreover, a simple pull system was implemented as well. A fixed number of jobs have been allowed in the system based on the estimated output capacity of the system. As soon as a job is completed, another job is released into the system. Reducing waste from the system resulted in fewer jobs being allowed in the system and therefore jobs on production or assembly have been controlled. Following the initial two implementations, several lean activities had simultaneously been implemented over time any many positive impacts on company's operations have been reported. For example, lead-time was reduced by 25%, WIP inventory was decreased by 30% and there was a significant improvement in quality problems.

2.6.3 Framework for Lean Manufacturing Implementation in SMEs

Helping small and medium enterprises (SMEs) configuring and implementing a lean manufacturing system (LMS), Dombrowski, *et al.* (2010) developed a holistic

framework consisting of four main levels and seven different implementation steps as shown in Figure 2-9.

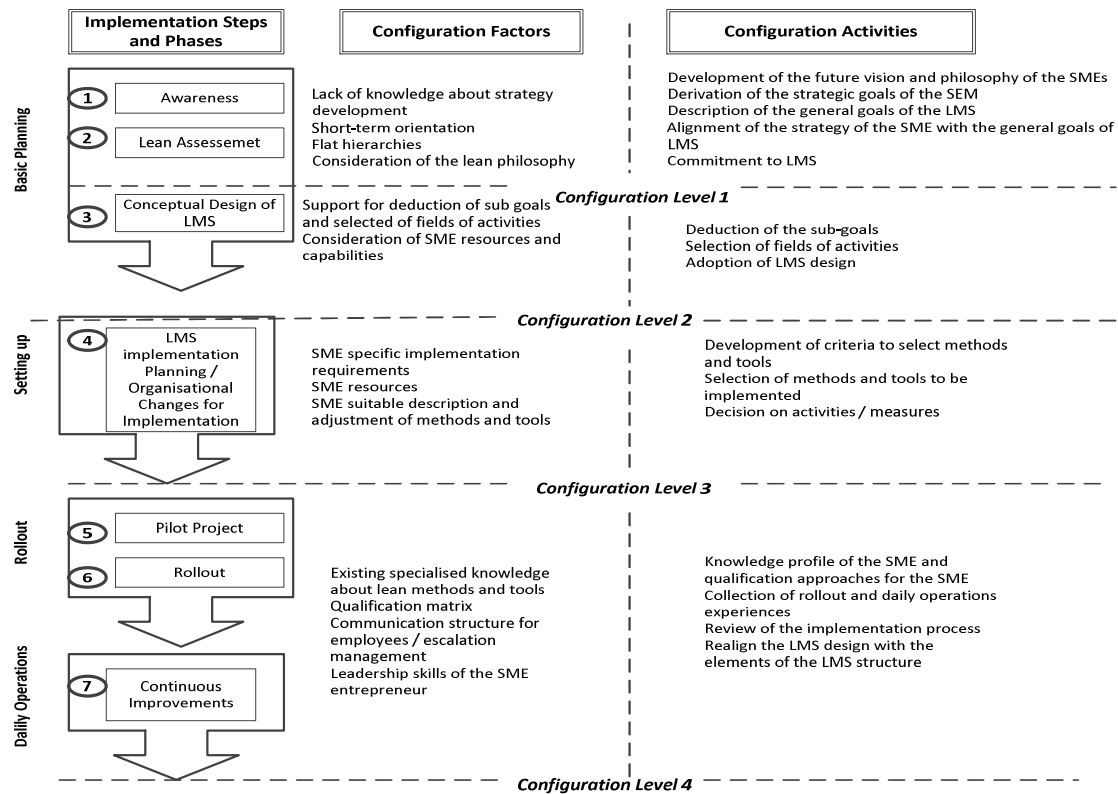


Figure 2-9 Framework for lean manufacturing implementation in SMEs (Dombrowski, *et al.* 2010)

The framework illustrates the factors that a company should consider to configure a LMS and the activities that should be executed during the configuration process. Usually the implementation of lean starts with the awareness and then follows by company lean assessment /strategic planning. In the first level of this framework, some factors as to a company's strategy development should be taken into account, for instance: The ability of the company to develop its strategy, the type of company's organisational structure, and whether the company tends to focus on short or long term planning. That should help the company develop its future vision and determine its general strategic goals (competitive priorities) which should be aligned with the general goals in LMS.

In the second configuration level and due to their limited know-how resources, SMEs should seek external support to determine its sub-goals and select the required activities to achieve them.

In the third level of the implementation process, several requirements and resources for implementing lean should be addressed. For instance, team building, the person who will play the role of champion, setting communications paths, setting key performance indicators, selecting the proper and suitable methods and tools. Tools should be selected according to several criteria such as company strategic goals, lean knowledge level, and financial resources. For example, if the a company aiming to increase product quality by detecting and eliminating defects in manufacturing processes in early stages, thus the company should select tools related to that goal, such as Poka Yoke or practice Jidoka. The last level supports the company to improve the LMS continuously by carrying out some activities. For instance, examining the level of lean knowledge among the employees, and tracks the progress of each worker by utilizing a qualification matrix. A pilot project will be used as a learning foundation telling us about any necessary changes required for the LMS to be adoptive to new implementation environment.

2.7 Lean Manufacturing Implementation Roadmap

Many researchers have argued that there is no a universal formula for implementing lean and asserted that the journey to leanness is usually embarking on a case-by-case basis (Bhasin, 2012). It depends on the company's current state and where it wants to be in the future, every organisation is unique and likely to have distinctive problems and constraints.

Considering that, Anvari *et al.* (2011) have developed a dynamic roadmap to help companies determine which lean tools to be implemented based on type of industry and the current state of the company. As shown in Figure 2-10, the framework consists of four main phases besides one initial phase.

- Phase 0: Initial Investigation
- Phase 1: Prepare
- Phase 2: Identify Pilot Project
- Phase 3: Expend
- Phase 4: Pursue perfection

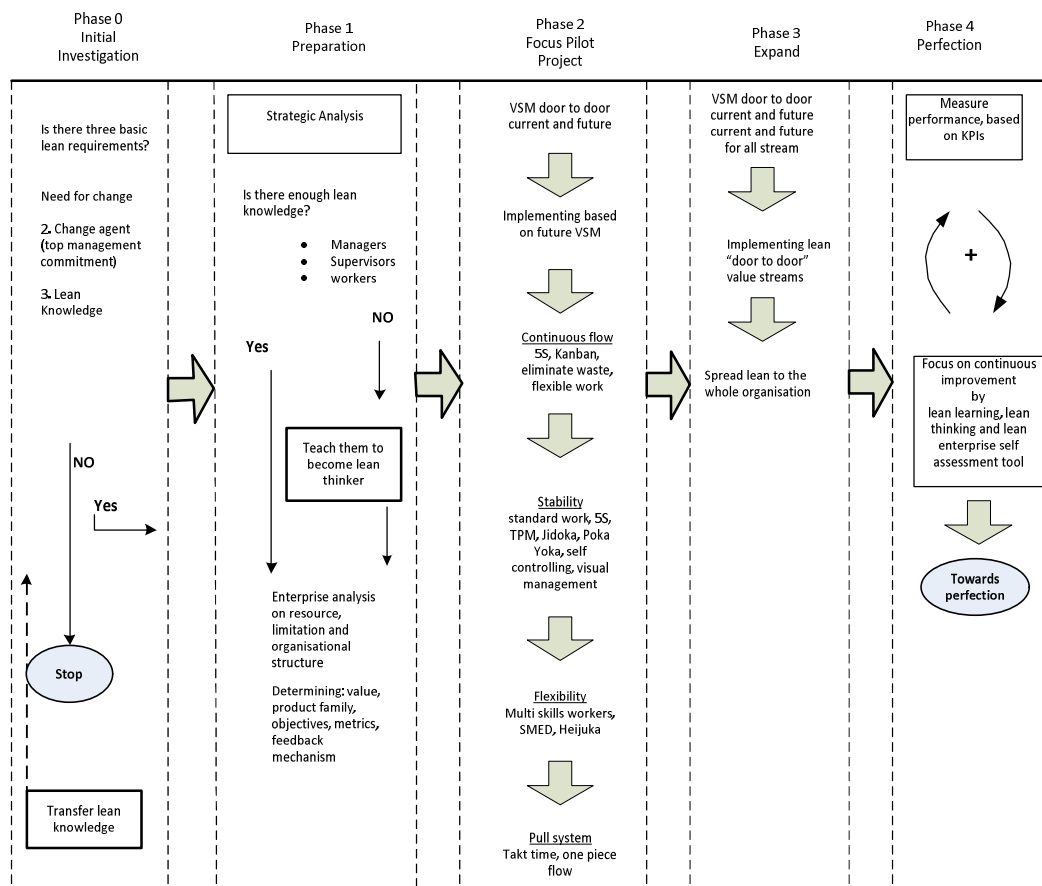


Figure 2-10 Dynamic roadmap to lean manufacturing (Anvari *et al.* 2011)

As a first step, the company must be diagnosed to have a clear picture of where it currently is. Level of management commitment, change agents, lean awareness and knowledge are usually investigated in this phase. Proper selection of the change agents is vital as success depends on their motivation levels, flexibility, and ability to lead others. It is highly recommended that the change agents have assumed different roles across the organisation. A change agent with a high level of lean-related knowledge should lead to short-term improvement and long-term sustained change (Done *et al.*, 2011). The results of the investigation will provide indicators whether or not to start

the initiative. The next step is to prepare the company by identifying and addressing critical company requirements using Hoshin Kanri / policy deployment. Strategic planning is carried out to analyse the company whole system in order to identify the value, objectives, policies, procedures, metrics, and feedback mechanism. In the next stage, a family product should be selected as a pilot project to map the value stream (both current and future). Based on future value stream map lean tools and techniques are implemented according to their major role and their sequence. Then the model of pilot project can be expanded to whole system. In the final stage, perfection is pursued through feedback and continuous improvements and Plan – Do – Check - Act (PDCA) cycle.

2.8 Sequence for Implementing Lean Manufacturing

The sequence of lean activities implementation differ from case to case and depends on several elements such as the particulars of the current state, nature of manufacturing processes and type of waste (Lee, 2007; Moyano-Fuentes and Sacristán-Díaz, 2012). Taking a cue from Anvari *et al.* (2010) an order of precedence lean steps classification, the researcher has identified the common steps being taken to leanness and their sequence as they have been emphasised by various researchers as shown in Table 2-4. That sequence is supposed to give the researcher insights and would be helpful when identifying the activities' sequence in the aimed lean manufacturing transformation strategy.

Table 2-4 Common sequence of lean manufacturing stages and steps

Author	Stage 1: Preparation								Stage 2: Design					Stage 3: Implementation				
	Steps in each stage																	
	1	2	3	4	5	6	7	8	1	2	3	4	5	1	2	3	4	5
Åhlström and Karlsson, (2000)								*	*					*				
Hines and Taylor, (2000)			*				*	*	*		*		*	*				
Dombrowski <i>et al</i> , (2010)		*	*	*				*			*		*					
Hodge <i>et al.</i> , (2011)		*	*	*			*		*				*	*				
Wong and Wong,(2011)			*					*	*		*		*	*	*			
Mejabi,(2003)			*		*	*		*	*		*		*	*				
Upadhye, <i>et al.</i> ,(2010)	*		*		*				*		*							
Wan and Chen (2009)						*		*	*	*			*	*				
Anand and Kodali, (2009 a)				*	*	*		*	*						*			
Anand and Kodali, (2010 b)		*	*	*					*	*	*			*		*		
Chakravorty, (2010)								*										
AlukaJ, (2003)	*	*	*		*	*			*	*		*	*	*	*	*	*	
Rose, <i>et al.</i> ,(2010)	*			*		*		*	*	*	*			*	*			
Sánchez and Perez,(2001)		*							*					*				
Dombrowski and Zahn, (2010)						*					*							
Anvari <i>et al.</i> , (2011)	*							*	*					*				
Turesky and Connell,(2010)		*				*			*					*				
Aulakh and Gill, (2008)						*		*	*		*			*				
Mo, (2009)						*			*		*			*				
Rivera and Frank Chen,(2007)								*						*				

The results of the comparison that was conducted in Table 2-4 are presented in **Error! Not a valid bookmark self-reference..**

Table 2-5 Frequency analysis of the sequence of lean steps

Important Priority to Leanness	Frequency of Occurrence
1. Mapping the value stream	18
2. Pilot project	16
3. Identify need for change	13
4. Identify location needing improvement	11
5. People training	10
6. Establishing the objectives	9
7. Understanding waste	7
8. Strategic planning	5

The results of the comparison that was conducted in Table 2-4 are presented in **Error! Not a valid bookmark self-reference..**

Table 2-5 presents the frequency analysis of the sequence of steps being taken to leanness by the selected researchers. As it can be seen, the vast majority of the authors stressed the importance of value stream mapping as an effective tool in implementing lean manufacturing. Also, among the reviewed studies, 16 authors have reported the importance of pilot project to introduce lean and its tools and techniques to the organisations that took the initiative. The reason behind restricting the implantation of lean to a specific area is the organisation's desire to see the effect of lean in action before expand it throughout the area or the production line or to the entire organisation. Starting with a pilot project also gives workers self-confidence and gets them comfortable with the tools and techniques. Other activities such as employees training and identify the need for change have been explicitly prioritised.

2.9 Lean Practical Examples: Successful Implementation Case Studies

Chines *et al.*, (2010) have introduced lean manufacturing to materials handling system in a petroleum drill bits manufacturer aiming to find a smooth way to move parts and their components through a variety of manufacturing process.

The management decided to start the implementation process by selecting a project that could yield quick productivity gains. Hence, a single cell was addressed as a pilot project (crown machine cell).

The next step was to identify the areas of opportunities to reduce the potential waste in material handling system by mapping the current states of the system operations. Mapping the current state has disclosed the following possible improvement areas - locations where changes in materials handling system may have an impact on waste reduction - :

- Transporting and placing shank components in the stock area
- Moving shanks from inventory to workstation
- Staging material to machine
- Handling, moving, attaching components to the crown

After identifying the pilot project and disclosing the areas of improvements, the next step was reviewing the business goals and comparing them with the four identified areas improvement. The top management has selected the following goals:

- Enhance productivity
- Reduce cycle time
- Reduce incident rate
- Reduce hand injuries

Comparing the business goals to opportunities of improvements, several solutions and their affects have been proposed to meet business goals. Among the proposed general set of solutions, the management has prioritised the ones that contribute well

in addressing the identified waste and meeting the business goals. The selected solutions were:

- Changing the way shanks are handling and staging into the machine cell
- Changing the location of shank inventory
- Changing the way shanks are attaching to crown by incorporating a new handling device

Based on business goals, identified areas of potential improvements and the prioritised solutions, the objectives of lean manufacturing was to introduce and implement a material handling system or procedure which help in eliminating waste during materials handling process, and also to increase the operators productivity. To meet those objectives, several lean manufacturing principles and tools (space utilisation; visual control; 5S; communication plan; Kanban system and workers tanning and empowerment) have been selected to bring about shanks a storage device that helped in achieving the lean manufacturing objectives as to material handling system. Based on the selected lean tools, the device was designed in such a way that ensures smooth flow of materials and helps the operator handles material more ergonomically. In addition, shanks have been stored in the device in manner that enables parts to be pulled as needed creating a Kanban pull system. Storing parts by size enables the operator to quickly note when stock levels drop down to be restocked by inventory workers in the right time and right quantity. Training was also put in place to make workers fully aware of best practices when using the device. Workers also have been advised to have clear path of communications to keep materials flow and also they must have good knowledge of their roles and responsibilities. After the device has been installed and operators and all workers became familiar with the new method of handling the shanks, the next step was to monitor the implementation process and then map the future state (after the implementation) to be compared with the state map before the implementation to discover the improvements that have been made. Last stage of the implementation process was to evaluate the

performance by weighing up the objectives of lean manufacturing against selected lean metrics to learn about the effect of the implementation of the proposed solution.

Chapter 3 Literature Review of Critical Success Factors for Lean Transformation

3.1 Introduction

The need to manage change to lean manufacturing has widely been addressed in operations management literatures (Bhasin and Burcher, 2006; Crute *et al.*, 2003; Motwani 2003). The successful management of lean change requires organisations to thoroughly understand certain factors (managerial and operational factors) that govern and facilitate the process of successful lean transformation. The awareness of these critical successful factors (CSFs) will benefit the companies, which are embarking on a lean journey (Kundu and Manohar, 2012).

The critical success factors (CSFs) are defined as the essential elements that are required and vital to reach success. These factors must be achieved by the organisation to identify which areas will produce the greatest “competitive leverages” (Rockart, 1979; Rungasamy *et al.*, 2002). The CSFs for a particular improvement programme are the vital ingredients of the programme and the processes that can be controlled by the management to meet a company’s aims and objectives (Boynton and Zmud, 1984; Schultz *et al.*, 1987).

In the context of lean manufacturing, CSFs imply that if the conditions associated with the factors are not achieved; then sustainable lean manufacturing transformation has little chance of becoming reality (Timans *et al.*, 2012). Therefore, identifying those factors that explain lean manufacturing transformation process is a priority for those

organisations that are planning to embark on a lean manufacturing project (Forrester *et al.* 2010; Jayaram *et al.* 2008; Rich *et al.* 2006; So and Sun 2011).

These factors act as facilitators or inhibitors during lean manufacturing transformation process (Karlsson and Åhlström 1996; Bruun and Mefford 2004; Hines *et al.* 2011; Fullerton and Wempe 2009; Serrano-Lasa *et al.* 2009). In order to benefit from lean initiatives, organisations are required to understand lean CSFs, so they can understand the risk of failure associated with lean adoption and therefore take actions to ease that risk (Kundu and Manohar, 2012).

In the present study, a systematic literature review on lean critical success factors has been conducted. According to Cook, *et al.* (1997), and Kitchenham, (2009), this kind of literature review follows replicable and transparent steps. The main objectives of a systematic review are to identify key contributions and issues in a given area of research, and to identify common outcomes that are often studied and emphasised by different researchers and experts in the field (Becheikh *et al.* 2006).

Four steps have been set out as a preferred manner for identifying the studies that have addressed lean critical success factors:

1. Identify the database that the researcher has access to, such as Business Source Complete (EBSCO), ABI Inform Complete (ProQuest), and Scopus.
2. Identify studies that investigated lean success factors in developed well-industrialised countries. (*Section 3.2*)
3. Filter and classifying the identified lean success factors. (*Section 3.3*)
4. Identify studies that focus on current issues in transforming lean to developing countries. (*Section 3.4*).

3.2 Lean Critical Success Factors in Developed Countries

Lean practices have been and continue to be largely adopted in the manufacturing sector within different industries in the developed countries. In fact, there is considerable evidence that western companies have gained competitive advantages,

achieved greater efficiencies, and have boosted productivity and improved results by being successful lean implementers (Portioli-Staudacher and Tantardini, 2012; Timans *et al.* 2012).

As an example of the popularity of lean manufacturing in European developed countries, the UK government has launched a productivity improvement initiative known as the MAS “*Manufacturing Advisory Service* (Achanga *et al.* 2012) in order to promote the use of lean manufacturing within the SMEs. In addition, an organisation called “*Productivity Europe*” has been helping European companies to adopt and implement lean practices for more than 25 years (Göthberg and Simonchik, 2013). Another example, the ERIP project “*European Regions for Innovative Productivity*” has launched a new lean change methodology to provide the SMEs with a way to adopt lean sustainably (April *et al.* 2010). In addition, a programme funded by the British government called NEPA “*The North East Productivity Alliance*” has helped manufacturing companies in North East of England to improve performance and productivity through the adoption of lean practices and knowledge transfer (Herron and Hicks, 2008).

Therefore, the developed western companies can be a good resource to facilitate the emulation of lean best practices and also to allow for a suitable level of comparison between the developing and the developed context, which is considered among this research pillars.

Following point number 2 listed under section 3.1, a number of lean success factors have been identified. A sample of these findings has been presented in Table 3-1, and the rest have been illustrated in Appendix 1. The identified factors alongside their related studies and the countries where the studies have been conducted, as well as the used methodology have also been presented.

It might be worth to mention that the absence of a factor should not be understood as a complete rejection of it or of the activities and practices used to reach it. Other factors are available in different formulas, however only few factors have been

presented below, the ones that have been explicitly and intensively mentioned in the literature. They are as follows:

Table 3-1 Sample of lean success factors review in developed countries

Country where research conducted	References	Focus of Research	Research Design / Methodology	Key Findings / Remarks
1. UK	Achanga <i>et al.</i> (2006)	Identifying critical factors required for lean implementation in SMEs	<ul style="list-style-type: none"> • Literature review and • semi-structured questionnaire • visitations and observation of firms practices • personal interviews • a ten case study 	Lean critical success factors: <ul style="list-style-type: none"> • Leadership & management • Financial capabilities • Skills and expertise • Organisational culture
2. UK	Crute <i>et al.</i> , (2003)	key drivers for Lean and examine the assumption that cross-sector transfer may be difficult.	<ul style="list-style-type: none"> • case studies • semi-structured interviews • literature review on lean adoption process criteria • observations 	key factors affecting the rate of lean change: <ul style="list-style-type: none"> • management commitment • change strategies • organisational cultural • focusing on a specific product value stream • time and space for change

- Awareness of lean concepts and senior management commitment
- Lean manufacturing change champion
- Pilot project
- Organisational culture change
- Knowledge transfer and training
- Organisational culture change
- Workforce empowerment

- Job security
- Stakeholders communication

3.2.1 Awareness of Lean Concepts and Senior Management Commitment

The importance of the role of the senior management understanding and commitment to change process is widely accepted in the literature (Mefford 2009; Timans *et al.* 2012; Turesky and Connell, 2010). The senior management commitment could be demonstrated in the form of developing clear vision, ensuring sufficient financial resources, and providing strategic leadership (Barraza and Ramis-Pujol, 2010).

It has been found that the direct role of the top management in leading the transformation to lean manufacturing practices reinforced the importance of the lean initiative and aided in opening communication lines with employees on the shop-floor (Worley and Doolen, 2006).

Deflorin and Scherrer-Rathje, (2011) concluded that high level of management commitment is characterised by credibility, consistency, and support. Lack of commitment may lead to issues such as limited access to resources, unusual delay in decision-making process, and ineffective flow of communication (Kundu and Manohar, 2012).

These perspectives are in line with the research literature which has totally emphasised the importance of top management commitment and support in adopting lean successfully (Achanga *et al.* 2006; Barraza and Ramis-Pujol, 2010; Coronado and Antony 2002; Crute *et al.* 2003; Dora *et al.* 2012; Scherrer-Rathje *et al.* 2009; Timans *et al.* 2012). Senior management must respect employees' efforts and work to create interest in the implementation and communicate the change to all people in the company. Scherrer-Rathje *et al.* (2009) stated that in the absence of management commitment employees may not realise the importance of lean, which in turn lead to employee not being totally interested in lean efforts, which will negatively contribute to the lean success.

3.2.2 Lean Manufacturing Change Champion

In order to improve an organisation lean readiness, appointing an internal credible change champion is one of the steps that must be taken (Achanga, *et al.* 2012). Lean manufacturing champion is usually the implementation team leader and he/she sets up and chairs the lean change steering committee to ensure best practice is transferred across all functions. The implementation of lean manufacturing initiative needs support at the grass-roots level in the organisation, and it becomes incumbent on the lean champion to make the organisation aware of the importance of lean at all levels (Panizzolo *et al.*, 2012). Rother and Shook, (2003) stated that the champion of lean is considered vital when it comes to embarking on a lean initiative. The lean champion must exhibit specific qualities and have capable communication skills to disseminate lean concepts throughout the organisation. The lean manufacturing champion should act only as a facilitator and the process must be owned by the actual people who operate it.

3.2.3 Pilot Project

Running a pilot project to have an organisation motivated for lean and to exhibit quick victories is widely accepted in literature (Losonci *et al.*, 2011; Scherrer-Rathje, *et al.*, 2009).

Pilot project can be used as a classroom in the education process, because many people tend to understand things easier when they look at tangible example. When selecting an area to apply lean in, the management needs to take into account two things (Anvari *et al.*, 2010):

- Ensure that the selected project is a success because the rest will be built upon it
- Select the project that will easily demonstrate tangible benefits

One of the advantages of using a pilot project is encouraging the employees by giving them chances to personally experience the real value of lean in early stages; (Losonci *et al.*, 2011).

Scherrer-Rathje, *et al.*, (2009) reported two lean manufacturing implementation projects within the same company; the first was not successful due to employee resistance while the second achieved a level of success. In the second attempt, the employees had been involved as early as possible in lean implementation by using a pilot project, which enables the company to show very quickly the benefits of adopting lean. Once the success of the used pilot project is proven, the top management rolls out the programme.

3.2.4 Organisational Culture Change

Dealing with differences in organizational culture is the number one challenge facing an organisation transforming to lean (Herron and Braiden, 2007; Holweg, 2007). Wong 2007 has argued that the organisational culture is the most important driver for creating strategies to achieve the company's objectives. An organisation's culture can have a positive or negative effect on the organisation's lean efforts (Atkinson 2010; Vinodh and Balaji 2011).

Before taking the initiative to adopt lean manufacturing, the company is required to change its culture and the way its employees behave (Shah *et al.*, 2008; Angelis, *et al.*, 2011). This is because the company's culture and change management is considered as an underlying cause behind every lean programme failure (Bicheno and Holweg, 2009; Saurin *et al.*, 2011; Panizzolo, *et al.*, 2012).

Hines *et al.*, (2004) concluded that it might be easy for an organisation to set the structural elements of lean manufacturing however; companies usually face difficulties while adopting the essential organisational culture and mind-set. Wong and Cheah, (2011) investigated the relationship between the attributes of organisational culture

with the implementation of lean manufacturing. They argued that factors such as values, beliefs, and ideologies that affect the behaviours and practices of the workers in an organisation are very important in lean transformation. Organizational dimensions such as - the employee tendency to work in teams or individually; the nature of command and supervision whether is authoritarianism or liberalism; and the company's organisational structure is flat or hierarchical – are found influential in lean manufacturing transformation.

3.2.5 Knowledge Transfer and Training

One of the problems of employee lack of acceptance of lean initiatives is caused by the lack of employee education and training (Harris, 2004). Through creation of a learning culture and not just using the lean tools, the companies can make successful improvements. In order to get workers to become more involved in lean programmes, the company may initiate a company suggestion scheme providing cash incentives for recommendations leading to process or equipment improvements (Kocakülâh *et al.*, 2011). The team take on leading a lean initiative must be well trained to effectively produce the desired results and training program must provide in a clear and concise manner with respect to understanding lean principles and applying its techniques (Sim and Rogers, 2009). Training programs are usually provided by hired consultants or in-house lean champions and combine both classroom learning with shop-floor practical exercises.

The motive for adopting lean must be well relished and accepted and organisations must provide consistent training programs to all members involving in lean implementation (Turesky and Connell, 2010; Worley and Doolen, 2006). Investing in workers training may help in producing workers with multi-tasking capabilities and being able identifying process bottlenecks and contribute well to waste reduction (Panizzolo, *et al.* 2012).

3.2.6 Workforce Empowerment

Anand and Kodali, (2009a) have found that when it comes to the actual implementation shop floor employees have more responsibility than other stakeholders of the organisation do. They claimed that 17 lean manufacturing practices are usually carried out by shop-floor workers. In line with that, Hines *et al.* (2011); Panizzolo *et al.* (2012); Saurin, *et al.* (2011) emphasised the importance of employees engagement in the continuous improvement activities, expansion of their autonomy and responsibility.

Employees being under close inspection by top management resulted in work conditions of blame culture. This is one of the factors considered to affect the workers' ability and desire to involve in lean manufacturing activities (Crute, *et al.*, 2003). Similarly, Hofer, *et al.* (2011) have found that employee involvement was hindered by social and cultural natures, workers tend to defer to their supervisors which resulted in putting workers in a risk aversion environment which considered as a vital barrier to workers involvement. Organisations must put efforts on building a culture of experimentation that should embrace failure as a learning experience, which leads to employee empowerment.

Snee, (2010) and Scherrer-Rathje *et al.* (2009) concurred that an employee autonomy and empowerment is of a vital importance and must be supported and enabled to avoid some effects such as employee frustration, too long decision-making processes, and necessary requests for lean success being refused. The importance of bringing employees together and involving them in lean decision-making process is widely mentioned in the literature (Benders and Van Bijsterveld, 2000; Bhasin, 2013; Crute *et al.*, 2003; Forza, 1969; Meybodi, 2013 and Poksinska *et al.* 2013).

3.2.7 Job Security

Job security has been found as a major factor affecting workers contribution to lean implementation (Sim and Rogers, 2009; Yu *et al.*, 2011). One of the procedures to encourage workers to participate in lean activities was that job security provisions had

been written into the collective bargaining agreement so that no one would be involuntarily laid off due to the lean principle of eliminating manufacturing resources (Kocakülâh *et al.*, 2011). Ensuring job security contributes positively to lean adoption process by eliminating fear and distrust among workers (Mathew and Jones, 2013; Sadikoglu and Zehir, 2010).

3.2.8 Stakeholders Communication

All levels of employees are involved in lean implementation. Consequently, the need arises for a good communication process to enable a smooth flow of processes (Puvanasvaran *et al.*, 2009). Communications can be verbal between individuals, written report or oral reporting to a board or as instructions given to a group of subordinates. Examples of communication subjects for the management and workforce are:

- Overview of the change programme, detailing the compelling need, approach to be taken and the likely outcomes of change
- Regular discussion between the implementation team and the workforce to capture problems or suggestions for improvement
- Regular meeting between the implementation team and the lean manufacturing steering committee

The communication between team members cross all levels should be an authentic two-way process to pay off and once starts must be sustained (Bateman, *et al.*, 2004) and, gaps of information sharing cross functionally, among all levels and between shifts need to be eliminated (Turesky and Connell, 2010).

The above review provides valuable insights on the criteria and the factors that should be taken into consideration when an organisation is being transformed towards leanness.

The investigated literature yielded similarities in terms of defining lean manufacturing success factors. Even though, some of the identified factors – in comparison to others

– have only been supported by a few studies, they had not been dismissed in any studies as not pertaining to lean manufacturing success.

3.3 Filtration and Classification of Lean Manufacturing Success Factors

The classification of lean critical success factors in this research is based on the wide consideration in literature that lean manufacturing is a socio-technical system approach (Lathin and Mitchell, 2001; Lander and Liker, 2007; Marodin and saurin, 2013; Mefford and Bruun, 1998; Paez *et al*, 2004; Shah and Ward, 2007).

In lean manufacturing literature, there are two trends in terms of transformation models. While some focus more on the technical dimensions of lean, “hardware aspects”, others centre on social dimensions “software aspects” (Anvari *et al.*, 2011). During the last two decades, the main focus of literature was the tools and techniques aspect, however, the interest of lean has now been shifted from tools to human aspects (Nordin *et al.*, 2012).

The principle of “joint optimisation” of socio-technical theory suggests that a system’s objectives within an organisation are not achieved by only the optimisation of the technical aspects of the system but by both the social and technical aspects (Appelbaum, 1997; Clegg, 2000, Shani *et al*, 1992). As a result of the collaboration and the interaction between social and technical constituents of the system, the system should yield the anticipated results (Das and Jayaram, 2007). With regard to manufacturing systems, this implies that the adoption of a new system requires the introduction of new technical procedures (“technical aspects”) alongside new working practices (social aspects).

In this research lean manufacturing and its embedded central role of humans is viewed as a sociotechnical system. This suggests that social aspects and technical aspects of lean must be developed jointly for a lean manufacturing system to be appropriate to its environment. This is even more true in a developing country such as Libya where the culture and social environment are very different from the culture where lean was originated and popularised.

Therefore considering lean as sociotechnical system should help the researcher to gain a better understanding of successful factors, and thus contribute to the understanding of introducing lean to a developing country such as Libya. Lean manufacturing success is a result of a harmonious interplay between its technical and human aspects. This is especially true when introducing lean to a different country context with different culture context.

Finally, presenting lean as a socio-technical system perspective will be very helpful in providing an integrated view on the interaction of human and technical aspects within lean. Thus, a socio-technical systems perspective has been followed in this research to classify and group lean critical success factors that have already been identified in the previous sections. This approach is useful in order to emphasise the importance of human and technical aspects for lean manufacturing success factors when the intention is to develop a strategy to adapt lean to a different country context. The identified lean success factors have been classified into the four subsystems that form the basic structure of a socio-technical system, namely work organisation, external environment, human, and technical (Figure 3-1) (Kleiner, 2006).

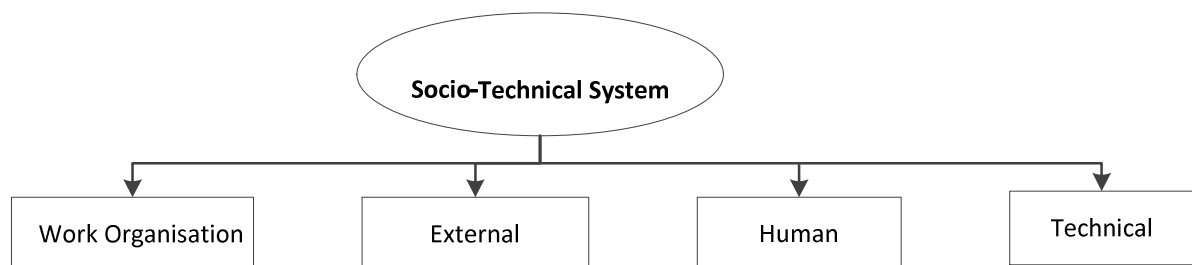


Figure 3-1 Basic structure of a social-technical system (Kleiner, 2006)

Many researchers have emphasised the necessity of viewing lean manufacturing as a socio-technical systems approach (Marodin and saurin, 2013; Paez *et al*, 2004; Shah and Ward, 2007). Lander and Liker, (2007) further elaborated the importance of interplay between social and technical aspects of lean. They described lean as based on technical (tools) aspects and social aspects (people).

3.4 Transferring Lean Manufacturing to Developing Countries

Despite the acceptance, popularity, and governmental & non-governmental encouragement of companies to embrace lean thinking more broadly in developed countries, the adoption of lean in organisations in developing countries is not widely spread in comparison to its western counterparts. Although lean practices have already been applied in many developing countries (Al-Najem *et al.* 2013; Bhutta *et al.* 2013; Karim *et al.* 2011; Singh and Ahuja, 2013; Zhang *et al.*, 2012), the level of understanding its underlined philosophy is varying (Al-Najem *et al.* 2013). It is very recently that organisations in developing world have addressed lean adoption as an attempt to improve productivity and enhance performance (Bhutta *et al.* 2013).

Marodin and Saurin (2013), systematically reviewed lean manufacturing literature that have been published from 1996 up until 2012, they found that only 14% of the studies have been conducted in developing countries whereas 86% have been carried out in the developed western countries. There are a number of studies that have examined lean manufacturing issues and main barriers when companies adopt lean in developing countries. Table 3-2 presents a sample of those studies and the rest have been illustrated in Appendix 2.

Table 3-2 Sample of barriers of lean manufacturing in developing countries

Country where research conducted	References	Focus of Research	Research Design / Methodology	Key Findings / Remarks
1. Pakistan	Bhutta <i>et al.</i> (2013)	Exploring the diffusion of lean manufacturing practices in eight textile firms	<ul style="list-style-type: none"> • Structured interviews • plant tours 	<ul style="list-style-type: none"> • Pakistani firms are in the early stages in implementing lean manufacturing • Much work have to be done to truly implement lean manufacturing • Opportunities are available for Pakistan firms to improve their operating performance by properly adopting lean practice.
2. Saudi Arabia	Karim <i>et al.</i> (2011)	Evaluating the main lean	<ul style="list-style-type: none"> • Literature review • Semi-structured 	<ul style="list-style-type: none"> • Barriers of lean manufacturing

		barriers and investigating lean implementation levels	questionnaire	implementation: <ul style="list-style-type: none"> ○ Organisational culture ○ Lack of management commitment ○ Lack of skilled workers
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For instance, Karim *et al.*, (2011) evaluated the barriers of lean implementation in a sample of Saudi manufacturing organisations. They contended that organisational culture, lack of top management support and lack of skilled workforces are the main lean barriers.

Furthermore, Al-Najem *et al.* (2013) found that the current operational and managerial activities practiced by Kuwaiti manufacturing companies do not encourage lean manufacturing environment.

Many factors that negatively affected lean success level have been identified, the most significant have been: the low level of employee skills and education, lack of effective communication channels between workers and departments, lack of urgency / pressure to convert to lean due to the lack of competitiveness in the market, and lack of government support.

Singh and Ahuja, (2013) discovered lean adoption inhibitors in Indian manufacturing companies. They emphasised many factors that contribute to lean failure such as: lack of commitment at various management levels, lack of customer awareness about product quality, lack of teamwork, lack of knowledge and training programmes, poor maintenance, lack of understanding lean techniques.

A cursory review on of the recent literature, Table 3-3 provides a summary of the main obstacles along with literature sources that affect organisations the most in their attempts to leanness.

Table 3-3 Main barriers to lean manufacturing implementation

Barriers to Lean Manufacturing	Literature Sources
1. Culture: lean is viewed as set of tools and not	Bhasin, (2012); Herron and Hicks, (2008);

as an ideology of radical culture change	Mothersell <i>et al.</i> , (2008); Nordin, <i>et al.</i> (2012); Pradabwong, <i>et al.</i> (2012)
2. Poor internal communication system	Puvanasvaran, <i>et al.</i> (2009); Sim and Rogers, (2008); Worley and Doolen, (2006).
3. Financial related barriers	Achanga <i>et al.</i> (2006) Nordin, <i>et al.</i> (2012).
4. Workers attitudes	Bhasin, 2012; Nordin, <i>et al.</i> 2012; Panizzolo <i>et al.</i> 2012; Saurin <i>et al.</i> (2011); Glover <i>et al.</i> (2010).
5. Lack of benefits measuring system	Rivera and Chen, (2007); Bayou and De Korvin, (2008).
6. Resistance / reluctant to change	Bhasin, 2012; Hodge <i>et al.</i> (2011); Sim and Rogers, (2008); Silva <i>et al.</i> (2012); Womack and Jones, 2005
7. Lack of knowledge and training programmes	Pradabwong, <i>et al.</i> (2012); Bayou and De Korvin, (2008).
8. Management style	Bhasin, (2012); Glover <i>et al.</i> (2010); Saurin <i>et al.</i> (2011)

3.5 Proposing Lean Success Factors for Developing Countries

Based on the analysis of lean critical success factors, and mapping those factors in developed countries with lean barriers and current issues in developing countries, the researcher has proposed a list of potential critical success factors that are expected to facilitate and positively contribute to lean manufacturing adaption to manufacturing enterprises in developing countries. These proposed factors include:

1. Top management commitment and support
2. Provide lean education and training programmes
3. Employee involvement
4. Communication channels between workers
5. Organisational culture change
6. Developing reward and recognition system
7. Selecting proper lean tools

This is to help organisations in developing countries overcome obstacles to successful lean transformation in order to improve operational and managerial competencies and increase their level of preparedness and state of readiness for market competition.

The above proposed lean success factors have been found in line with what was expected regarding the status of lean manufacturing related activities in the Libyan industry, which give more support to the proposed list of success factors. For example, Graisa and Al-Habaibeh, (2011) have identified several factors that were behind the absence of implementation strategy for the concept of total productive maintenance (TPM) in cement industry in Libya, which affected the production levels and the productivity of the plants included in their study. They found that the lack of human resources development is the main barrier behind that issue. Furthermore, lack of top management support and commitment, lack of reward system, lack of workers motivation were also negatively contributed to the absence of TPM implementation. In addition, Hokoma *et al.*, (2010) found that the implementation levels of just-in-time practices and TQM in Libyan iron and steel industry is in very modest levels. They identified several barriers behind the very limited implementation degree (i.e., lack of knowledge and training; lack of top management support and commitment, lack of detailed action plan; low level of understanding of manufacturing and quality management systems). In addition, Arshida, (2012) investigated the critical success factors for adopting TQM in Libyan manufacturing companies. He identified the main impediments as: poor vision and plan statement, government influence and lack of top management commitment. The key success factors that were identified in this study included: top management commitment, education and training, supplier quality management, employee involvement, vision and plan statement, recognition and reward and customer focus.

Comparing the results that have been obtained from the field study in this research (as will be shown in Chapter 4) with the results described by the few available previous studies that have investigated only single lean manufacturing related practices in Libya, indicates a high level of homogeneity regarding the barriers that hinder the adoption of lean as a management philosophy. Those barriers – if they are tackled carefully – should facilitate the process of lean transformation to Libyan manufacturing organisations. This result suggests that a lot of work need to be done to systematically and comprehensively foster Libyan manufacturing companies to adopt lean

manufacturing successfully. In other words, in order to help Libyan manufacturing companies to set the right transformation path to lean manufacturing, a lean manufacturing transformation strategy (LMTS) is required. This strategy (which is the main aim of this study) is to be proposed and explained in details in Chapter 6.

3.6 Research Gaps

Reviewing lean manufacturing literature as to implementation level revealed the following research gaps which are directly relevant to this research project:

1. Lean Manufacturing has been proven as a source of competitive advantage to organisations. However published literature focus mainly on the tactical level rather than the strategic level. The tactical level is limited to those tools or techniques that are applicable within the specific context whilst the strategic level focuses on the creation of value. Therefore, a study is needed to investigate lean strategic level in more depth.
2. The literature review has not provided sufficient information on factors that affect the successful implementation of lean manufacturing within companies in the developing world.
3. Although lean manufacturing has been the focus of both, academics and manufacturing managers; researchers in the area have focused mainly on industries in developed countries. Therefore, there is a need for further work to address the introduction and application of lean manufacturing in developing country, such as Libya.
4. The issues related to culture, education, training, organisation structure, etc. are important in introducing and implementing lean manufacturing. Therefore,

there is a need for a lean manufacturing unifying strategy to aid the customisation of the work in the developing countries.

Chapter 4 Research Methodology

4.1 Introduction to Questionnaire Development

The research area on assessing the current lean readiness level and the adoption level of lean practices is challengeable in terms of designing the research instrument that thoroughly and comprehensively captures the different components of the concept and yet is applicable to organisations along a wide continuum of implementation progress (Bhutta *et al.* 2013; Shah and Ward, 2007). Therefore, to facilitate the present study's research instrument development, the researcher has reviewed a number of previous studies that employed questionnaire instruments and followed similar methodology (e.g. interviews, and observations) in capturing and assessing the use of lean manufacturing practices. A sample of the identified studies has been presented in Table 4-1 and the full list was shown in Appendix 3.

Table 4-1 Sample of studies to assess the degree of lean manufacturing adoption

Study	Investigated Area	Data Collection Method	Assessed Lean Manufacturing Practices
Sezen <i>et al.</i> , (2012)	Shop-floor	Questionnaire	Pull production, one piece flow, value stream mapping, process improvement, preventive maintenance, cellular manufacturing, 5 why, employee suggestion system, continuous improvement, Poka-yoke, waste elimination
Bhasin, (2011a)	Shop-floor and administrative	Questionnaire and Observations	Safety, flow, pull, reduce WIP, visual management, mistake proofing, continuous improvement, top management support, need for change strategy, lean champion, organisational culture

It was notable that most of the lean assessment past studies were limited to shop-floor practices investigating the operational perspectives of lean, lacking the strategic perspective components of the concept, such as: top management support and commitment, recognising the prevailing culture, the importance of lean champion, and linking culture to the company's performance.

In order to gauge the degree of preparedness of Libyan companies to adopt lean manufacturing, and to discover whether or not their practices are consistent with lean environment, a comprehensive questionnaire is required to capture their current operational and managerial activities. In other words, prior to initiating any lean manufacturing project, Libyan companies are required to know whether or not they have the proper foundation for launching the lean initiatives.

4.2 Structure of the Questionnaire

The development of this questionnaire has been based on the inspirations provided by past studies presented in Appendix 3, such as Bhasin, (2011a), Doolen and Hacker, (2005), Panizzolo, (1998). However, it was not a suitable choice to employ one of those questionnaires as they had been employed in the mentioned literatures. That is because the objectives of those studies differ from the main objective of this study. Therefore, it was not a wise decision to imitate the same measurement scales that have been used in those studies, as the purpose of the studies is different. This is consistent with Schmalensee, (2003) and Devlin *et al.* (1993) who argued that there are not best or perfect scales, scales change with time. They also advised that the selection of measurement scales is often predicated on research objectives.

Most of the questionnaires that have been identified in previous literature were designed to measure the degree of leanness in companies that claimed they have practiced and experienced lean for several years which is not the case in this undertaken research. For example, some of those questionnaires have emphasised the importance of practicing concurrent engineering in new product development

Meybodi, (2013); which has been proven to the researcher that Libyan manufacturing practices are far from being in this level.

This questionnaire is aiming to evaluate the Libyan subject companies' operational and managerial practices in association with lean. This is to provide a clear landscape whether or not the subject companies are capable to implement lean manufacturing.

In short, this questionnaire is aiming to gauge the readiness for lean and not to measure the degree of leanness in the targeted sector of this research (Libyan automotive industry).

In order to develop a questionnaire that clearly and effectively operationalises the concept of lean, the researcher used the definition provided by Marodin and Saurin, 2013 as a starting point. Marodin and Saurin, (2013) have defined the implementation of lean manufacturing as the process of applying a set of lean principles and practices, exploring their synergies and adapting them to a particular context. Given this definition, a well-structured questionnaire should not be limited to a specific lean practice (e.g. JIT or visual management) but it must cover all lean practices and principles that promote synergistic relationships which positively contribute to the success of lean manufacturing transformation, and that reflect and integrate the multi – dimensions of lean.

This is consistent with the conceptual definition proved by Shah and Ward, (2007). Their definition encompassed the underlying multi-dimensional and integrated structure of lean production. Shah and Ward, (2007) have suggested that a state of the art and a well-developed lean production strategy requires companies to address many lean practices / tools in their pursuit of lean production. They have advised companies that pursuit a lean system should make significant effort along a number of dimensions simultaneously.

Building on Shah and Ward, (2007) and Marodin and Saurin, (2013), and with their definitions as a basis the questionnaire has been customised by synthesising and tweaking a number of previously reviewed studies (Appendix 3). The following points have also been considered in designing the questionnaire:

1. Utilising the lean manufacturing best practices and lean critical success factors identified in literature.
2. Integrating several previous questionnaires and lean assessment tools.
3. Feedback and notices provided by the academic supervisor of this research and

feedback from other academics working in this area.

4. Feedback received after running a pilot study in Libya.

The process of questionnaire development is illustrated in Figure 4-1. The overall structure of the questionnaire encompasses and encapsulates the vital components and principles that represent and constitute the concept of lean manufacturing that have already been elaborated in previous chapters in this research.

This questionnaire has defined three main investigation areas consisting of 24 items, which have been incorporated to give a clear and a detailed picture of the status of the manufacturing and the managerial practices in the targeted companies. The three main constructs that constitute the questionnaire are:

1. Process and Equipment.
 - 1.1. Visual management.
 - 1.2. Cellular Manufacturing.
 - 1.3. Total Productive Maintenance (TPM).
 - 1.4. Setup Time Reduction
 - 1.5. Pull production system (JIT Flow)
 - 1.6. Commitment to quality, mistake proofing
2. Planning and Control.
3. Human Resources.

Each of the above investigation area has been further specified by a set of related activities or supporting practices. A set of defining activities or practices that are regarded as important determinants of lean adoption process have been incorporated under each main area.

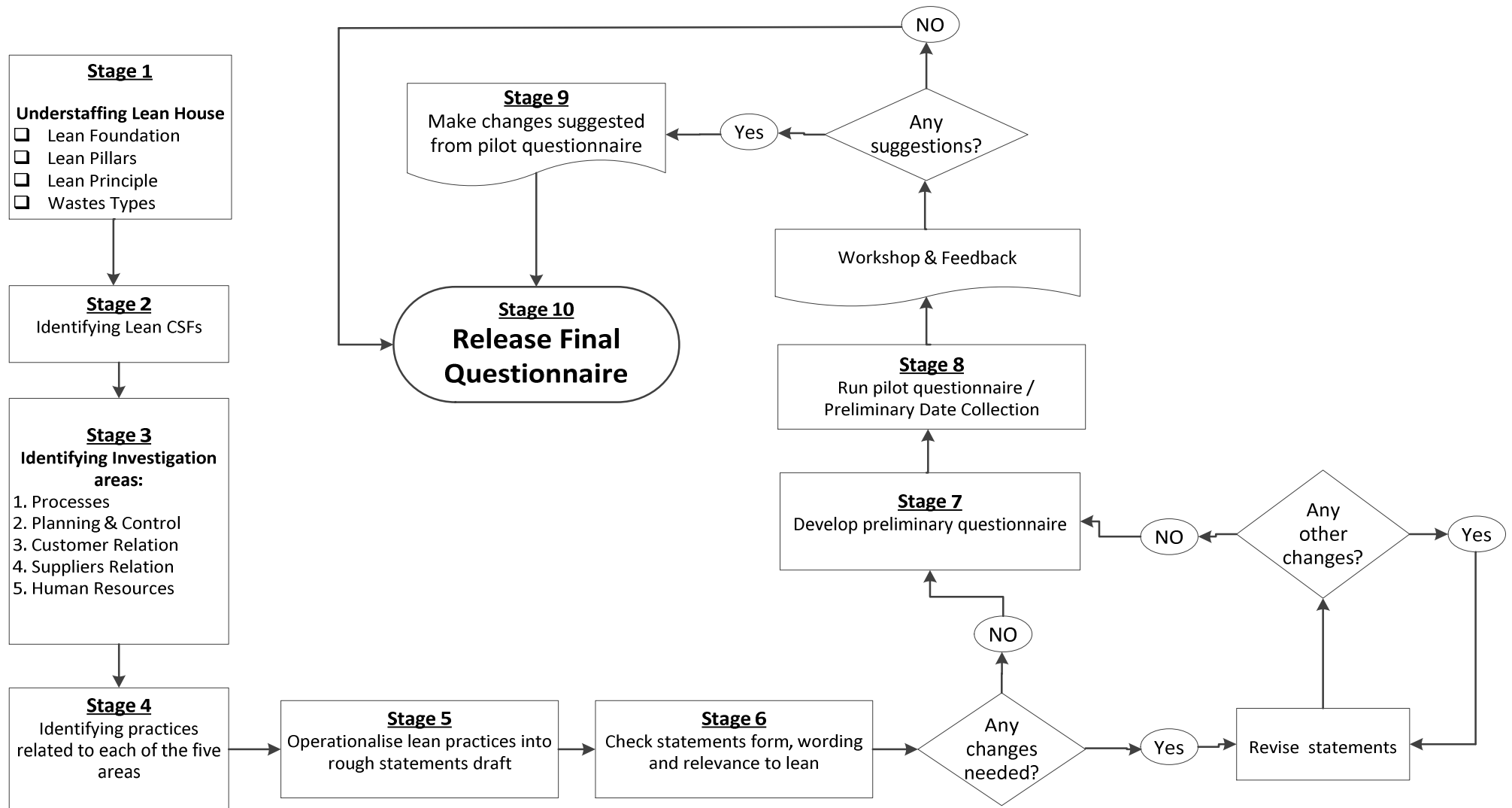


Figure 4-1 Schematic presentation of the questionnaire development process

Short descriptions of some of these activities are presented in Table 4-2. Among these activities and practices are: setup time reduction, visual management, total productive management, work standardisation, commitment to quality, utilising manufacturing space, pull production, cellular manufacturing, workers empowerment, providing education and training programmes, introducing reward systems, maintaining long-term relations with suppliers, understanding customer requirements.

Table 4-2 Definitions of the lean practices composing the research questionnaire

Questionnaire Main Items	Definition	Literature Evidence
Visual Management	<ul style="list-style-type: none"> Systems that enable anyone to immediately assess the current status of an operation or process at a glance, regardless of their knowledge of the process. This can take many forms such as: charts, metrics, procedures, process documentation 	Achanga <i>et al.</i> (2006), Wan and Chen, (2009)
Total Productive Maintenance (TPM)	<ul style="list-style-type: none"> Total Productive Maintenance (TPM) is the philosophy and practice of preventing the loss of productive machine time due to: breakdowns, minor stoppages, idling, operating at less than planned for cycle times, changeovers / setups, unacceptable quality. TPM involves everyone in identifying, monitoring, and correcting the root causes of each of these losses. 	Shetty <i>et al.</i> , (2010), Saurin <i>et al.</i> , (2011)
Work Standardisation	<ul style="list-style-type: none"> Standardised work is the documentation and application of the best practices of a manufacturing process. It may include photographs and/or drawings. It ensures that production operations are performed the same way each time. It is developed with the operators and it is posted at the workstation. 	Saurin <i>et al.</i> , (2011), Garza-Reyes <i>et al.</i> , (2012)
Cellular Manufacturing	<ul style="list-style-type: none"> Product- centered series of operations Layout: U-shape or semi-circle. Equipment movable and placed closely together Quick feedback between operators. Workers in manufacturing cells typically are cross-trained to perform multiple tasks. 	Sezen <i>et al.</i> , 2012, Kumar <i>et al.</i> (2009)
Pull Production system	<ul style="list-style-type: none"> Actual customer demand drives the manufacturing process as much as possible. A system of cascading production and delivery instructions from downstream to upstream activities in which nothing is produced by the upstream supplier until the downstream customer signals a need. The rate of production for each product is equal to the rate of customer consumption. 	Sezen <i>et al.</i> , (2012), Lasa, <i>et al.</i> , (2009)
Mistake Proofing	<ul style="list-style-type: none"> A method that uses simple, low cost devices that prevents defective parts from being made or passed into the process. Devices: Contact devices (e.g. switches, limit switches). Sensing devices (e.g. vibration, pressure). Warning devices (e.g. colour code, lights). 	Gurumurthy and Kodali, (2009)
Customer	<ul style="list-style-type: none"> In lean manufacturing, the value is defined solely by the 	Doolen and

Relations	<p>customer, so the company must ensure they deliver products closely to what the customer are willing to pay for.</p> <ul style="list-style-type: none"> • Understanding customer needs is essential, so building long relations with customers is required for the company to understand their needs and thus base their products on the actual customer demand. • The highest level of company-customer relationship is when the company manufacturing system is being driven by actual customer demand. 	Hacker, (2005)
Supplier Relations	<ul style="list-style-type: none"> • Organisations must ensure their suppliers are qualified. • Well qualified suppliers who are able to deliver items without these items being re-inspected by the manufacturer. • For a company to maximise its JIT manufacturing, the company should deal with closely located suppliers who is able to supply JIT. • Organisations should ensure a minimum number of suppliers. • Organisations should develop and keep long-term relations with suppliers and involve them in activities such as product development. This could play an active role in enhancing the quality of products. 	Sánchez and Pérez, (2001)
Human Resources	<ul style="list-style-type: none"> • All workers are required to be involved and take part in getting products developed. • Lean manufacturing requires people to be multi-skilled to be able to carry out different job. • For people to be multi-skilled, they should be offered cross-training programmes to participate in suggesting ideas to improve processes and the whole system. • People at all levels must be motivated and rewarded to be encouraged to take part in delivering improvement suggestions and ideas. • Organisations must ensure effective communication channels are in place as this is vital for ensuring lean is success. • Workers should be organised in teams. This is an important element for lean success as it establishes a platform for sharing new ideas and knowledge among workers. In addition, setting people in teams is helpful in terms of encouraging people to suggest improvement ideas and also motive them by creating challenges among them. 	Panizzolo, (1998); Jeyaraman and Teo, (2010)
Top Management	<ul style="list-style-type: none"> • For lean manufacturing to reach a level of success, top management should be visible in the shop floor to recognise performed tasks and thus workers get motivated. • Top management should invest in training programmes. • Top management should ensure enough financial resources that are required for lean success, such as hiring experts and buy consultations to be able to improve the system. • Top management should make efforts to build trust between the organisation and its workers. For example, ensuring job security is vital in that direction. Ensuring job security and increasing workers' commitment level are essential for increasing workers creativity, their capacity to carry out tasks, and their general performance. 	Roslin <i>et al.</i> (2012)
People Involvement	<ul style="list-style-type: none"> • A lean organisation develops highly trained, motivated employees who investigate problems and find solutions as part of their job. • Decision making and system development are pushed down to the lowest levels. 	Al-Najem <i>et al.</i> (2013)

	• An empowered team approach is essential.	
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Lean manufacturing practices (operational and managerial practices) that have been included in this questionnaire have been derived mainly from different reports and studies that have been done in the well-industrialised countries around the world and have been published in high impact scientific journals. Therefore, it is believed that most of the questionnaire's items are vital and a requirement for a company to be a successful lean implementer irrespective of the company's size and its geographic location.

Due to the term "*Lean Manufacturing*" is relatively new in Libya; efforts have been made to avoid any direct connections between lean terminologies and the companies' practices being investigated. Therefore, simple parameters have been used in the questionnaire, which is well related to a wide spectrum of measures by which leanness has usually been assessed in past studies.

Furthermore, this questionnaire was formulated in a way to avoid the drawbacks identified in past studies by paying equal attention to both operational and managerial practices. As such, the tactical nature of lean manufacturing components as well as the strategic nature was both considered in this questionnaire.

Five-point Likert scale was used in this questionnaire to identify the extent to which lean manufacturing practices had been adopted by the investigated companies. The respondents have been given the choice to rate their current adoption degree of lean manufacturing practices by selecting from 1 (strongly disagree) to 5 (strongly agree). The collected numerical data are processed in Chapter 6.

A sample of the questionnaire content is presented in Table 4-3 and the full version was presented in Appendix 4.

This questionnaire is touching the entire journey of lean manufacturing transformation; from manufacturing processes to human resources, planning and control, to customer and supplier relationships and senior-management practices and its role in this journey.

Table 4-3 Sample of questionnaire content

Process and Equipment Practices		Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE01	Your company follows active policy to help keep shop floor tidy, clean and uncluttered.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE10	Your crews use techniques that are helpful in minimising machines setup and tools/mould changeovers.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE12	Upstream production processes are triggered only by actual demand initiated by downstream processes (actual production is demand-driven).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

This inclusiveness in the questionnaire design should enable it to identify the most prominent; both, internal (people and process) and external (customers and suppliers) related dimensions of lean production. This should enable this questionnaire to be a powerful tool to adequately reflect the vast majority of the underlying constructs of lean production. Therefore, this should enable the researcher to provide a descriptive account of the current organisations' practices (realities) associated with lean manufacturing in the subject organisations. This then will be helpful in defining the suitable lean manufacturing strategy that should guide organisations throughout the lean adoption process in Libya and in other relevant developing countries.

4.3 Questionnaire Validity and Reliability

4.3.1 Questionnaire Reliability

Reliability is to check to what extent the questionnaire yields the same results on repeated trials (Zikmund *et al.*, 2012). In other words, reliability is to make sure that our obtained results (scores) are consistent and stable if the questionnaire is applied in different occasions over time.

According to Robson, (2011), there are two factors that may affect the reliability of a research, namely; respondent's bias and the researcher's bias. Cronbach's alpha test is

widely used to check the internal reliability of the obtained findings, running pilot questionnaire is also common to enhance the questionnaire reliability.

In this study, alpha value was 0.73 which gives an indicator that the scores obtained by this questionnaire are reliable over time.

4.3.2 Questionnaire Validity

Questionnaire validity provides the extent to which the questions are conceptually able to express the research topic (Garver and Mentzer; 1999, Li *et al.* 2005). Questionnaire validity is to make sure that the obtained results represent the reality of the situation being investigated. In short, it is to make sure that the researcher is asking the right questions to reflect what is happening in the situation being assessed. Therefore, when developing the questionnaire it is vital to ensure that all questionnaire's questions are relevant and related to the intended purpose for which the questionnaire has been developed or designed.

In order to ensure the questionnaire's relevance, copies of the questionnaire have been sent out to several academics and industrial experts to ensure its content is perfectly related to the purpose the questionnaire was designed for (capturing and evaluating the operational and managerial practices of the targeted companies). The aim of this action is to ensure the questionnaire's items are valid enough to extract the required information from the respondents as to their readiness level to successfully adopt lean manufacturing.

4.4 Pilot Questionnaire Test

Conducting a pilot study is widely used by researchers to ensure and increase the questionnaire's validity and effectiveness and, hence, increase the findings validity and reliability (Robson, 1993).

In this research, a pilot questionnaire has been carried out to ensure that the questionnaire content is as robust and reliable as possible in order to ensure our findings would be valid and reliable. The pilot questionnaire has been administered in a small range of the targeted

companies to test the developed questionnaire in terms of its content clarity and to explore how far its items are well related to lean manufacturing subject.

Nine copies of the questionnaire were submitted to collect feedback on the developed questionnaire; three people in each participated company have been selected as a sample to test the questionnaire. To ensure that we have different opinions and the feedback would come from all organisational levels; the employees had been selected from different departments, one shop-floor operator, one production manager, and one was from top management. In addition, copies of the pilot questionnaire have been sent out to three industrial experts with a minimum of ten years experience to capture their feedback. The industrial experts have been working for several manufacturing companies in Libya and one of them is now working as consultant for Libyan Ministry of Industry. In addition, other copies of the draft (pilot) questionnaire were circulated to a number of academic members of staff in Lawrence Technological University, for feedback that might improve the questionnaire.

After complete testing the questionnaire (the pilot questionnaire), a workshop was arranged and conducted to discuss the questionnaire's items in more details. This was helpful and useful in exposing the questionnaire's weaknesses and allows for improvements in being able to meet its purpose. The pilot questionnaire was also expected to provide feedback and reflection on the current state in the targeted companies.

The pilot questionnaire was expected to improve the questionnaire in terms of:

1. Identifying the difficulty / complicity and the clarity of the questionnaire items.
2. Identifying the respondents' understanding level of the questionnaire items.
3. Identifying and eliminating any unrelated questions from the questionnaire.
4. Identifying the approximate time required to complete the questionnaire and ensure the reasonability of the needed time.
5. Identifying any necessary improvements to the current version of the questionnaire.
6. Uncovering any logistical issues that might occur using the questionnaire.
7. Giving the researcher a chance to collect preliminary data.

8. Giving the researcher an indicator whether or not the current research instrument (the questionnaire) is adequate or other instruments (e.g. interviews, observations, case studies) are needed to rich data sources.

The most striking feedback of the pilot questionnaire was the recommendation to translate the questionnaire to Arabic language. Even though the large majority of the targeted respondents are qualified people and their English language level is quite good, it has been recommended that the questionnaire should be translated to Arabic language. This was to make sure that there would not be any difficulties facing shop-floor workers in understanding English language, and also to clarify any possible issues or doubts related to questionnaire structure.

4.5 Final Questionnaire Administration

Following the completion of the pilot questionnaire (testing the draft questionnaire), the outcomes that have been achieved from the workshops; notes; comments; and the feedback received from respondents were all considered in finalising the final version of the questionnaire. After the feedback has been deeply dealt with and carefully addressed, the draft questionnaire has then been revisited, some items / questions have been modified and others have been left out.

As it has already been clearly stated in section 1.2 of this research, the targeted sector of this study (the population of this study) is the automotive industry sector in Libya. The main objective of developing and administering this questionnaire is to investigate the “readiness levels” of this sector for adopting lean manufacturing; and eventually to come up with an adoption strategy to help this sector to effectively adapt to lean practices environment. Choosing the automotive industry sector as the main research focus has enabled the researcher to reap the benefits of the wide literature available on this sector.

The sampling frame of this questionnaire consists of three companies. According to information received from the Libyan Ministry of Industry, and to the best of the researcher's knowledge, these companies are the only ones, which are operating in the automotive industry sector in Libya. Future researches could focus on other manufacturing

sectors and investigate the relationship between company's performance and the adoption of lean manufacturing in the country.

Once the scope of this study has been defined by selecting the Libyan companies that operating in automotive industry sector, official letters have been sent out to those organisations soliciting their participation in this study. Follow - up emails and telephones calls had been made two weeks later following the circulation of the solicitation letters. Once positive responses have been received, visits to the three targeted companies have been arranged. Moreover, plants tours have been planned for each participating company. An employee from public relations department in each company has been allocated to this project to work with the researcher as a coordinator (the researcher's assistants). The main coordinators' duties were:

- Accompanying the researcher on the factory tours to observe the production operations and shop floor activities.
- Distributing the questionnaire among the targeted employees.
- Promoting the employees to effectively participate in the questionnaire, and collect the completed ones and returning them to the researcher.
- Coordinate and arrange any activities related to this research, such as arranging interviews and workshops.

Administering the questionnaire in face-to-face manner provides the opportunity of ensuring the interviewees' identity and therefore maximising the reliability of the provided information (Abrunhosa and Sá, 2008; Martínez-Jurado and Moyano-Fuentes, 2014). Furthermore, performing questionnaires on face-to-face basis guarantees high response rates by ensuring questionnaires are fully completed and returned to the researcher. Moreover, conducting a questionnaire in face to face manner is recommended if the sample of the study is drawn from a restricted number of locations, which is the case of this study.

Despite of that, it was not possible to run the questionnaire in face to face manner due to several logistical problems that were encountered. For example, there have been difficulties in realising the required employees to complete the questionnaire face-to-face with the presence of the researcher on site. This has been attributed to the evident workload stress, pressures, and workers' time constraints.

Nevertheless, the missed advantage of administering the questionnaire on face-to-face basis has been mitigated. The research coordinators in the targeted companies have been commissioned for distributing the questionnaire among a group of employees from different organisational levels. Then, a number of copies of the final version of the questionnaire have been handed over by the researcher to the research coordinators in each of the three participated companies. The questionnaires then have been submitted to a list of employees with specific roles and positions in the companies.

The respondents have been given a chance to complete the questionnaires at their earliest convenience and return them in due course. This manner of performing the questionnaire is believed to be appropriate especially if the employees' time at work sites is limited, which was the case of this study (Natarajan *et al.*, 2011). This method of administering the questionnaires gives the respondents sufficient time that is required to fill out the questionnaires, ensures their privacy, and also places less stress and pressure on them (Fotopoulos *et al.*, 2010). Furthermore, the provided sufficient time furnishes the respondents with good opportunities to carefully and exhaustively read and answer the questions.

Out of a total of 195 questionnaires that were distributed to the targeted companies (65 questionnaires to each company), only 106 questionnaires have been returned. However, 7 of the 106 questionnaires were missing important information and therefore they were left out from the analysis. This has resulted in 99 questionnaires being fully completed and hence can be worked out statistically to better understand the subject companies' operations. The total number of the usable received questionnaires (the 99 copies) equates to about a 51 % response rate. Comparing this response rate with previous studies on lean manufacturing subject, the 51 % is considered not only an acceptable rate but also a high one (Alsmad *et al.*, 2012; Sezen *et al.*, 2012). The number of respondents and their overall positions in each of the three responding companies is presented in Appendix 5.

In selecting this study's population, it has been necessary to ensure that the data would be gathered from authorised and knowledgeable employees. In order to meet this condition, there has been a focus on the organisational level and the positions of the targeted

respondents. Employees from senior management levels have been the central focus of selecting the type of the respondents.

Managers are considered as a rich source of information as to quality issues, as well as about operational issues related to embracing and managing any improvement initiative such as lean manufacturing (Li *et al.* 2005). Hence, in this research there was a focus on managers to have them participate in filling out the questionnaire form. In particular, there was a focus on production managers. The reason behind focusing on top management level is that lower level staff might be not knowledgeable enough to answer some critical questions on the level of practicing lean manufacturing principles. For example, responding to questions such as: whether or not the company is using external experts to evaluate the company's performance could better be answered by managers not by shop floor workers. Similarly, answering the question of whether or not the outcomes of suggestions system are taken into consideration would usually be better reflected by people from top management levels.

However, the focus on top management managers did not imply that lower level workers have somewhat been neglected, as neglecting lower level employees could result in some important information being missed. For example, the information about the frequency of employees' rotation, workers' empowerment and involvement, is better to be sought from lower level employees.

Managers usually have view on what is happens, but shop floor workers see what is happens in real. Managers - in many cases – spend less time on shop floor and see what is happens through key performance indicators (KPIs), metrics or charts. Whereas shop floor workers experience the work first hand and they live with it day by day, hour by hour. Therefore, to ensure the variety of the received responses and not to have a bias view, respondents have been selected from several functional departments within the targeted companies as illustrated in Appendix 5.

In addition to the prime source of data (administration the questionnaire), other data collection methods were adopted. For instance, semi-structured face-to-face interviews have been held with a few of companies' representatives at different managerial levels. This was to gain more insight on their operational and managerial practices. In order to facilitate

transcription process, all the conversations between the researcher and the interviewees have been recorded. Furthermore, the interviews have been backed by shop-floor observations and also by having informal conversations with the front line workers and managers as well.

In order to enrich the data source, the participated companies have been asked by the researcher to permit access to some of their reports and documentations. As it was anticipated, the researcher has been granted access to several reports, such as: productivity reports, maintenance reports, training schemes, customer complaints due to manufacturing, and other related documentations. This great variety in data collection techniques must enable the researcher to achieve triangulation and thus being able to ensure the validity of the obtained results.

The questionnaire and the field study have helped in capturing and evaluating the current practices on both managerial and operational levels in the targeted companies. The captured practices have provided insights on whether or not the organisations' taken direction is in the same direction of lean manufacturing. The captured practices have been analysed and mapped against successful lean implementers' practices, in order to help in the formulation and identification of suitable lean manufacturing strategy.

4.6 Background of the Participated Companies

The three companies have been selected according to their long experience in the automotive industry sector in Libya. In fact, the three selected companies are the only manufacturing organisations working in the automotive industry in the country.

The three companies have national and regional reputation for their products' quality. Table 4-4 provides profile of these companies. The three selected companies are joint ventures between Libyan government and Italian manufactures.

Table 4-4 Participated companies profiles

Company	Year of founding	Industry Sector	Owner	Employees	Market Focus
1. National Trailers Company (NTC)	1981	Manufacturing trucks equipment	Libya government with Italian partner	600	National
2. Libyan Trucks & Buses Co. (TBCo)	1980	Manufacturing of trucks & buses	Libya government with Italian partner	790	National and regionally
3. Libyan Tractors Company (LTC)	1977	Manufacturing tractors and other agricultural machineries	Libya government with Italian partner	580	National and regionally

4.6.1 National Trailers Company – NTC

Company overview

National Company for trailers (NTC) is one of the companies affiliated with the Libyan Ministry of Industry. It was established in 1981 with a capital of seven million, six hundred thousand Libyan dinars (LD 7,600,000.00) - about three million, eight hundred thousand pound sterling (GBP 3,800,000.00).

NTC is home for 400 employees who have been locally and externally well trained. The company manufactures different models of trucks equipment in accordance with the international specifications with an annual production capacity of 1,200 units. The NTC is ISO 9001 – 2000 certified (international standards for quality management system). Since established, NTC entered into a partnership with an Italian company operating in the sector.

The average of the company's annual production is about LD 10,000,000 (ten million Libyan dinars, about GBP 5,000,000.00 (five million pound sterling)).

Company Products

The company produces variety of products, such as:

1. Tipper Body for the Truck 50 - C15

Specifications:

- The equipment is made of carbon steel.
- The equipment's dimensions are 3600 x 1900 x 1000 mm.

- The equipment's payload is 2500 kg.
- The equipment is capable of unloading in three directions at an angle of 50 degrees.

2. Mobile refrigerators for the Truck 50 - C15

Specifications:

- The equipment is used for transporting and keeping food products.
- The equipment's dimensions are 3500 x2000 x2225 mm.
- The cooling point reaches 20°C below.
- The equipment is supplied with electric energy through an external electric source or through the truck's engine.

3. Refrigerator for the Truck 1.5 Tonnes

Specifications:

- The equipment is used for transporting and keeping food products.
- The equipment's dimensions are 2310X1700X1470 mm.
- The cooling point reaches 0 °C.
- The equipment is supplied with electric energy through the lorry's engine or through an external electric source

4. Cesspool emptying for the Truck 190

Specifications:

- The equipment is made of carbon steel.
- The equipment's capacity is 10000 litres.
- The draining depth up to 8 m.
- The draining pressure up to 5 bar.
- The interior of the equipment is treated with tar.

5. Sewer - Cleaning Tank for The Truck 190

Specifications:

- The equipment is made of carbon steel.
- The equipment's capacity is 10000 litres.

- The maximum clearance pressure up to 100 bar.
- The furthest clearance distance up to 80 m.
- The interior of the equipment is treated with tar.

6. Concrete Mixer for the Truck 380 - 420

Specifications:

- The equipment is made of carbon steel.
- The mixer's capacity is 9 cubic meters.
- The water tank capacity is 800 litres.

7. Refuse compactor for the truck 50 - C15

Specifications:

- The equipment's made of carbon steel.
- The equipment's capacity is 6 -7 cubic meters.
- The refuse pin with the capacity of 1100 litres is used to dump refuse into the equipment through a hydraulic system.

8. Semi-Trailer Cement Carrier Tank

Specifications:

- The equipment is made of iron metal.
- The tank's capacity is 40 cubic meters.

9. Low-bed Semitrailer - 70 Tonnes

Specifications:

- The chassis made of steel FE 510.
- The webs of the main beams are submerged arc welded.
- Plat form made in chequered steel plate.
- Loading ramps are mechanically operated by compensation springs.

10. Tipping semitrailer

Specifications:

- The chassis made of steel FE 510.
- Plat form made of plate steel thickness 8 mm and the sides plates thickness 6 mm .
- The capacity of box is 32 m.

11. Fixed body semi-trailer with sides and props

Specifications:

The equipment is made of iron metal.

The dimensions of the equipment are 12500 x 2500x700 mm.

The equipment's load is up to 60000 kg.

12. Tipper Body for the Truck 380 - 420

Specifications:

- The equipment is made of carbon steel.
- The equipment's dimensions are 5380x2360x 1000 mm.
- The equipment's payload is 25000 kg.
- The equipment's capable of unloading in three directions at an angle of 50 degrees through a hydraulic system.

13. Fuel Tank - on Semitrailer

Specifications:

- The tank made of steel FE 430.
- The capacity of tank 40000 litres
- Horizontal axis tank with polycentric section.
- The tank is provided with internal baffle.

The company is also capable to produce equipment for special orders and designs according to customers needs.

4.6.2 Libyan Trucks and Buses Co. (TBCo)

Company Overview

Libyan Trucks & Buses Company (TBCo) is a company with more than 20 years of experience in engineering, manufacturing, assembling and marketing of Trucks & Buses and their spare parts and components. TBCo is based in Tripoli / Libya, shared with Industrial Vehicles Corporation (IVECO) - an Italian industrial vehicle and bus manufacturing company based in Turin, Italy. TBCo is certified by TÜV Management Service GmbH (ISO 9001: 2000). TÜV (*Technischer Überwachungs-Verein*) is an independent German technical inspection association, an organisation that works to validate the safety of products of all kinds to protect humans and the environment against hazards.

The TBCo has great capabilities, majority of which are used in achieving its manufacturing Purpose.

These capabilities are distributed among many factories: Trucks factory, Buses factory Pressing Centre, Metallic Cabins Factory, Light factory, Shock absorber factory, and Engine factory.

Company Products

The company provides the local market with a range of products, such as: different models of trucks (heavy and medium), two and five tonnes pickups, several types of buses (from 16 up to 47 passengers).

4.6.3 Libyan Tractors Company (LTC)

LTC is a joint venture company with Massey Ferguson – Italy, the world's leading tractor brand for decades. LTC is based in Tripoli and founded in 1977; the company manufactures different models of tractors and other agricultural machineries.

Company products:

- High Horsepower Tractors
- Mid-Range Tractors
- Utility Tractors
- Compact Tractors
- Sub-Compact Tractors
- Seeding and Tillage equipment: Ploughs, cultivators, combine harvester

Chapter 5 Data Analysis and Findings of the Industrial Field Study

5.1 Introduction

This chapter is dealing with the data gathered from the field study that has been conducted in three manufacturing organisations which are all operating in the automotive industry in Libya.

This research has used some methods and techniques for gathering data on the state of lean manufacturing in the three participated companies. These data collection techniques are: administering questionnaire, conducting interviews with selected managers and engineers, and making observations in the targeted companies. Moreover, in a later stage of this research a case study is to be performed and experts' opinions are to be sought which are considered valuable sources of data. The analysis of the data collected by the above methods should make it possible to answer the research questions and therefore give credibility to findings obtained by employing these methods. Answering the research questions will show that the study is reliable and the findings are valid. The research questions that have been set forth in this research were presented in Chapter 1, section 1.4

5.2 Analysing the Questionnaire

The questionnaire has been designed to gather data that is suitable to meet this research purpose, which is exploratory and descriptive in nature. An exploratory method was used because the situation of lean manufacturing practices in Libya is not clear in the light of the lack of research in the existing literature. Furthermore, the descriptive method has employed the questionnaire to provide a clear and accurate picture of the current situation as to practicing lean manufacturing practices in the targeted sector and within the specified companies. By analysing the collected data we will be able to identify how close or far the companies are from lean and, hence it will be possible to identify which factors facilitating or hindering the process of adopting lean manufacturing in Libyan companies in the targeted sector.

In this study it has been assumed that if the total mean (M) for a lean practice has been scored equal to or greater than 4, then this practice is considered implemented in the company. This should enable the researcher to answer the research questions and provide insights whether or not Libyan companies are practicing lean manufacturing practices.

The main three constructs that form the questionnaire are analysed in the subsequent sections. These three constructs of the questionnaire have already been presented in detail in Chapter five. Briefly, they are as follows:

1. Process and Equipment (PE).
2. Planning and Control (PC).
3. Human Resources (HR).

5.2.1 Cronbach's alpha Value for the Questionnaire

The reliability and internal consistency of the received responses was defined by identifying the Cronbach's alpha values for the main three constructs that formed the entire questionnaire. Cronbach test has been presented in more detail in Chapter 1 and Chapter 4 (section 4.3.1). The alpha scale ranges from 0 to 1, and values above 0.70 are considered to be reliable and sufficient (Schutte *et al.*, 2000).

Cronbach's alpha test was performed to estimate the internal consistency of the 24 questions that form the whole questionnaire. Table 5-1 indicates that the Cronbach's alpha for entire questionnaire's items was 0.73, while each construct scored above 0.7, indicate an acceptable degree of the internal consistency among the questions on the scale.

Based on the results presented in Table 5-1, the alpha value for the entire data set was 0.73 for all five-point Likert scale statements (24 statements in total). The reliability of each construct was calculated separately; based on the accepted value of 0.7; all the constructs were accepted and considered reliable (Process & Equipment (PE) = 0.74; Planning & Control (PC) = 0.73; and Human Resources (HR) = 0.74.

Table 5-1 Reliability statistics for the questionnaire

Questionnaire Constructs	Number of Questions	Cronbach's alpha
Process & Equipment (PE)	14	0.74
Planning & Control (PC)	4	0.73
Human Resources Management (HRM)	6	0.74
Total of all Constructs	24	0.73

5.2.2 Descriptive Analysis

Descriptive analysis is used to understand the cumulative response rate of each of the questionnaire statements in the three constructs. The results presented in the following sections are provided in numbers and percentages, while in some cases the positive results were accumulated (e.g. “strongly agree” added to “somewhat agree”) and compared with the total negative results (e.g. “strongly disagree” combined with “somewhat disagree”) to give a better understanding and a clearer picture of the related lean practices being investigated. The discussion will be based on the percentage figures.

5.2.2.1 Descriptive Analysis of Process and Equipment (PE) Construct

The construct of “Process and Equipment” (PE) consists of 14 questions. These questions have been organised under several lean manufacturing related activities as shown in Appendix 4. The mean (M) values and standard deviation (SD) for the entire 14 questions were calculated and presented in Table 5-2. In addition, a summary of items statistics is presented in Table 5-3. Based on the used five-point Likert scale (1 = strongly disagree, 2 = somewhat disagree, 3 = neutral, 4 = somewhat agree, 5 = strongly agree), the mean (M) values indicate that most of the responses fall under “Disagree” category with an average mean (M) of 2.251 for the entire “Process and Equipment” (PE) construct as presented in Table 5-3.

Table 5-2 Descriptive statistics for process and equipment construct

Item Statistics			
Questions	Mean	Std. Deviation	No. of Respondents
PE01 Process and Equipment 01	2.17	1.000	99
PE02 Process and Equipment 02	1.83	.926	99
PE03 Process and Equipment 03	3.76	1.378	99
PE04 Process and Equipment 04	2.43	1.263	99
PE05 Process and Equipment 05	2.30	1.305	99
PE06 Process and Equipment 06	2.03	1.273	99
PE07 Process and Equipment 07	2.90	1.418	99
PE08 Process and Equipment 08	1.88	1.033	99
PE09 Process and Equipment 09	2.01	.995	99
PE10 Process and Equipment 10	2.30	1.281	99
PE11 Process and Equipment 11	1.94	.867	99
PE12 Process and Equipment 12	2.04	.979	99
PE13 Process and Equipment 13	1.68	1.038	99
PE14 Process and Equipment 14	2.24	1.333	99

Note: PE01,... PE014 are the questions that were listed under construct 1 in the questionnaire.

It can be seen from Table 5-2 the question PE03 (mean = 3.76) is most practised by the investigated companies, while the question PE13 (mean = 1.68) is the least practised one in those companies.

Table 5-3 Summary of process and equipment items statistics

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	2.251	1.677	3.758	2.081	2.241	.279	14

In order for Libyan manufacturing organisations to adopt and practice lean successfully, they need to enhance their processes in terms of having an organised workplace, minimising the loss in machines' productive time, make their production driven by customer demand (internal or external customer), follow flow and focus on cellular manufacturing. Equally important, Libyan manufacturing organisations must have clear standards; and thorough records of important measures, such as cycle time and lead time.

The next sections will shed the light on the realities of the manufacturing processes within the Libyan manufacturing organisation in the targeted sector.

Within the "Process and Equipment" (PE) construct, 14 lean related practices have been investigated, these 14 practices were organised into six groups as previously illustrated in Appendix 4.

Group 1: Visual Management

Statement 1 (PE01): Your company follows active policy to help keep shop floor tidy, clean and uncluttered.

This group consists of two questions (PE01 and PE02) which have been aimed at discovering the current organisations' processes in terms of the visual management concept. Figure 5-1 provides the results obtained for PE01.

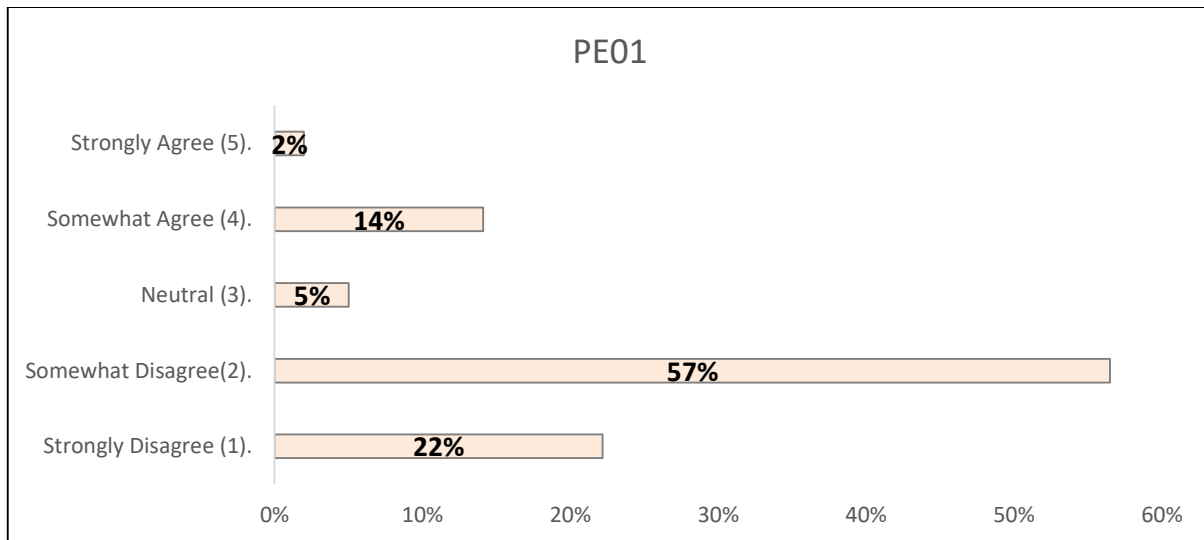


Figure 5-1 PE01 frequency

Based on the received responses, most of the respondents (79%) answered negatively to this question (22% were “strongly disagree” and 57% were “somewhat disagree”. This result indicates that the majority of the respondents were not agreeing that their workplaces are organised and equipped with only the necessary objects.

This was proved right during the factory observations where it was notable that the shop floor in the visited companies was usually untidy and also unnecessary tools were around everywhere, the pictures presented in Figure 5-2 supports the observations made during plants visits.

This result is considered as a negative indicator towards adopting lean successfully, as lean requires the shop floor to be clean and organised to make it more productive and therefore waste could be eliminated.

Statement 2 (PE02): A visual labelling system is in place to locate tools in shop floor and ensure they are in the right place.

As it can be seen from Figure 5-3, the vast majority of the respondents have answered negatively to this question (88%) while 10% of them agreed with this statement.

This result indicates that the investigated companies do not consider this factor as a vital element of their processes. This support the results obtained from question PE01, which give more evidence that most of respondents see their shop floor not organised and tools and objectives are not kept in their right places.



Company A



Company B

Figure 5-2 Examples of unclean shop floor observed during field study

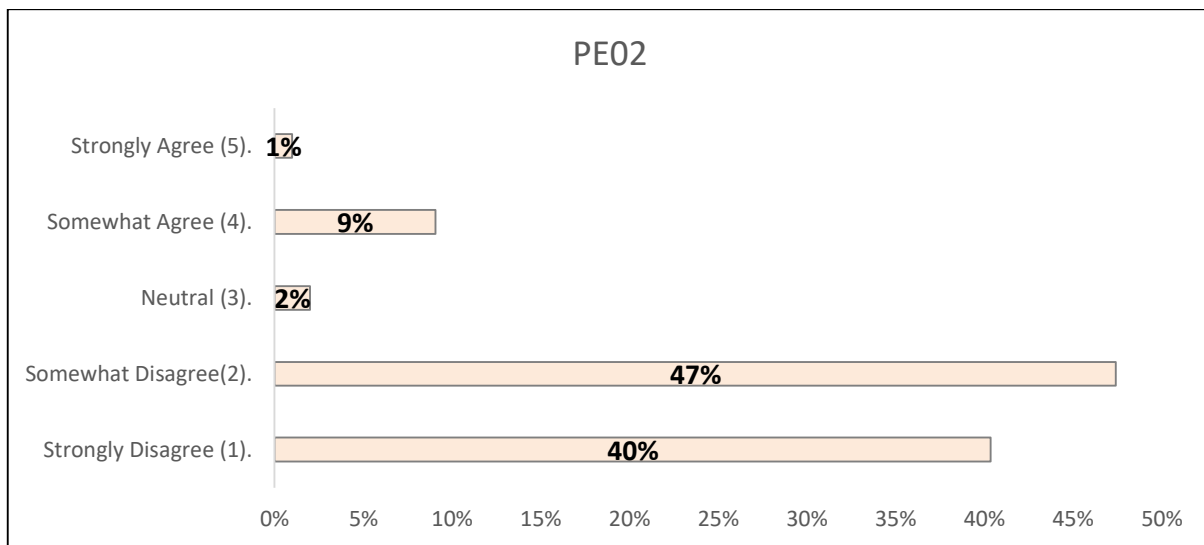


Figure 5-3 PE02 Frequency

Group 2: Cellular Manufacturing

This group of questions (PE03, PE04, PE05, and PE06) have been aimed to reveal the behaviour of the companies as to cellular manufacturing practices which is a vital element of lean manufacturing as presented in Chapter 4, section 4.2 in this research.

Statement 3 (PE03): Dissimilar machines are grouped together and dedicated to process collections of items that have similar production requirements (e.g. tolerance, machine tool capacities, required operations, etc.).

The PE03 question has been aimed to identify the type of shop floor configuration. It is to know whether the machines and operators are dedicated to a process type or to a part / product type.

It has been observed that shop floors in the investigated companies were divided based on the requirements of the allocated production tasks and each section of the shop floor has specific tasks to do. This structure of the manufacturing configuration could also be understood from the high respondents' response rate of 71 % (Figure 5-4) who agreed that a dissimilar piece of manufacturing equipment are grouped together and dedicated to

process clusters of parts or products that have similar production requirements (e.g. tolerance, machine tool capacities, required operations, etc.).

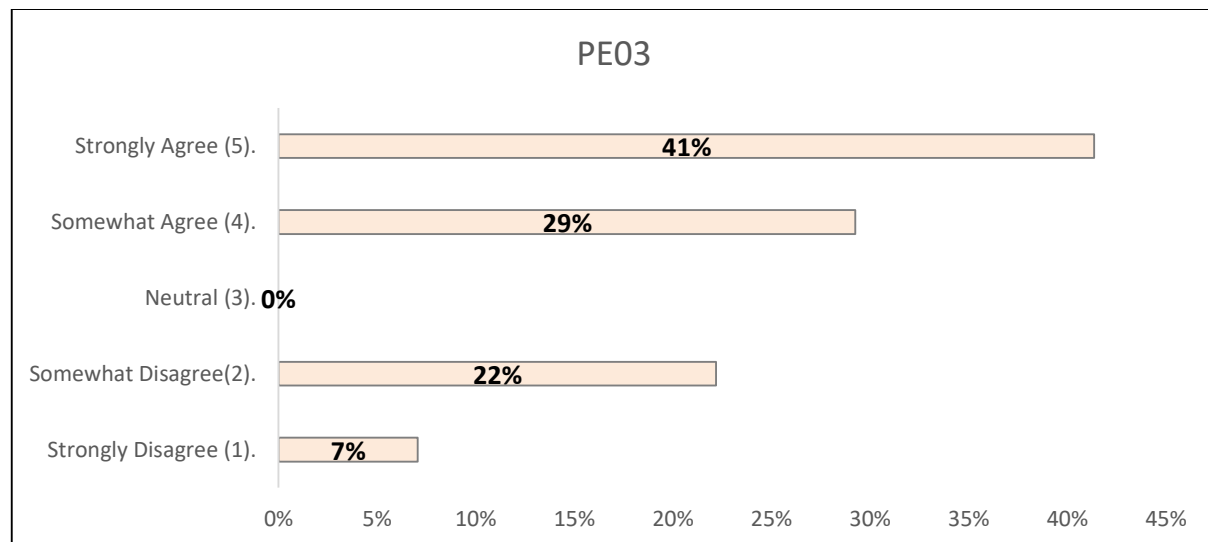


Figure 5-4 PE03 Frequency

The result of question PE03 indicates that the shop floor layout is determined based on products rather than on functions (shop floor is in a product oriented flow rather than in shops).

The plants visits provide further support to this question where it was observed that different machines were grouped together and dedicated to process clusters of parts that have similar production requirements. This result is considered a positive indicator towards adopting lean, because such layout (the product layout) contributes positively to waste reduction (Barbosa and Carvalho, 2014), such as unnecessary workers' movements between workstations.

Statement 4 (PE04): The processes used within similar operations are located and carried out in close proximity to each other.

As it has been shown in Figure 5-5, the large majority of respondents (72%) responded negatively to this question with a total mean of 2.43. This indicates that processes are located and performed far from each other. The result of question PE04 might be

understood as a contradiction in terms to the result of question PE03 in which 71% of the respondents were agreed that machines have been co-located.

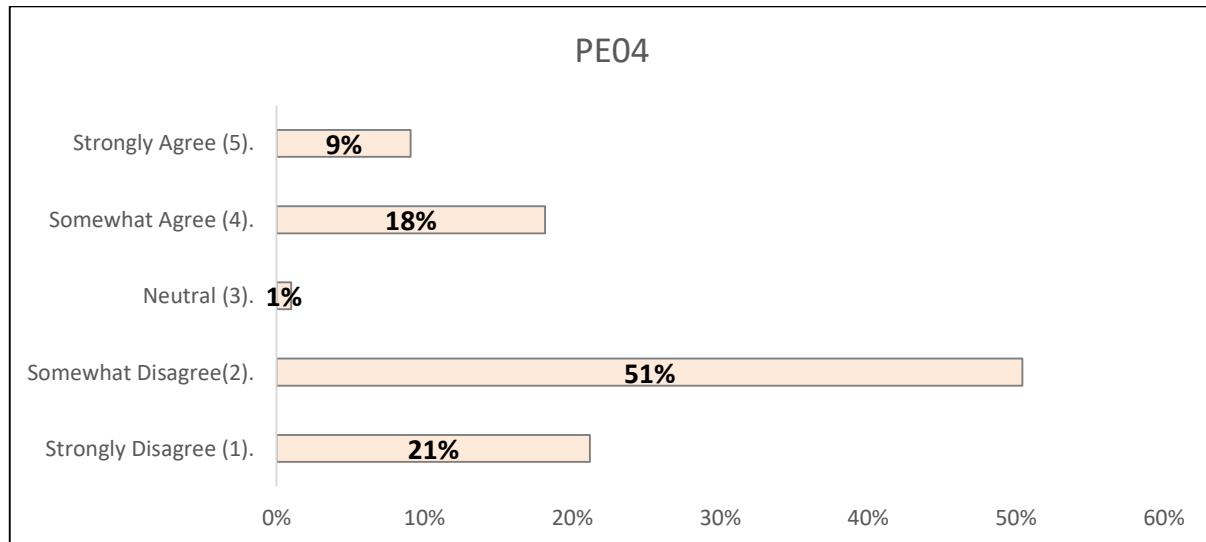


Figure 5-5 PE04 Frequency

This co-locating of machines (question PE03) might be interpreted as an implication that processes are performed close to each other (PE04) which is not the case in this research, as revealed by the result of question PE04 where the majority of respondents replied negatively to this question (72%). Therefore, to clarify this possible contradiction, the PE04 question was further investigated through conducting observations and chatting with operators and lines supervisors within the investigated companies. The aim was to figure out why machines are being grouped together (question PE03), yet processes are disconnected in terms of space – question PE04 – (processes are being carried out far from each other).

From the observations, the reason behind that behaviour (machines are being co-located yet processes are being performed far from each other) could be attributed to the type of configuration or the arrangement of production lines' equipment. It has been observed that machines have been organised in single assembly lines, these lines have been devoted to manufacture single high-volume products. Due to this machines layout, only a few of tasks were performed in close proximity to each other, in particular, those tasks that were located very near to line centre, while many pairs of workstations on the lines were disconnected in

terms of space. Furthermore, it has been observed that the size of assembly lines was quite big (25-30 worker in general) in all visited companies. Due to this high number of line operators, workers who were located far from each other (for example at the first and last stations in an assembly line) found it difficult to communicate with each other. One consequence of line big size is the interrupted feedback between stations and the decreased efficiency of the line.

Moreover, while chatting with a line supervisor during a plant visit, he negatively commented about the line layout. The supervisor said “[...] due to processes being far-located, workers at a station “A” – for example - have no access to production related information (e.g. quality and parts availability) at a station “B” on the same production line. “This has resulted in workers being isolated in terms of space and information alike”.

Additionally, during one of plant tours within the case companies, the researcher has noted that the production at a workstation was completely stopped, while the previous and the subsequent stations were operating independently and the production operating activities were running normally. Moreover, within the visited companies, it has been observed that space linkages among operators were strong only to a certain degree and it depended on the number of workers at the stations in the line. When the line size exceeds a certain number of operators the connections between operators becomes weaker and weaker till the extent it becomes difficult for them to see, hear and communicate easily.

Based on the above analysis and observations, Libyan companies are missing an important aspect of cellular manufacturing (processes flow), since it was found that tasks and operators who perform them were disconnected in terms of space.

Statement 5 (PE05): There is very little delay between task completion time at one workstation and the start time at the next workstation.

This question (PE05) is looking into discovering the extent to which the tasks required and those who performed them are closely linked in terms of time. In this context, time linkages imply that operating time (waiting and transfer times between stations) is to some extent reduced.

Figure 5-6 presents the result of the PE05 question. As it has been shown, 73% of the respondents disagreed that their processing times are minimised. This indicates that there is a big amount of time is being wasted somehow during their production processes

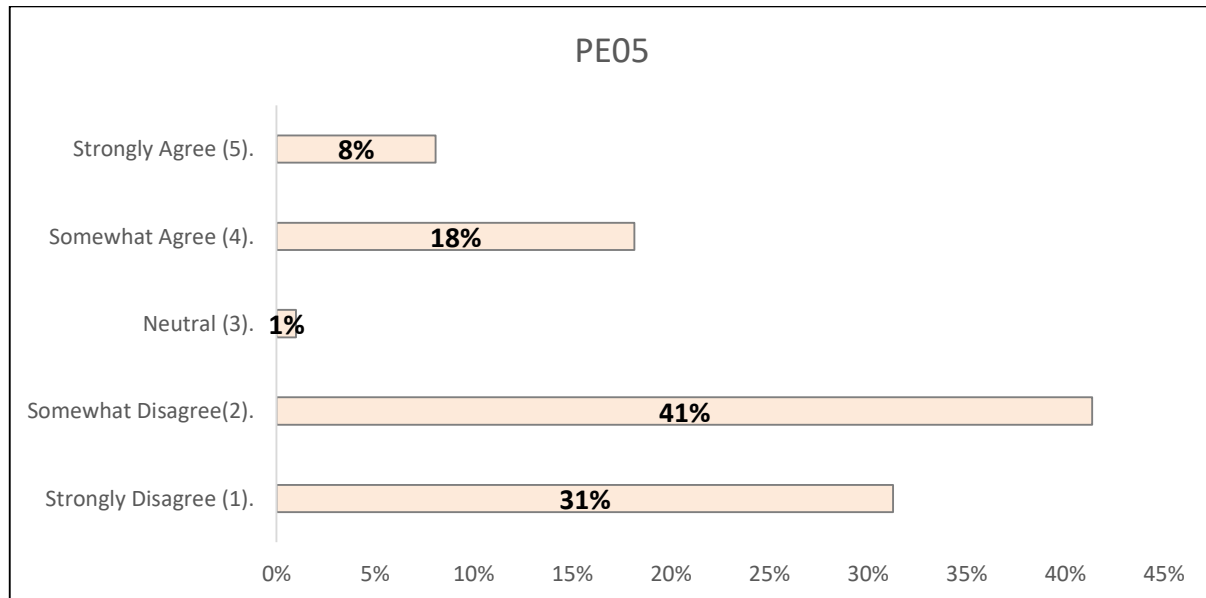


Figure 5-6 PE05 Frequency

Statement 6 (PE06): People and equipment responsible for workstations activities have access to timely and accurate information about the disposition of work (e.g. order status, part availability, equipment function, procedures, production goals, specifications).

This question (PE06) is to investigate the extent to which tasks and workers are connected in terms of information. Information connections in this sense imply that operators and equipment have access to full information as to work arrangement. As it has been illustrated in Figure 5-7, the vast majority of respondents answered negatively to this question (79%) with an overall mean of 2.03. This was proven right during plant observations.

During companies visits it has been observed that operators were isolated in terms of information availability. The operators of the production lines have not had access to timely, accurate, and full information related to production activities. If such information was available to the operators, then effective decisions could be made.

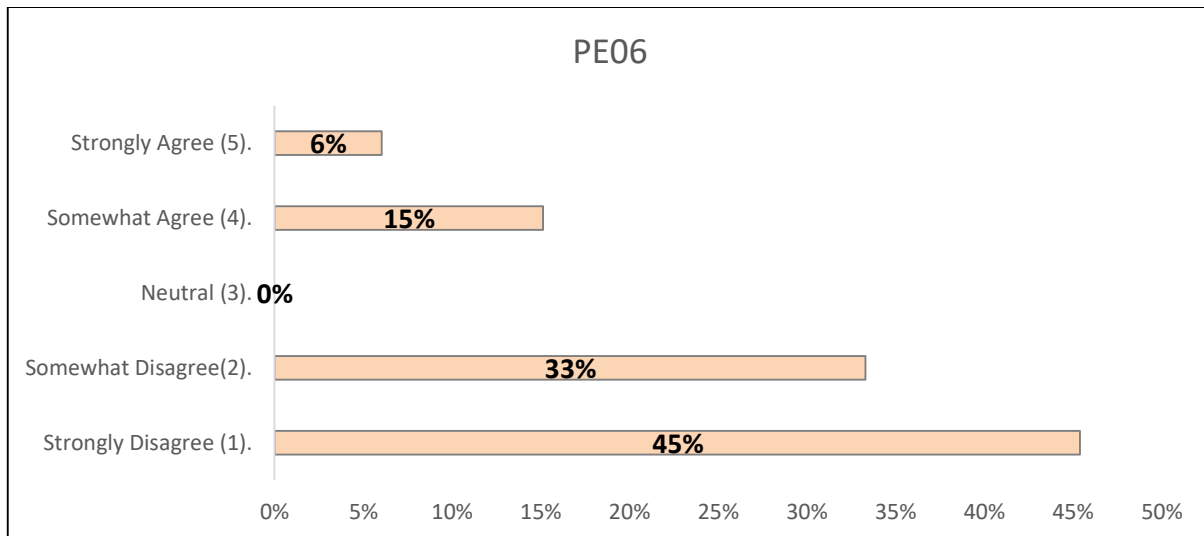


Figure 5-7 PE06 Frequency

For example, if an operator had sufficient and timely information about components availability (item shortages – for example), and if the operator is empowered enough to adjust production schedules; then he / she can make effective decision about order sequencing. Therefore, costly delays could be avoided and smoother flow could be ensured, which eventually will lead to reduce operating times and enhance lead times. This is an example of how the accessibility of information affects lead times.

Group 3: Total Productive Maintenance (TPM)

The issue of machines downtime should be addressed to realise a level of machine availability. This machine availability is achievable by adopting regular and frequent maintenance programmes through total productive maintenance (TPM). The questions of PE07, PE08, and PE09 are developed to investigate the Libyan companies' awareness of one of the underlying lean manufacturing factors, which is total productive maintenance (TPM).

Statement 7 (PE07): Your company emphasises more on preventing machines sudden-breakdown (preventive maintenance) rather than machine failure repairing (breakdown maintenance).

The PE07 is aimed to discover the type of maintenance system the companies adopt. In particular, it is to know whether companies follow preventive or breakdown maintenance.

The result of this question has produced a mixed response. As shown in Figure 5 8, almost half of the respondents (47%) have indicated that their companies adopt preventive maintenance, while 49% indicated that they do breakdown maintenance.

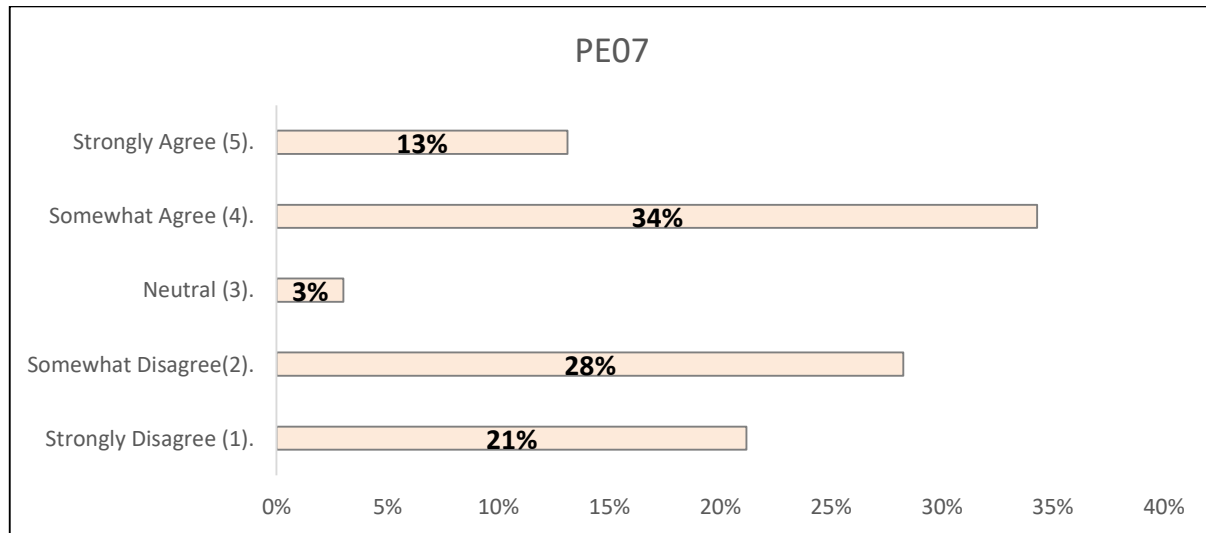


Figure 5-8 PE07 Frequency

This result does not give a clear indicator as to the type of maintenance initiatives that Libyan companies are adopting. This matter has been further investigated during managers' interviews. It has been found that the case companies in many occasions adopt the both types of maintenance (preventive maintenance and breakdown maintenance). One of the interviewed managers commented on this: "When we note that our machines are not in good order, we take immediate action and repair them" "This manner of maintenance we usually follow with our small and simple machines. However, in the case of our complicated and more expensive machines we usually inspect them routinely on regular basis to find out any potential source of breakdown and carry out the required actions to keep our machines run normally and prevent any possible failure during our daily operations". A manufacturing engineer said: "In case of low-cost maintenance equipment which does not take time to be repaired; our maintenance activities are confined to reactive actions when equipment failure occurs". This implies that they adopt breakdown or reactive maintenance with certain types of equipment. The engineer added: "However, in the case of the sophisticated and costly machines, we usually adopt preventive maintenance to reduce unplanned stoppages, avoid the disadvantages of undue expenses, undue damage,

undue maintenance and idle time, keep equipment safer, and to extend the useful life of machines”.

The result of analysing the question of PE07 shows clearly that the Libyan investigated companies adopt both types of maintenance programs (breakdown and preventive). However, transforming the manufacturing system from the traditional type to lean type requires the basic perception of the maintenance system to be gradually upgraded to finally realise total productive maintenance (TPM).

PE08: Your company follows standardised operating procedures to efficiently perform maintenance activities.

Documenting and preserving records for all machines maintenance related activities and following standardised maintenance procedures are essential for lean manufacturing.

As it can be seen from the response to question PE08 (Figure 5-9), Libyan companies have not appropriate documentation system, as 84% of the respondents answered negatively to this question (41% strongly disagree and 43% somewhat disagree).

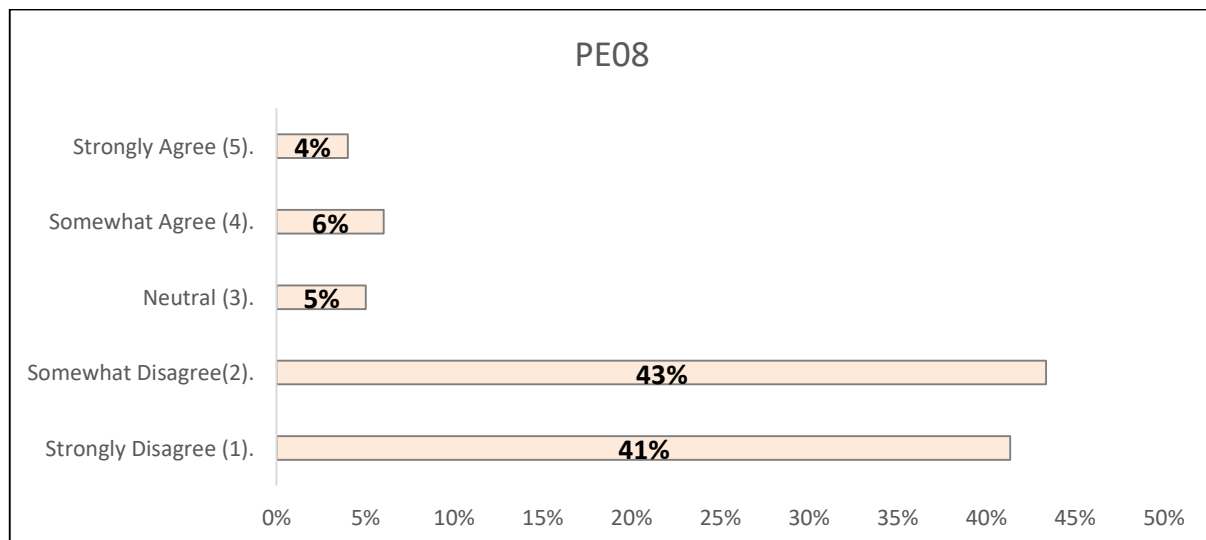


Figure 5-9 PE08 Frequency

While 10% of the respondents have suggested they adopted standardised procedures in caring of their equipment.

PE09: Maintenance programmes are performed in partnership between several departments' workers (e.g. maintenance, production, and engineering) as part of their daily jobs.

As it has been shown in Chapter 4, section 4.2, one of the most important principles of TPM is the total participation of workers in the maintenance process. TPM requires workers from several departments (e.g. production, engineering, design) to execute basic autonomous maintenance tasks as part of their routine activities.

The question PE09 is to examine the autonomous maintenance within the case companies. As illustrated in Figure 5-10, the vast majority of the respondents (86%) indicated that autonomous maintenance is not in place. This high disagreement percentage might be attributed to the type of organisational culture in the Libyan companies where it has been observed that there is fixed divisions between responsibilities of the organisations' different departments.

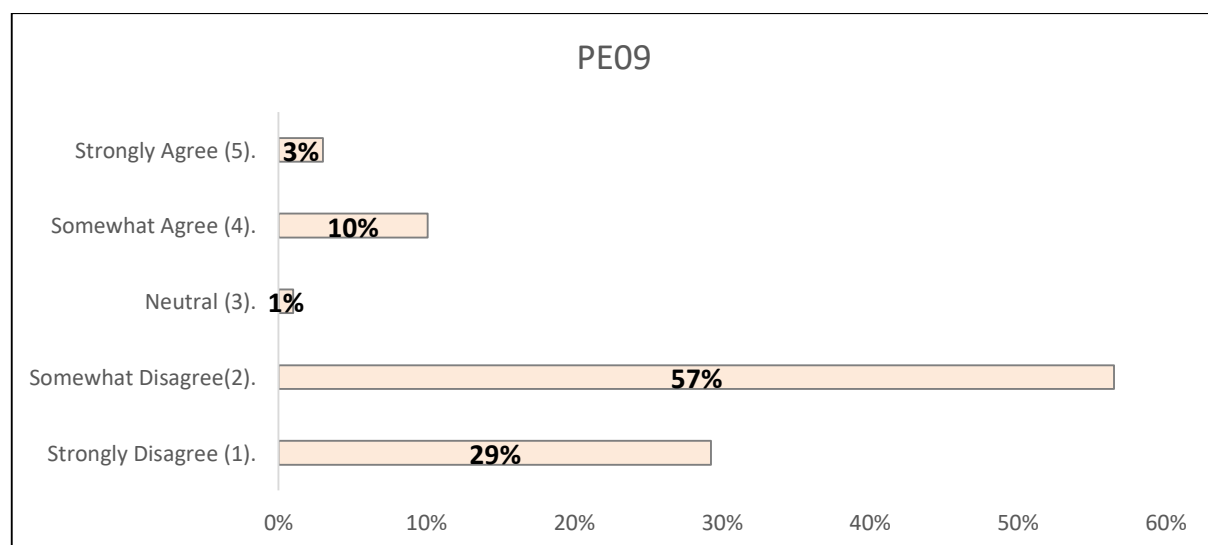


Figure 5-10 PE09 Frequency

This observation is supported by the comment of a maintenance manager when he was asked by the researcher why maintenance department does not empower production department shop floor operators to carry out basic autonomous maintenance activities on their equipment as part of their daily jobs. The interviewed manager commented: "This is because the general policy of our organisation where every department has its own

responsibilities and duties. “Every department workers are promoted to perform their own jobs and not to intervene in other’s jobs”. Another maintenance department manager has indicated that production department operators are not capable enough to carry out maintenance activities on their equipment; therefore they are not involved in such activities.

Group 4: Setup Time Reduction

PE10: Your crews use techniques that are helpful in minimising machines setup and tools/mould changeovers.

The question of PE10 is to find out whether or not the companies are making efforts to improve their equipment set up times. As it has been shown in Figure 5-11, the results of this question has shown mixed answers, as 64% of the respondents did not appear that their companies are making efforts to reduce set up time. However, a relatively high portion of the respondents (28%) indicated awareness of the importance of reducing set up times and reported efforts to reduce it. The yielded mixed responses to this question might be attributed to the level and degree of awareness regarding the benefits of improving changeover times in the case companies.

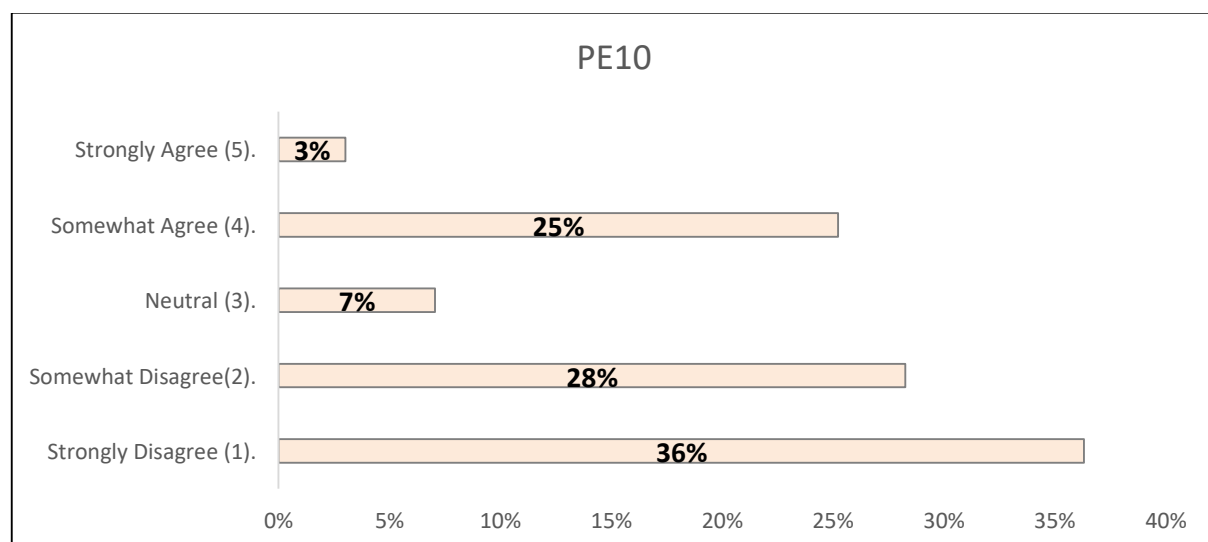


Figure 5-11 PE10 Frequency

One of the interviewed machine operators was not even familiar with a clear definition of set up time. He understands the set up time as the time taken to prepare his machine to perform a job. The operator has attributed this unfamiliarity of set up time definition to lack of knowledge and training programmes about their machines configuration. Another operator commented: “We have not been trained to use tools and techniques to reduce our machines’ exchange of dies”. Another operator has raised the issue of top management being ignoring ergonomics and safety related activities during exchanging dies of machines. The operator commented: “Due to operating in unsafe workplace circumstances, I have witnessed several shop floor accidents during dies handling and mounting, the matter that had negative effects on production processes and overall productivity”. The interaction between operators and machines should be simply designed and arranged in order to reduce operator physical efforts and eliminate operator discomfort, thereby efficiency and productivity should be maximised. Furthermore, during a plant visit, the researcher has observed that operators use manual jigs to lift the dies and use a lot of efforts to skew the nuts. However, in another plant visit we have noted that material are being moved and handled by automated methods such as forklift, thereby the changeover time should be lowered.

On the other hand, a line supervisor in one of the visited companies has claimed that their operators have been trained on how to reduce their machines set up times. During the visit of this company, it has been observed that operators use tools (i.e. quick connections, hinged joints, and lifting devices) to improve machines changeover times. Furthermore, a senior production manager in this company has commented: “We are planning to provide our machines’ operators with a training programme provided by external expert. “The programme aims to familiarise our operators with clear definitions of internal and external set up times and also using drawings and checklists to help in simplifying and standardising the operations and thus help operators reducing set up times”. “Additionally, this training will also focus on how to change the internal activities to external ones”.

PE11: Most of your internal setup time has been converted to external setup time while the machine is running.

The purpose of this question is to figure out the extent to which the case companies apply the methodology of Single Minute Exchange of Dies (SMED) in order to lower changeover time. The principle of single minute exchange of dies is to reduce machine idle time by converting the internal setup activities to external ones while a machine is still operating. As it can be seen from Figure 5-12, the vast majority of the respondents indicated this practice has not been applied in their companies as 90% of the respondents negatively responded to this question.

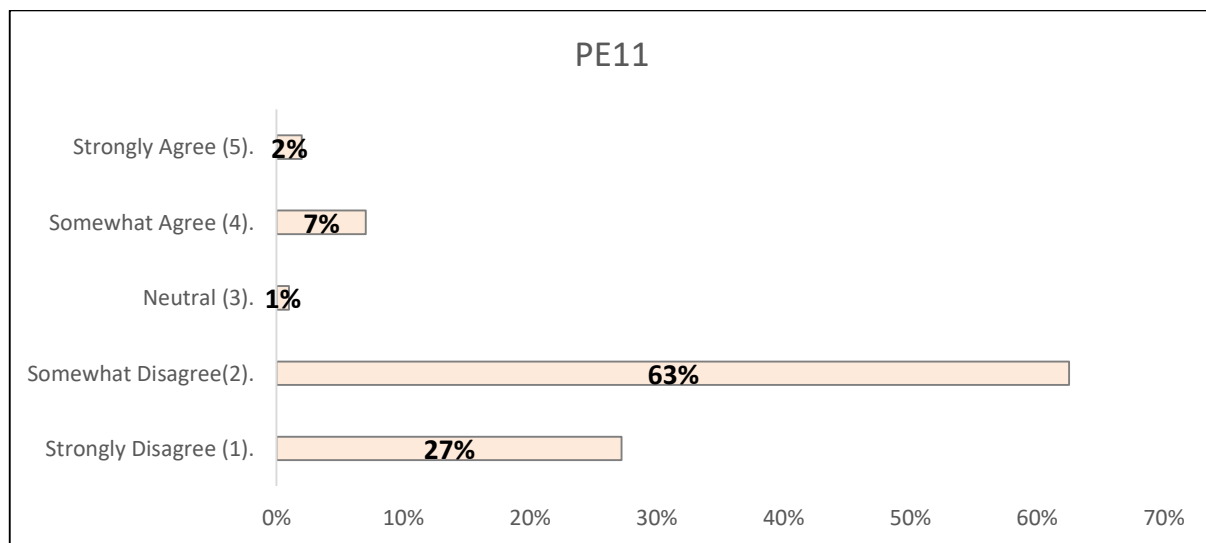


Figure 5-12 PE11 Frequency

This result can be supported by the observations made by the researcher and the comments made by the interviews managers and operators regarding the previous question (PE10).

Group 5: Pull Production System

PE12: Upstream production processes are triggered only by actual demand initiated by downstream processes (actual production is demand-driven).

The result of this question has shown that the production processes within the case companies are not demand-driven. As shown in Figure 5-13, a large portion of the respondents (81%) responded negatively to this question. This result is considered non-supportive to lean manufacturing, as it may require buffering or leads to improper communication between work stations.

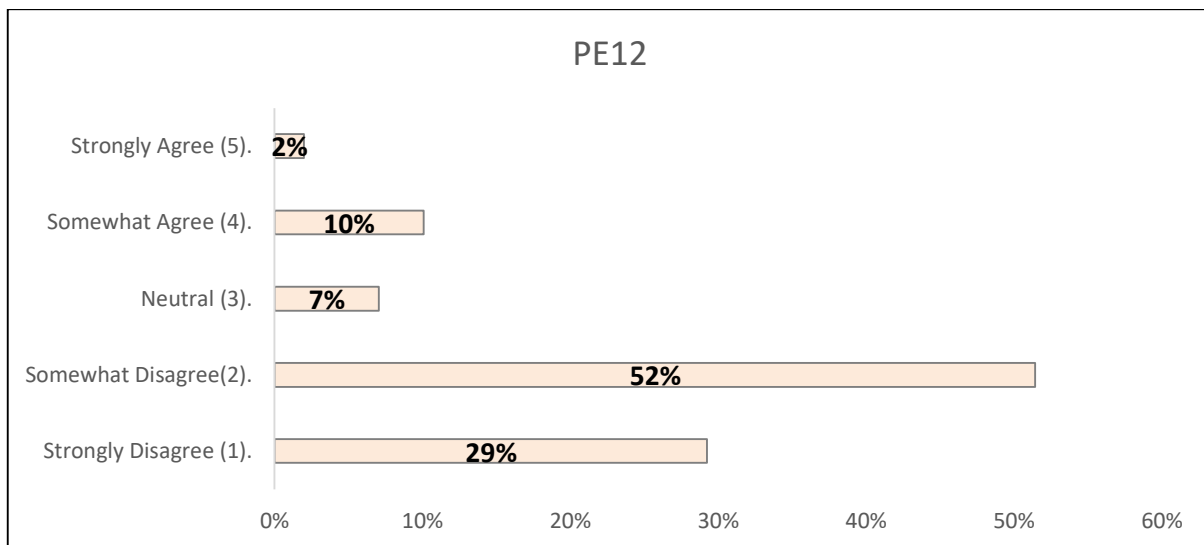


Figure 5-13 PE12 Frequency

During plant tours within the case companies, the researcher has noted that the production at a workstation was completely stopped due to machine breakdown, while the previous and the subsequent stations were operating normally. This miscommunication between those two stations was due to the type of machines layout. It has been noted that that the machines were organised in single assembly lines, these lines have been devoted to manufacture single high-volume products. In addition to that, it has been observed that the size of those lines was quite big and due to this big size, workers who were located far from each other found it difficult to communicate with one another, thereby feedback and the flow of information between stations was interrupted, which resulted in the decreasing of line efficiency. This indicates that the processes of the Libyan companies are not consistent with the pull principle of lean manufacturing which asserts that the actual station demand drives the manufacturing process as much as possible, where nothing is produced by the upstream station until the downstream station signals a need. These observed characteristics of the production processes in the Libyan companies (which are not consistent with pull principle) are considered as a source of waste that must be tackled.

PE13: There are visual methods (such as cards) with relevant information being attached, communicating production requirements between work stations to support PE12 practice.

This question is to explore whether or not the manufacturing system in the case companies use visual methods such as a card signal (Kanban) to facilitate and authorise items movement between stations. Since the result of the previous question (PE12) has indicated that pull system has not been adopted in the Libyan companies, therefore that result suggests – as a logical consequence – Kanban system also has not been adopted in Libyan companies. This inference is supported by the result of PE13 question as presented in Figure 5-14 where the vast majority of the respondents (87%) indicated that Kanban system is not in place in their companies.

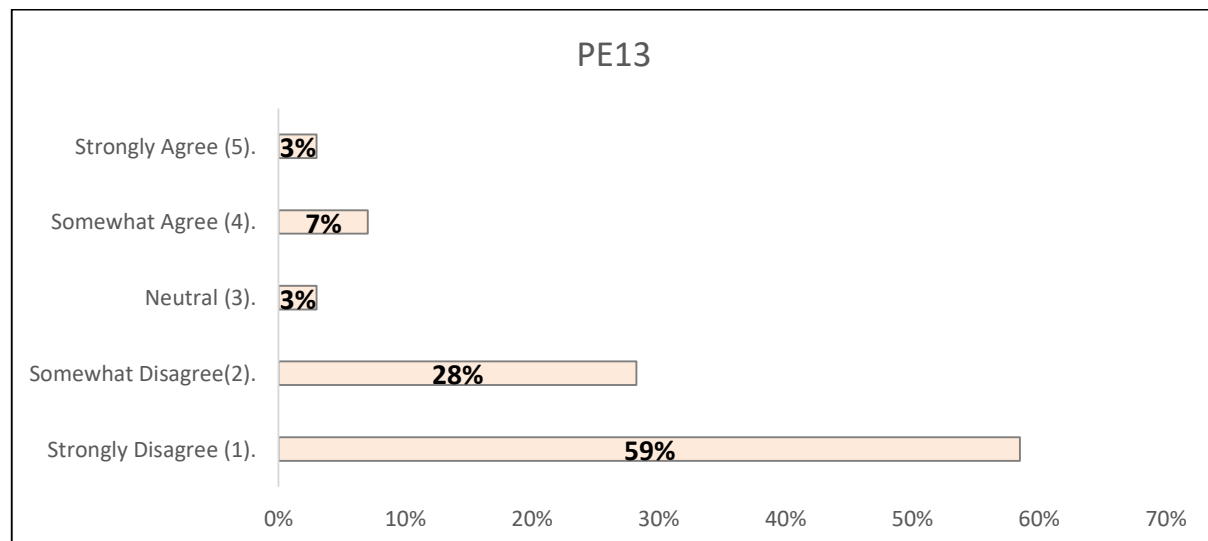


Figure 5-14 PE13 Frequency

PE14: All machines have devices either for preventing or detecting abnormalities. These devices – for example – are: warning lights; colour codes; limit switches; toggle switches; jig devices; or sensors.

This question is to investigate the behaviour of the companies regarding the use of mistake-proofing devices in order to enhance quality system by eliminating the source of errors that create defects. Errors are usually caused by several factors such as: human error, incorrect

procedures, excessive variation in process, inaccurate measuring devices, and excessive variation in the raw materials.

As it has been presented in section 3.2 and section 3.3 in this research, mistake proofing is a process improvement that is designed to prevent error from producing a defect or to prevent a defect from ultimately passing on to the customer.

As it can be seen from Figure 5-15, the large majority of respondents (91%) have indicated that their companies do not have such practice in place.

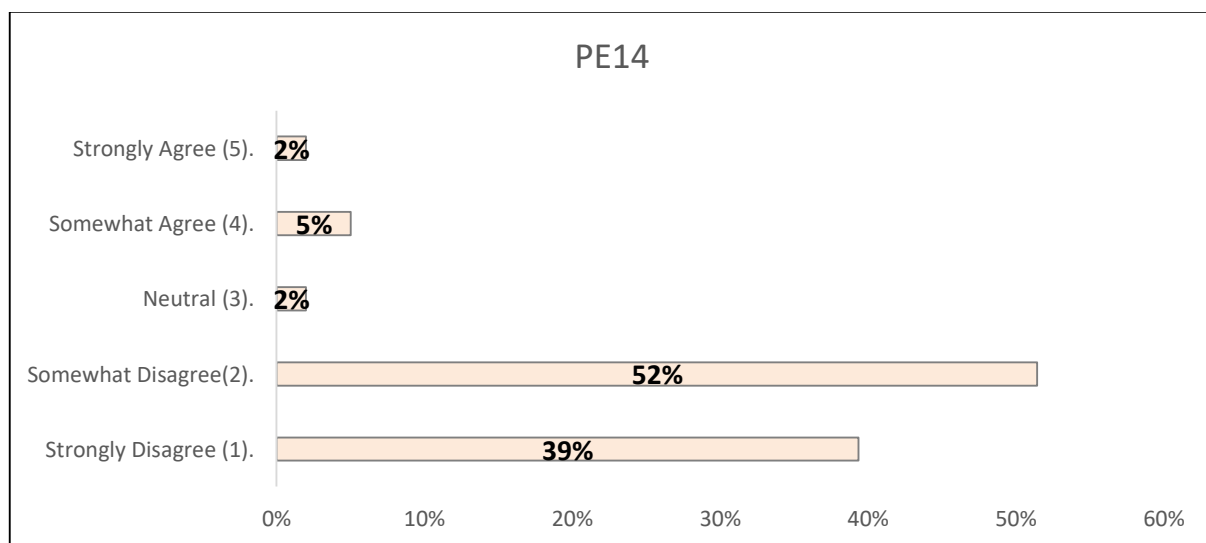


Figure 5-15 PE14 Frequency

It has been observed that all the three case companies rely on final inspections in order to reduce defect levels and hence enhance the quality of their products. One of quality enhancement methods that used by world-class manufacturers is setting up a team to brainstorm the cause and effect diagram to brainstorm possible error proofing ideas. As it will be shown later in question PC04, the case companies also do not have such practice in place, therefore the result of question PC04 reinforces the result of question PE14.

5.2.2.2 Descriptive Analysis of Planning and Control (PC) Construct

There are four questions within the “Planning and Control” construct as presented within the questionnaire shown in Appendix 4. The mean (M) and standard deviation (SD) values were computed for each question and the results have been presented in Table 5-4.

Table 5-4 Descriptive statistics for planning and control items

Item Statistics			
Questions	Mean	Std. Deviation	No. of Respondents
PC01 Planning and Control 01	2.05	1.232	99
PC02 Planning and Control 02	1.63	1.075	99
PC03 Planning and Control 03	1.80	.979	99
PC04 Planning and Control 04	1.62	.889	99

Note: PC01,... PC046 are the questions that were listed under construct 2 in the questionnaire

Moreover, the statistics summary for this group of questions has been presented in Table 5-5.

Table 5-5 Summary of planning and control items statistics

Summary Item Statistics							
	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	1.773	1.616	2.051	.434	1.269	.041	4

Based on the used five-point Likert scale, the mean (M) values indicate that most of the responses fall under “Strongly Disagree” selection with an average mean (M) of 1.77 for the entire planning and control construct as presented in Table 5-5.

Planning and control construct in this study embodies several aspects that are needed in order for Libyan companies to adopt lean manufacturing successfully. For instance, companies should use analysis techniques (i.e. cause and effect diagrams, or so called fishbone / Ishikawa diagrams), benchmark the performance with other companies in the same industry to create awareness of industry performance and provide a platform for improvement. Also, the companies are recommended to share with their employees key performance indicators to highlight abnormalities that restrict the targeted production from matching output.

The following sections present the descriptive statistics for the four statements that the planning and control construct is consisted of.

PC01: Your company conducts regular focus group meetings to identify wastes and solve problems by creating new ideas.

As presented in Figure 5-16 most of the participants (77%) have indicated that they do not organise focus groups to help them enhance their process and identity and reduce wastes. Whereas 21% claimed they practice focus groups as a technique for sorting out issues and eliminating non-added value activities. Conducting focus groups is vital for lean as it helps in reducing previous recurring issues as organisations tend to tackle the real source of the problems.

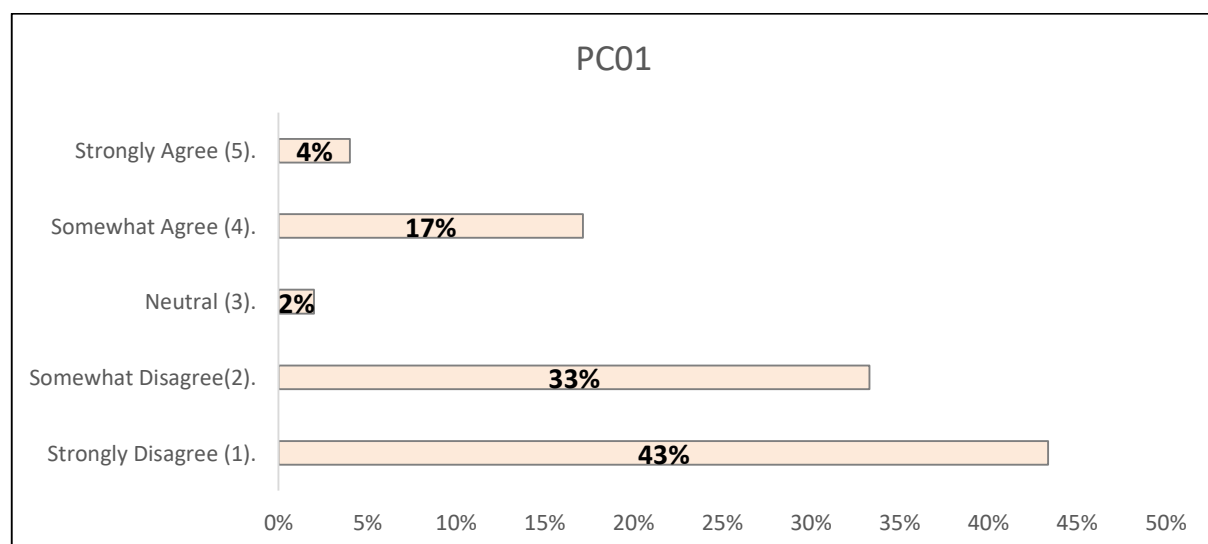


Figure 5-16 PC01 Frequency

PC02: Your company benchmarks its performance with similar industry companies in the region.

Most of the respondents (86%) have not indicated that their companies benchmark themselves against similar industry companies in the region. This reflects a level of unawareness from the companies in terms of ways in which to enhance their performance.

The result of this question indicates that Libyan companies do not consider benchmarking as an important practice for enhancing their processes.

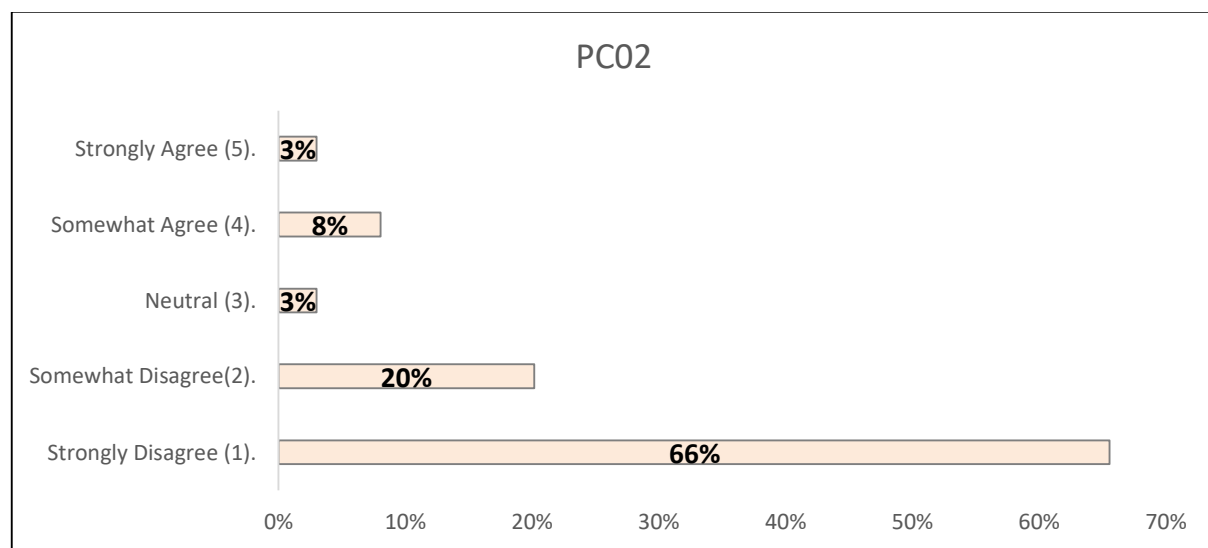


Figure 5-17 PC02 Frequency

Therefore, this is considered as a negative aspect of the Libyan companies regarding the possibility of adopting lean manufacturing successfully.

PC03: There are up-to-date charts displayed on the shop-floor. These charts (Key Performance Indicators) showing important information to communicate current progress against targeted plan. These information such as: defect per unit, error per unit, cycle time (hours per unit), and / or schedule adherence (i.e. 2 hours behind or ahead of plan).

The result of this question has shown that the Libyan case companies are not aware of the benefits of using key performance indicators, as 85% of the respondents replied negatively to this question (Figure 5-18). Using key performance indicators (KPIs) is vital aspect of lean manufacturing to add enhancement to production processes. The most beneficial and effectual KPIs are effectively shared with all employees and constantly kept up to date.

The KPIs bring forth beforehand warning of any potential deficit in the targeted production outcomes, thereby giving managers chance to highlight issues, react in timely manner, and take corrective actions.

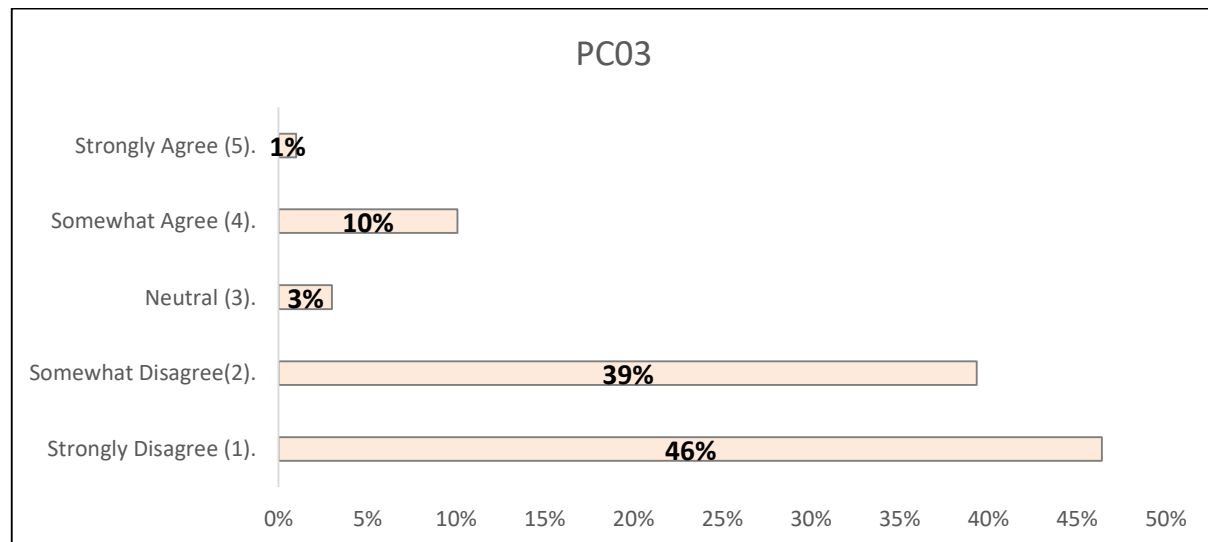


Figure 5-18 PC03 Frequency

PC04: Your company uses analysis techniques such as “Cause and Effect Diagrams”, “Quality Circles” as tools attempting to identify potential root causes of quality problems to address them before the escalation of the problem.

The result of this question has revealed that the case companies do not follow specific issue-solving approach, as 89% of the respondents have answered negatively to this question (58% strongly disagree plus 31% somewhat disagree) as presented in Figure 5-19.

The result of this question supports the result of question PC01 where it has been found that 77% of the respondents do not conduct focus group meetings to generate ideas in order to identify the causes behind waste in the manufacturing processes.

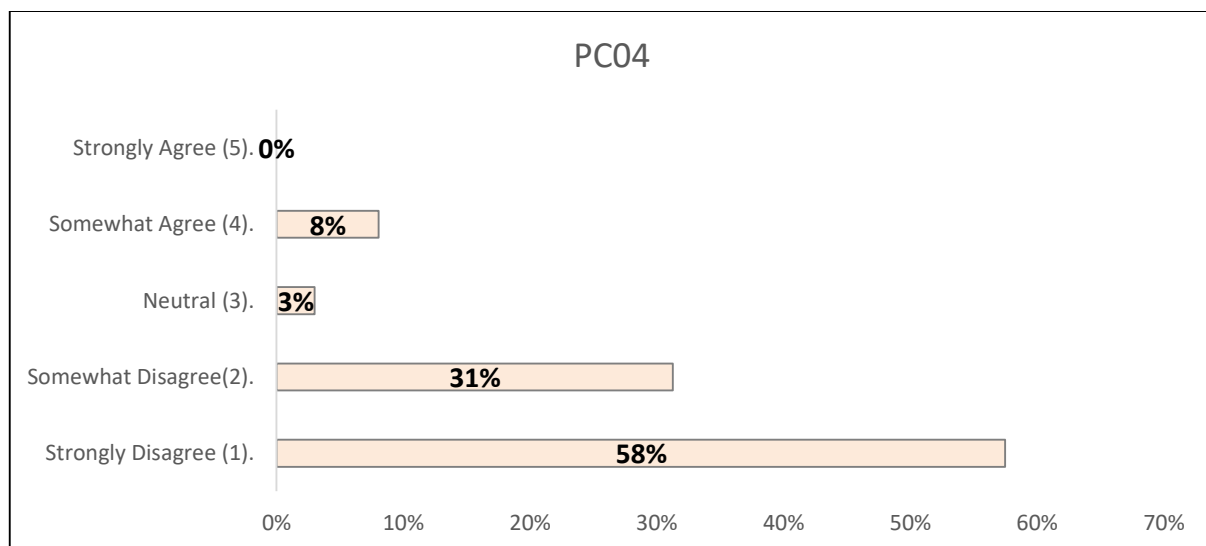


Figure 5-19 PC04 Frequency

The whole idea is to start organising workers thinking and provide some structures to the problem solving process. This helps improve idea generation, categorise potential sources of defects or root causes of problems. Also, it helps in identifying possible failure modes. Using analysis techniques such as cause and effect diagrams is useful in producing quick solutions by identifying and eliminating the root cause behind problem.

Addressing issues quickly is essential to lean manufacturing as the introduction of lean principles necessitates removing much “fat”. Hence, failure to solve an issue out in its early stages might affect the production processes, which eventually affects the final customer.

5.2.2.3 Descriptive Analysis of Human Resources Management (HRM) Construct

The mean (M) and standard deviation (SD) values for the six items that comprise the human resources construct are presented in Table 5-6. From this table it can be seen that item HRM05 (mean = 3.33) is the most practiced by Libyan companies while HRM06 (mean = 1.99) is the least adopted practice.

Table 5-6 Descriptive statistics for human resources management items

Item Statistics			
Questions	Mean	Std. Deviation	No. of Respondents
HRM01 Human Resources Management 01	2.24	.834	99
HRM02 Human Resources Management 02	2.15	.813	99
HRM03 Human Resources Management 03	2.01	1.025	99
HRM04 Human Resources Management 04	2.19	.955	99
HRM05 Human Resources Management 05	3.33	1.059	99
HRM06 Human Resources Management 06	1.99	1.093	99

Note: HRM01,... HRM06 are the questions that were listed under construct 3 in the questionnaire.

Based on the used five-point Likert scale the mean (M) values for human resources questions indicate that most of the responses fall under “Disagree” selection with an average mean (M) of 2.30 for the entire human resources construct as presented in Table 5-7 which represents the summary of this construct’s items statistics.

Table 5-7 Summary of human resources management items statistics

Summary Item Statistics							
	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	2.320	1.990	3.333	1.343	1.675	.257	6

As presented in Chapter 3, section 3.3, lean manufacturing is widely accepted as a socio-technical manufacturing approach and people at all levels are the heart of this approach. The importance of human resources to lean manufacturing lies in its crucial role in fostering workers’ abilities and increasing workers’ retention. Human resources practices are prerequisite for those companies launching lean from scratch, thus, organisations considering lean are highly recommended to invest in human resources practices to setup the human foundation on which the technical practices of lean could be developed.

It has been highlighted in Chapter 3 and Chapter 4 that human resources management (HRM) practices positively contribute to the effectiveness of lean practices. Moreover, lean human resources management practices enhance the synergy and complementarity of other lean bundles. In particular, human resources management practices foster the

implementation of certain lean manufacturing practices (e.g. set-up times reduction, pull production), which in the long run lead to enhancements of the overall operational performance. Therefore, addressing human resources management practices is a vital factor if lean transformation is a target.

Human resources management practices could be demonstrated in several forms such as: employees' involvement, employees' training and education, employees' suggestion systems, reward systems, job rotation, encourage people to work in small teams to realise common goals...etc. The following sections will shed new light on the status of these human related practices in the investigated Libyan companies.

HRM01: Shop-floor workers are encouraged to bring manufacturing-related issues to problem-solving small group sessions to clearly determine these issues in order to find solutions.

The result of this question revealed that most of the respondents believed that their companies do not support working in problem-solving teams, as the large majority – 85% – negatively replied to this question (Figure 5-20).

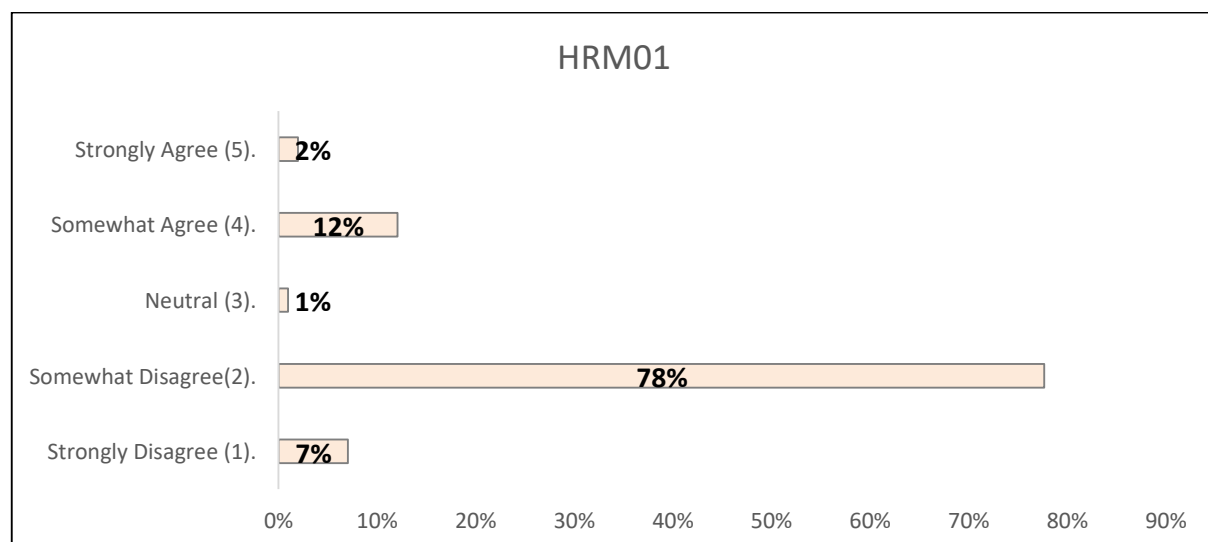


Figure 5-20 HRM01 Frequency

As it was shown in Chapter 4, section 4.2, employees' suggestions systems are important qualifiers to lean manufacturing, thus management should have in place such system. For

example, “quality circles” (a type of employees’ suggestions systems) is useful in sparking new ways of lowering setup times, therefore, smoothing the way for pull production flows which is a core principle of lean manufacturing.

During field study the researcher has learnt that the three case Libyan companies were founded as joint ventures with Italian manufactures and most of improvement ideas were coming from the Italian side. This implies that Libyan companies have not made efforts to organise workers in team-based sessions to discuss production-related problems and offer ideas and suggestions for improvements. Neglecting the practice of workers’ suggestions systems to generate improvement ideas is clearly demonstrated by the high percentage of 85% of the respondents who negatively responded to this question.

HRM02: Your company makes efforts to utilise the different abilities of shop floor workers (e.g. physical, creative, mental, abilities).

The result of this question has shown that the case companies do not effectively utilise their shop-floor workers, as 85% of the respondents negatively responded to this question (Figure 5-21).

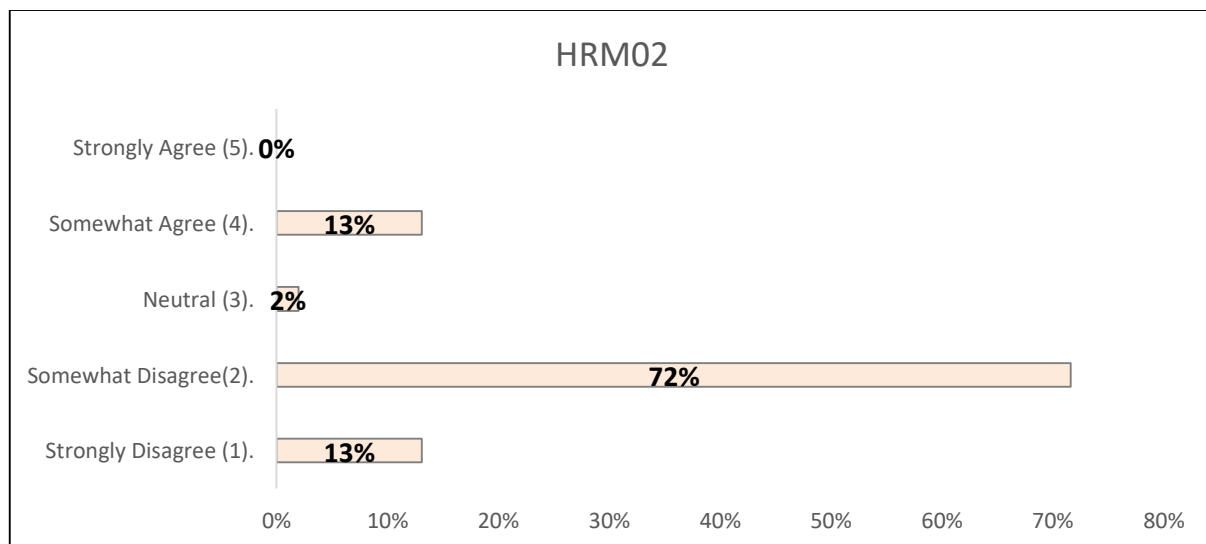


Figure 5-21 HRM02 frequency

In successful lean companies usually the mental, creative, and physical abilities of workforce are usually utilised, whereas in non-lean companies the physical attributes is only considered which is regarded as waste in the lean companies (Sullivan *et al.*, 2002). Some of the more common reasons for this type of waste are: organisational culture, inadequate

hiring policies, poor workflow, lack of training, and high employee turnover. For example, it has been observed that the layout of production equipment in the case companies (workflow) led to workers being disconnected in terms of time, space, and information. In particular, the arrangement of the straight assembly lines was behind workers' disconnection from each other. Thus, this type of shop floor configuration (the layout of straight assembly lines) led to workers being underutilised in terms of their creative and physical abilities. Therefore, Libyan companies are highly recommended to better consider people utilisation as they intend to consider lean manufacturing.

HRM03: Shop-floor workers are trained in a variety of tasks to develop workers with cross-functional skills within production area.

The fact of workers being trained in several different jobs to carry out several different tasks is required to adopt lean manufacturing successfully, as it was highlighted in chapter 4, section 4.2. Libyan companies seem to miss this factor as the large majority (86%) of the respondents have indicated that their companies do not practice multi-functions training (Figure 5-22).

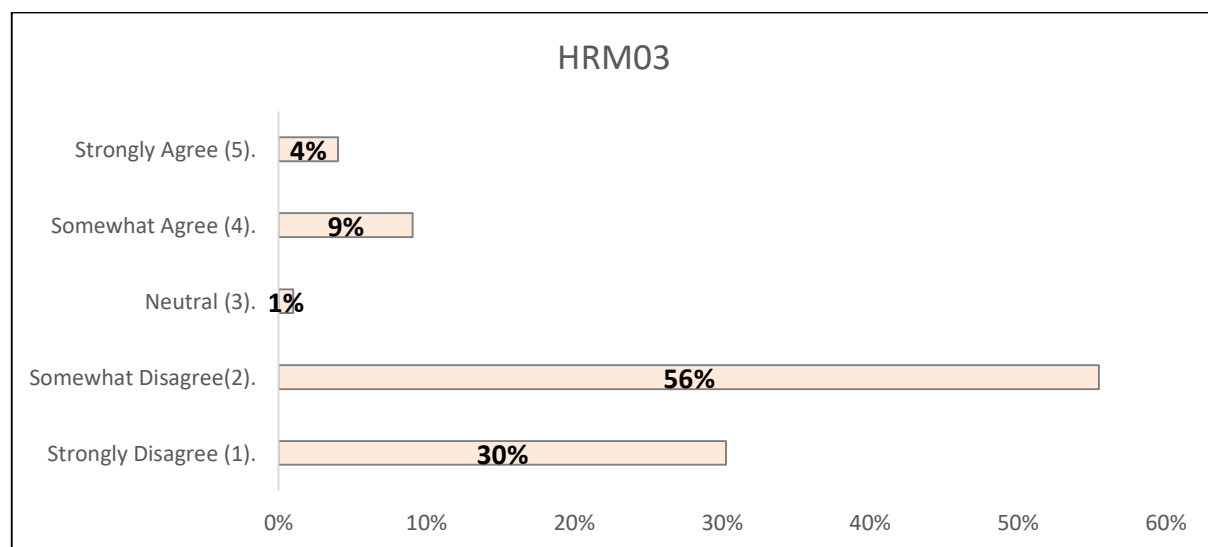


Figure 5-22 HRM03 Frequency

The training plans obtained during field study revealed that the three case companies train workers according to their specific specialisations. It is not common to offer workers training courses not directly linked to their areas. The cross functional skills can also be acquired

through rotating workers between different positions, the practice which does not currently exist within the case companies as it is illustrated by the next question.

HRM04: Workers are moved from a job to another within the plant in order to ensure they are able to carry out different tasks.

The result of question HRM04 (presented in Figure 5-23) has shown that most of the respondents believed that job rotation is not being practised within their companies, as 83% of the respondents replied negatively to this question. The importance of job rotation to lean production lies in its advantage in increasing workers' flexibility to respond to any unforeseen workers shortages or demand fluctuation.

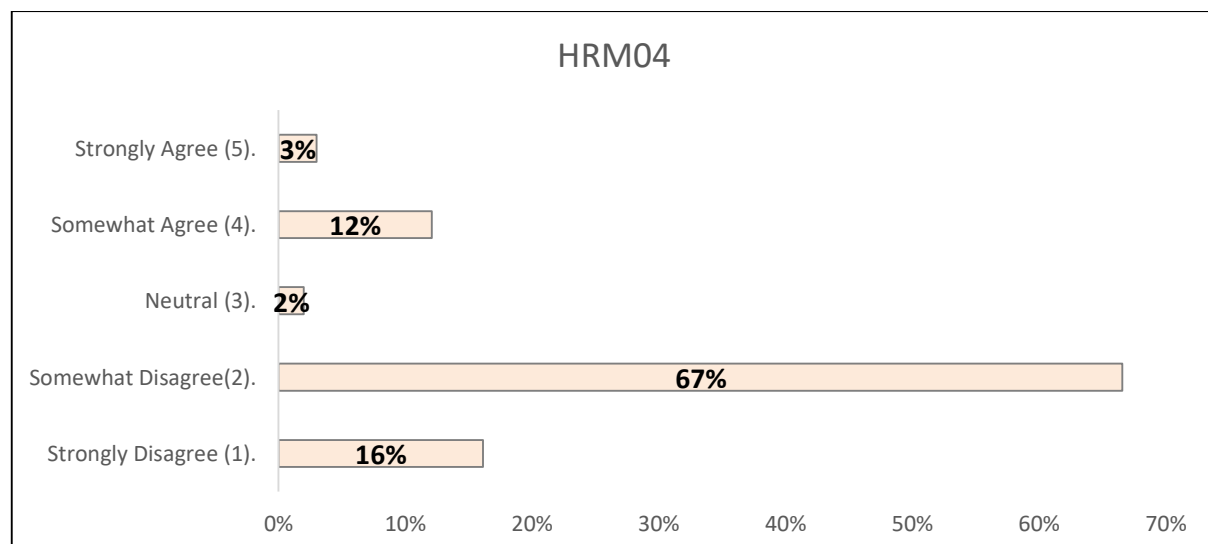


Figure 5-23 HRM04 Frequency

During the field study stage of this research, the researcher has learnt that two out of the three case companies used to practice a level of job rotation. That practice was carried out in compliance with the partnership agreement they had with the Italian partners. Workers were rotated between different positions in the shop floor on a nine month basis. A production manager has indicated that rotating workers from a position to another was regarded as a method of informal provision of training programmes. Another manager commented that the extremely low level of workers' turnover had encouraged the company

to invest in long term workers development, and the company used job rotation as way of doing that. Besides the importance of job rotation in enhancing the workers' skills, it has been reported by a production supervisor that job rotation had been useful in relieving the tedium of the repetitive everyday operators' activities; thereby workers' enthusiasm had been motivated, which eventually had enhanced workers' productivity and performance.

As it can be understood from Figure 5-23 above, the case companies do not have in place such system. A number of respondents have attributed the senior management neglect of job rotation practices to the management of the employment and hiring policy. For particular jobs, the top management makes efforts to maintain the very skilled local workers, and tend to hire cheap skilled enough workers from country such as Egypt and Tunis if necessary. By neglecting to invest in human resources development through job rotation, the top management attempts to avoid the expenses involved and the decrease in workers' efficiency during their training periods. Libyan companies should consider job rotation as an enabler that could foster the adoption of lean production.

HRM05: Reward and recognition system is initiated to motivate workers to do their best in order to generate ideas for improvements.

Initiating and establishing reward and recognition system within companies is important in terms of enhancing workers productivity and many other aspects. Effective reward and recognition system usually results in highly motivated workers and thus job satisfaction. Workers at all levels should be motivated by being rewarded to be encouraged to take part in delivering improvement suggestions and ideas. The importance of reward and recognition system was illustrated in Chapter 3, section 3.5 and Chapter 4, section 4.2.

The response to this question has produced almost a mixed result (Figure 5-24), 64% of the respondents have claimed that they have a reward and recognition system in place, while 34% indicated that they do not have such system within their companies. During the field study, it has been found that one out of the three case companies do not have a reward system at all, and this might explain the relatively high percentage of 34% of the respondents who replied negatively to this question.

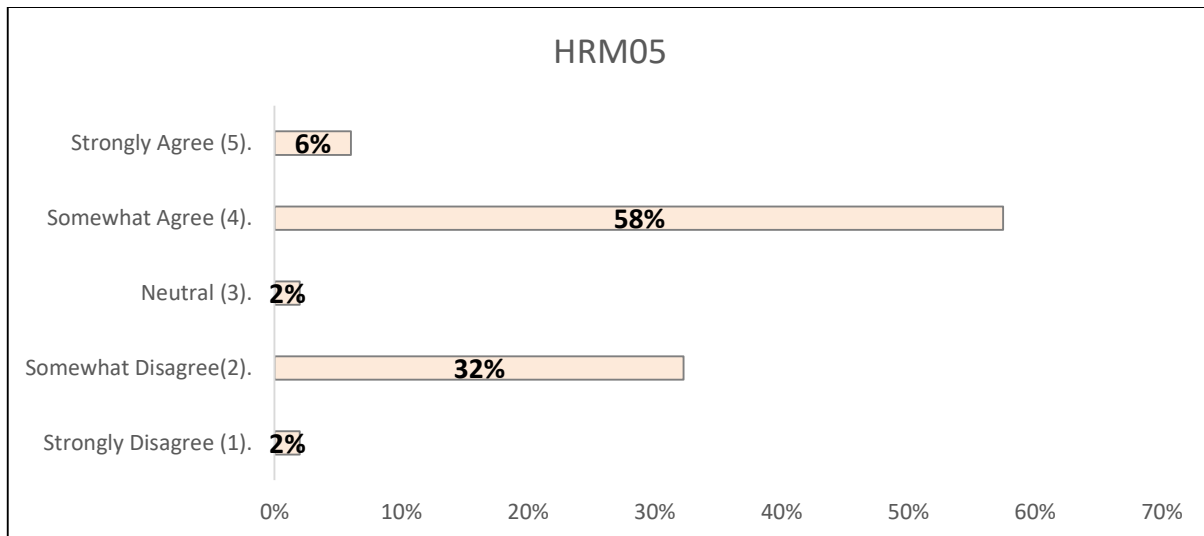


Figure 5-24 HRM05 Frequency

The negligence to use a reward system within this company was attributed by a senior manager to the relatively high salaries the company offer. The company regard its salaries values as a motivator to attract and maintain workers. The only rewarding criterion companies use was the length of service. It was found that workers' length of service is highly valued within the other two investigated companies as a method of rewarding workers. There was not any real reward system that encourages workers to drive improvement ideas to enhance processes.

HRM06: Shop floor workers have the decision making authority to stop a production line if abnormalities occur.

Lean advocacy of people empowerment is a commitment to make the workplace more humanistic, since lean manufacturing is largely considered as social-technical system as was illustrated in Chapter 3, section 3.3 in this research.

Although a number of respondents have indicated that top management encourages shop floor workers to deliver improvement ideas and suggestions (as shown in question HRM05 – Figure 5-24). It seems, however, that top management did not take and implement those suggestions as shown by the result of question HRM06 (Figure 5-25). The result of this question (HRM06) suggests that shop-floor workers' improvement ideas are being ignored as the large majority of the respondents (84%) indicated that shop floor workers are not

being given authorities to respond when abnormalities occur in their work areas. This implies that top management do not empower shop floor workers, which is considered as a negative aspect towards adopting lean manufacturing successfully. Top management negligence of the practice of workers' empowerment could be attributed to reasons such as management's lack of trust in their workers or the workers are actually not being capable enough to be empowered.

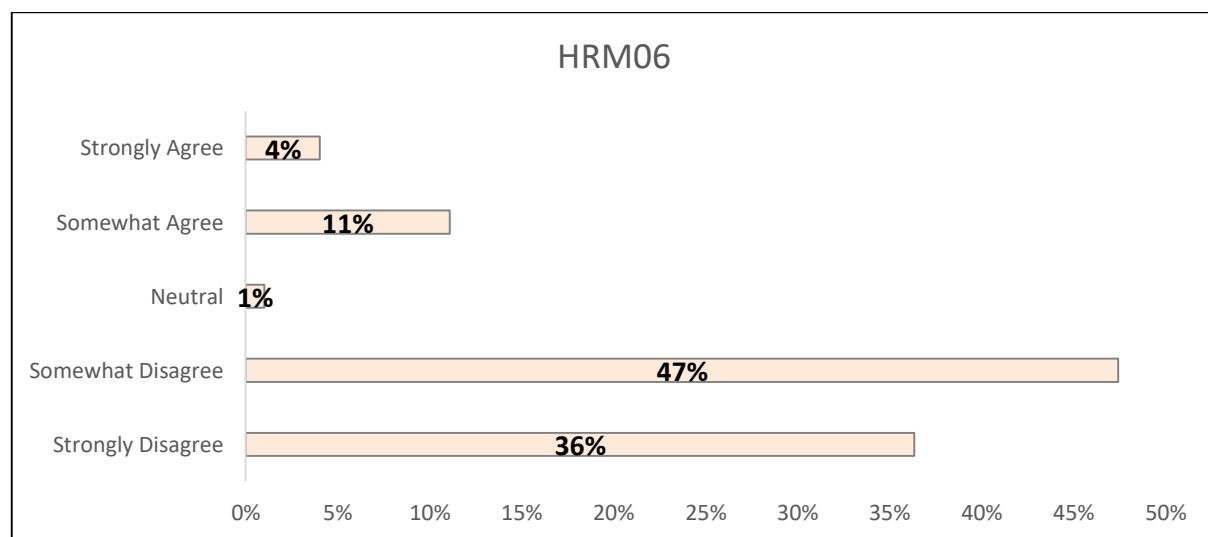


Figure 5-25 HRM06 Frequency

From the results of questions HRM03 and HRM04, it can be said that top management do not empower workers due to their limited capabilities. Ignoring workers empowerment might also be attributed to the closed predominant organisational culture in the Libyan society where the flat management concept does not exist within organisations and there are fixed divisions between responsibilities of the organisations' different departments, as observed by the organisational structure documents the researcher obtained from the case companies.

5.3 Questionnaire Analysis Concluding Remarks

This questionnaire has been set out to explore the current state of lean manufacturing related practices within the Libyan companies. The main goal of the questionnaire was to

figure out how far the Libyan companies from lean manufacturing. This questionnaire has investigated 24 practices that represent the necessary components of the concept of lean manufacturing. As previously illustrated in section 4.2, those 24 lean related practices were divided into three categories, namely (Process and Equipment; Planning and Control, Human Resources).

The results of the mean values and standard deviation for the investigated 24 practices are summarised in Table 5-8.

Table 5-8 Descriptive statistics for all questionnaire items

Item Statistics			
Questions	Mean	Std. Deviation	No. of Respondents
PE01 Process and Equipment 01	2.17	1.000	99
PE02 Process and Equipment 02	1.83	.926	99
PE03 Process and Equipment 03	3.76	1.378	99
PE04 Process and Equipment 04	2.43	1.263	99
PE05 Process and Equipment 05	2.30	1.305	99
PE06 Process and Equipment 06	2.03	1.273	99
PE07 Process and Equipment 07	2.90	1.418	99
PE08 Process and Equipment 08	1.88	1.033	99
PE09 Process and Equipment 09	2.01	.995	99
PE10 Process and Equipment 10	2.30	1.281	99
PE11 Process and Equipment 11	1.94	.867	99
PE12 Process and Equipment 12	2.04	.979	99
PE13 Process and Equipment 13	1.68	1.038	99
PE14 Process and Equipment 14	1.79	.872	99
PC01 Planning and Control 01	2.05	1.232	99
PC02 Planning and Control 02	1.63	1.075	99
PC03 Planning and Control 03	1.80	.979	99
PC04 Planning and Control 04	1.62	.889	99
HRM01 Human Resources Management 01	2.24	.834	99
HRM02 Human Resources Management 02	2.15	.813	99
HRM03 Human Resources Management 03	2.01	1.025	99
HRM04 Human Resources Management 04	2.19	.955	99
HRM05 Human Resources Management 05	3.33	1.059	99
HRM06 Human Resources Management 06	1.99	1.093	99

Note: PE01, PE02... HRM06 are the 24 questions which formed the questionnaire sections

Furthermore, the average mean value for each construct which formed the entire questionnaire's items is presented in Table 5-9.

Table 5-9 Mean values for entire questionnaire's constructs

Questionnaire Constructs	Average Mean
Process & Equipment	2.22
Planning and Control	1.77
HR Management	2.32
Total mean for the entire questionnaire	2.17

It is obvious that there are significant shortfalls compared with the performance of successful lean companies. As it can be seen from Table 5-8, the highest mean score (3.76) was for the lean related practice of PE03, while the lowest score was (1.62) for the practice pertaining to planning and control activities (PC04).

In this study it has been assumed that if the mean value (M) for a lean practice has been scored equal to or greater than 4, then this practice is considered implemented in the company. Based on those mean values as presented in Table 5-8, it is clear that lean related practices within the case companies are not supportive towards lean manufacturing.

The findings of questionnaire and observations indicate that the managerial and operational practices within the case companies are not supportive towards adopting lean manufacturing successfully. This can be seen from the low mean values ($M < 4$) for each of the three constructs that comprised the entire questionnaire (Table 5-9), namely (process and equipment; planning and control; and human resources). This shows that case companies lack the infrastructure for lean and their readiness level is comparatively low.

The average mean value for each construct that formed the entire questionnaire items are plotted in a chart as presented in Figure 5-26. This figure is based on the data obtained from the questionnaire analysis (Table 5-9) and it shows the current performance of the case companies regarding their lean manufacturing related practices (operational and managerial activities).

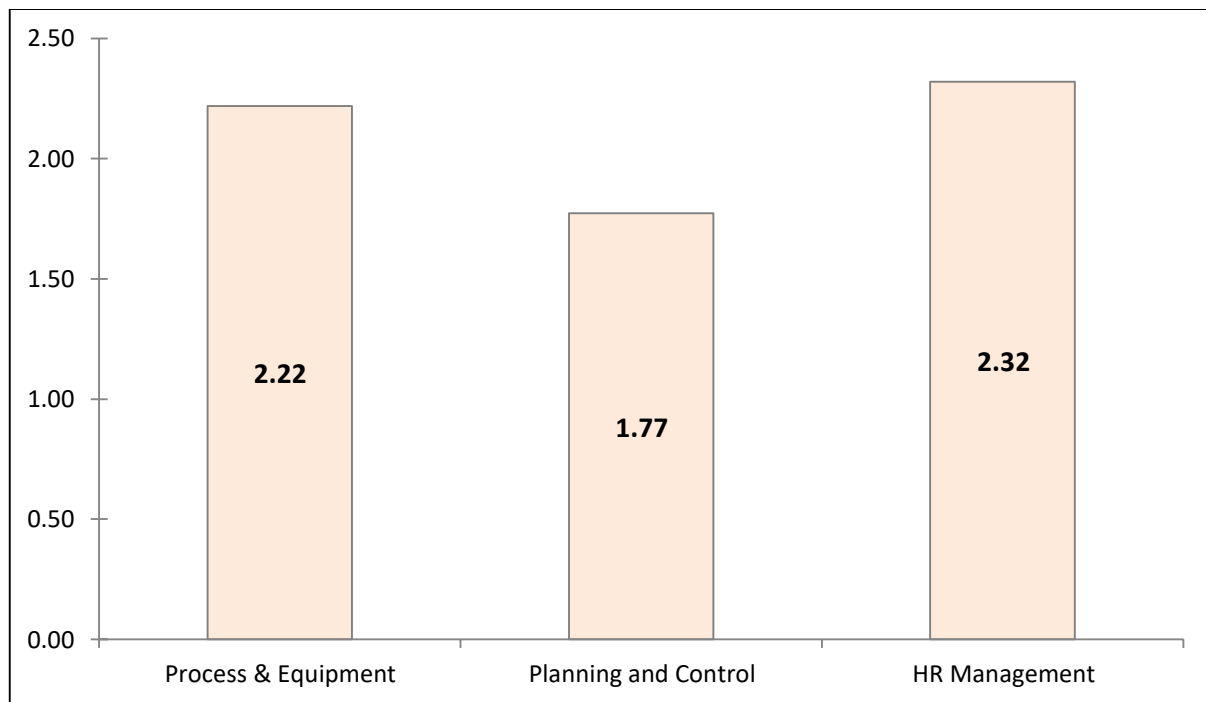


Figure 5-26 Current performance of the case companies

Returning to the research question number one (RQ1) posed at the beginning of this study (presented in section 1.4); it is now possible to state that the gap between the current state of lean related practices within the Libyan companies and the acceptable levels of performance of successful lean companies is very notable, as it can be seen from the low mean values for all questionnaire' constructs that were presented in Table 5-9 (all are less than 4). Therefore, the analysis of the questionnaire was useful in answering the first research question (RQ1).

The above results indicate that the investigated Libyan companies are not well prepared to successfully adopt lean manufacturing. Furthermore, this result clearly shows that the infrastructure for lean is very poor and the readiness level for adopting lean is very low within those companies.

In order to understand the factors that affect Libyan companies' preparedness and willingness to adopt lean, the current state of companies' practices is needed to be investigated further. For this purpose, semi-structure interviews with a number of companies' representatives are conducted, and the details are presented in the next sections. The analysis of the semi-structure interviews is expected to answer the second

research question (RQ2). Furthermore, a second plant visit for each company has been arranged to observe more details about shop floor activities.

5.4 Semi- structured Interviews

The results of questionnaire analyses that were presented in Table 5-9 showed that the managerial and operational practices within the Libyan automotive companies are not supportive towards lean manufacturing. For example the top management does not invest in long term human resources development and does not involve and empower workers to take action when needed. In order to figure out the reasons behind that, and to learn about the factors that hinder the adoption of lean manufacturing, semi-structure interviews have been conducted. Besides administering the questionnaire, conducting interviews should enable the researcher to enrich research data source. The variety of data collection techniques should allow for the achievement of data triangulation, thereby the validity and reliability of the obtained results could be ensured. Apart from its importance for data triangulation, conducting interviews should also increase familiarity with the automotive industry in Libya.

5.4.1 Interviews Protocol

After analysing the questionnaire and plants visits, it was obvious that the investigated practices are not supportive for adopting lean manufacturing successfully. Therefore, the need had arisen to investigate why lean is not implemented in the companies and what factors hinder its adoption. Towards that end, a semi-structured interview protocol was used.

Firstly, one-day workshop at every targeted company was arranged to introduce the concept of lean. The principles of lean manufacturing, tools, as well as successful case studies were presented to familiarise the audience with the lean concept and show the benefits that could be achieved by adopting lean manufacturing. The audience of the workshops were: a senior manager, a quality manager, a production manager, a logistic manager, a maintenance engineer, and a line supervisor. Interestingly, during the workshops it has been revealed that lean manufacturing was conceived as just-in-time

within the participated companies; however the audience's conception of the concept was very limited.

Afterwards, the content of the interview protocol had been developed based on plants observations and the initial results obtained from the questionnaire. Furthermore, a pilot interview had been conducted to ensure that the content of the interview protocol is as robust and reliable as possible in order to ensure the findings would be valid and reliable.

5.4.2 Interviews Protocol Findings

The participated employees in the interviews were seven people from each company (21 in total); they were from top management, production, quality, maintenance, and logistic function - (they were the same workshops' audiences). The interviews were recorded and then the tapes were transcribed and analysed by the researcher. The content and the analysis of the interviews can be summarised as follows:

Question 1: Does your company see any compelling need to adopt a new quality initiative for improvement such as lean manufacturing?

Most of the interviewees revealed that the liberalisation of the Libyan economy indicates the urgency of improving their processes in order to be able to compete with low-price imported products. One of the interviewees commented: "Libyan economy used to be closed and prices were protected by the government interventions. Therefore our local market share was guaranteed, hence there was not a real need to improve due to the absence of competitiveness and the small size of the local market. However, the game has now been changed and we need to adopt more effective production approach to boost our production processes in order to cope with the increased competitive market caused by low-prices imports." Another interviewee highlighted the issue of low-price imported products as a motivator for changing their current production approach to push down costs and maintain their market share by focusing more on current customers to retain them. He added: "Nowadays, there are several of local funding organisations (such as Islamic banks) importing several types of buses and trucks and reselling them to the public on loans, with exemption from duties and customs taxes, it is very difficult for us to compete with those organisations. Therefore, we need to cut down our costs to increase our profit".

After the meeting, the researcher had been provided with a document showing one of the case companies' market share data for the years from 2003 to 2010. The provided data are presented in Table 5-10 as an example to show the opportunities that company have had to increase its market share.

Table 5-10 Company XX market share from 2003 - 2010

Year	No. of Imported Units to the Libyan market	No of Sold Units	Libyan Market Size (Unite)	Company Market Share	Other Competitors Share
2003	501	998	1499	66.58%	33.42%
2004	559	967	1526	63.37%	36.63%
2005	563	1073	1636	65.59%	34.41%
2006	2309	476	2785	17.09%	82.91%
2007	2423	661	3084	21.43%	78.57%
2008	6561	1126	7687	14.65%	85.35%
2009	9030	1280	10310	12.42%	87.58%
2010	4506	960	5466	17.56%	82.44%

The manager who provided these data commented: "We have had notable opportunities to increase our market share if we performed better." The manager added: "For example in 2009, we had been able to sell only a 1,280 unit, whereas the market size was a 10,310 unit. The rest of the market size (9030 units) which accounted for 87.58% was taken by other organisations, mainly they were non-manufacturing organisations."

Another manager expressed his opinion for the need for a new production initiative such as lean in this way: "In the past it was easy to increase our profit by increasing our selling price, however in the light of the current market conditions, this advantage is no longer available because the price is determined by consumers and other competitors' prices, thus we need to cut down our costs for us to survive."

Furthermore, another interviewed manager claimed the need for changing the way they currently operate. He provided logically compelling evidence in support of his claim for the need of change. Production reports showing targeted and achieved production rates, and

the total of production lines stoppage, were provided as evidence for the need for adopting a new quality initiative such as lean manufacturing. The data are presented in Table 5-11.

Table 5-11 Production data for company XX during 2008 - 2013

Year	Targeted Production	Achieved Production	Productivity	Total of Stoppages (Hours)
2008	3,928	995	25.3%	274,711.10
2009	2,930	1,217	41.5%	179,034.06
2010	3,036	1,230	40.5%	176,131.75
2011	-	-	-	-
2012	1,678	294	17.5%	77,770.40
2013	1,654	382	23.1%	284,152.92

As it can be seen from Table 5-11, it is obvious that the amount of wasted time is considerable and the company have had -and still have- opportunities for improvement if they eliminate the stoppages throughout value stream and streamline production processes. After the meeting the researcher had been provided with a detailed report featuring the analysis of lines stoppage time and the reasons for not realising the targeted production rates.

The main and common reasons of stoppages can be summarised as follows:

- suppliers' delivery delays of raw material and the issue of missing components
- rework or correcting defective parts
- stoppage due to quality department (e.g. delays in approving sample materials, delays in carrying out final incoming inspection, delays as a result of damaged parts due to bad condition storages)
- stoppage due to machines breakdown
- stoppages due to internal suppliers (upstream suppliers) delay delivery of production components
- stoppage due to lack of machines spares parts required for repairing and restoring
- stoppage due to administrative issues (e.g. delays in releasing goods from customs authorities)
- stoppage due to materials lack of conformity to specifications.

Question 2: How is the performance of your workers is evaluated and what are the criteria for rewarding them?

Most of the interviewees have indicated that workers performance is appraised based on individuals' contributions. It has been stated by one of the interviewees: "In our company the performance of the employees is assessed individually, yet, we do not use a personal reward system by which employees' contributions should be evaluated and rewarded." Length of service and company loyalty was highlighted as tools of recognition and rewarding. In this regard a manager commented: "Length of service is held in high regard as vital tool for recognising the contributions of workers".....etc. "... Promotions to the managerial positions are based on seniority within the company; however selecting top management is not usually subject to this practice." The researcher has learnt that top management is usually appointed by Libyan Ministry of Industry, since the three case companies are government-owned. In addition to that, another manager has attributed the use of long service as a recognition and rewarding tool to its role in enhancing company loyalty. The manager commented: "Top management usually regards workers who spend long time in the company as loyal and they should be offered rewards." These mentioned rewarding criteria are in line with the result of the item HRM05 in the questionnaire analysis section that highlighted in the subsection 5.2.2.3.

On the other hand, none of the interviewees have indicated that their companies appraise the performance based on group / teamwork contributions. This is not surprising, since the culture of teamwork does not exist within the case companies. This conclusion is consistent with the results of the item HRM01 which was presented in the questionnaire analysis section (sub-sections 5.2.2.2), where the large majority of respondents indicated that their companies do not place emphasis on working in teamwork environment.

Question 3: How do you describe your company training policy?

Most of the interviewees have indicated that top management always develop training plans on year-by-year basis. While most of the programmes are run locally (inside the country), other programmes are organised in Europe – mainly in Italy. The developed plans

usually cover different areas (operational and administrative). One of the interviewees commented: “In fact it is the *Libyan’s Ministry of Industry* regulations that force our company to allocate a training budget, and the management must follow the rules, since the company is government-owned.” It might be worth to mention that all the three case companies are government-owned. Another interviewee commented: “Due to budget constraints, the allocated funds is usually not sufficient to implement the entire developed training plans. According to documents provided to the researcher by training office in one of the case companies, for example in the year of 2010, the number of targeted trainees was a 106 worker, however only 52 % of the number was achieved due to budget constraints.

Furthermore, another interviewee commented: “Most of our training programmes are run by local unqualified government organisations and we do not have a real in-house training system”. However, other interviewees indicated that they used to practice in-house training”. One added: “Periodically, our workers used to be rotated between different positions in the shop floor and this practice had been regarded as a provision of in-house training programme”. This account supports the result of questionnaire analysis (item HRM03).

Question 4: What are the key performance indicators used in your company?

All interviewees indicated that their companies do not use performance indicators to assess the performance. This is consistent with what it was disclosed by the result of the item PC03 in the questionnaire analysis (section 5.2.2).

Using performance indicator is important element for lean manufacturing in terms of identifying areas for improvement. It allows for investigating, assessing, and measuring key aspects of production processes (e.g. defect rate, inventory rates), hence identifying waste and improving the processes.

Question 5: How does your company identify customer requirements?

Most of the interviewees indicated that their companies are familiar with the actual customer needs. One manager commented: “We do involve our customers in the preliminary stages of our products design; therefore we are aware of product features that a customer values and is happy to buy”.

Another manager indicated: “The marketing office in our company regularly conducts surveys seeking previous customers’ opinions about the product performance in order for us to avoid any design or quality future problems”. However, another interviewee indicated that nothing more than their long existence in the market and the small size of the Libyan market that enable them to be familiar with customer value.

Question 6: How does your company seek and measure customers’ satisfaction?

The vast majority of the interviewees indicated that customers’ satisfaction is very important for them. One interviewee commended: “We regularly seek customer satisfaction because we believe customer is the number one in our business processes; losing customers will lead to dry up the flow of money tap.” Another interviewee expressed the importance of services and quality of products in realising customer satisfaction. He added: “We place great value on our services and product quality in order to meet a level of customer satisfaction, thereby maintain a reasonable market share in the light of competition from other players in the market.” Most of the interviewees have mentioned the use of surveys in seeking customers’ opinions regarding the service and the quality of products.

The researcher has been provided with a copy of a survey the company uses to solicit customers’ feedback in terms of services and quality of products. A manager commented on this by: “It has been five years since we started using this method [survey] to collect data from our customers to deal with their concerns in order to meet a level of customer satisfaction”. According to the provided survey, the customers being asked their level of satisfaction on several aspects such as, services provided by company’s employees; product delivery; selling price; and the warranty period. The survey also includes questions about

the satisfaction level on the technical aspects, such as engine; performance of steering system; air-condition system, vehicle brake system, and vehicles painting.

Question 7: How do you describe the relationship with your suppliers?

A number of the interviewees have indicated that they deal with a quite high number of suppliers; however other interviewees revealed that they make efforts to reduce the number of suppliers. Furthermore, most of the interviewees indicated they deal with local suppliers to avoid delays in delivering raw material. However, there are a lot of parts and components are not available in the local market, so those companies have to deal with overseas suppliers. The issue of materials delivery delays caused by overseas suppliers has been highlighted by many interviewees. In this regard, a manger commented: “Most of our production lines stoppage time is caused by long delays in delivering parts and components that are not available in the local market”. The researcher has been provided with a report showing the stoppage caused by suppliers. For example in 2008, stoppage caused by suppliers comprised 12.11% of the total stoppage time, whereas it accounted for 24.29% and 6.9% in the year of 2009 and 2010 respectively.

Moreover, some interviewees highlighted the issue of suppliers’ quality, some suppliers deliver materials that do not conform to quality requirements. An interviewee commented: “We usually experience defective delivered components, so we must do incoming inspection to ensure the quality of delivered materials.” According to the reports obtained from the participated companies during the field study, the time required for doing incoming inspection procedures contributes to the lines total stoppage times.

The response to this question supports the plant observations the researcher made during the field study. The researcher has observed workers from quality control department carrying out random inspections for components that were stored in a hall waiting for this inspection in order to ensure the quality (picture in Figure 5-27). The researcher has learnt that this procedure (incoming inspection) is common in that company due to quite high rates of non-conformance to quality requirements. The researcher has been informed by a

quality control manager that the company usually tend to source the raw materials from other suppliers if non-conformance to quality occurred frequently.



Figure 5-27 Materials incoming inspection for quality assurance

Incoming inspection of raw materials is considered as non-value added activities that should be avoided for Libyan companies to adopt lean manufacturing successfully.

Question 8: Does your company empower workers to take action?

Most of the interviewees indicated that any decision must be approved by top management which simply revealed that workers are not empowered to take actions when needed. This is consistent with the results of item HRM06 in the questionnaire analysis (section 5.2.2.3).

5.4.3 Interviews Concluding Remarks

The results of the interviews and the plants visits have shown deterioration in the basic practices that are considered essential for adopting lean manufacturing successfully. Furthermore, the basic knowledge of lean is not available within the case companies, and many additional issues have also been identified. All identified issues represent lean barriers

that Libyan companies face and must be carefully addressed in order to adopt lean manufacturing successfully. Those lean barriers could be summarised as follows:

- Lack of required knowledge and proper training programmes
- Lack of workers empowerment
- The absence of teamwork culture
- Lack of reward system
- The absence of key performance indicators usage
- The absence of good relationship with suppliers
- Lack of multi-skilled workers
- Lack of workers involvement in process improvement
- Lack of fund resources required for training
- Improper equipment layout
- High set up times
- Maintenance related issues
- High levels of inventory
- High lead-times

Furthermore, the observations made during plants visits have indicated that the investigated Libyan companies are missing many lean manufacturing aspects such as: visual labelling system, flow of processes, product layout of shop floor configuration, total productive maintenance, less set up times, pull systems, conducting focus groups and quality circles, and reliable suppliers

The analysis of the interviews and the observations made during plants visits make sense of the results obtained from the analysis of the questionnaire, since the interviews and observations have highlighted the same issues that were highlighted by the questionnaires' analysis. Furthermore, the interviews and observations made it possible to answer the second and third research questions that have been posed in chapter one (presented in section 1.4). The second research question (RQ2) sought to understand the factors that hinder the adoption of lean manufacturing in the Libyan companies. With respect to the third research question (RQ3), which aimed to investigate the companies' urgency for

adopting lean, the interviews (question one – in particular) made it clear that there is a real need for Libyan companies to adopt lean manufacturing.

The homogeneity of results obtained by the employed different methods of data collection (questionnaire, observations, and interviews) gives credibility to the obtained results.

5.5 Chapter Summary

The analysis of the field study has shown that the manufacturing processes of the case companies are suffering from many issues. According to lean manufacturing literature review, and many successful lean stories, there are several lean tools that could be customised and applied to attack and reduce the considerable amount of wasted time that is caused by a combination of several reasons as was shown in this chapter. Therefore, lean manufacturing could be a good option for Libyan companies to offer opportunities for improvements. However, it seems, there are no real efforts made towards lean manufacturing, since most of lean manufacturing related practices were found not supportive to adopt lean within those companies. This neglecting of manufacturing sector in Libya could be attributed to the fact that the Libyan economy is oil & gas-based (Tawiri and Marinov, 2011) where all efforts and support are given to this sector. According to the International Monetary Fund (Randall 2015), 95% of Libya's revenues and 60% of its GDP (Gross Domestic Product) currently stem from oil and gas sector. This seems to be the case in most of the oil-based Arab economies as argued by Alhaqbani, 2013. It is therefore recommended - in the light of instability in oil prices – that, Libya and other similar developing countries to take real steps towards finding ways to improve their economies. The manufacturing sector could be a good option to contribute to the economy, hence real efforts should be made to enhance this sector and make it more reliable by adopting more effective improvement initiatives such as lean manufacturing.

This chapter has provided a discussion of the main findings regarding the three constructs that comprised the entire questionnaire as well as highlighted the main results of the observations and interviews. These three constructs incorporate most of the practices that are considered important to lean manufacturing. Therefore it will be useful in facilitating the development of the aimed customised transformation strategy (LMTS) for introducing lean

manufacturing to the Libyan companies which will be presented and discussed in the next Chapter.

Chapter 6 Development of the Lean Manufacturing Transformation Strategy

6.1 Introduction

After analysing the data that have been collected from the field study which took place in three Libyan companies, and presenting the findings in the previous chapter, the current chapter, therefore, has been set out to present and discuss the lean manufacturing transformation strategy (LMTS) which is the main aim of this study. The general structure, determined modules, and the composition of the lean manufacturing transformation strategy (LMTS) should be helpful to introduce lean manufacturing to Libyan industries and other similar developing countries. Firstly, the approach for developing the LMTS will be introduced, and then the LMTS itself will be presented and discussed.

6.2 An Approach for the Development of Lean Manufacturing Transformation Strategy

A three phases approach has been developed and followed as a guide in order to develop the lean manufacturing transformation strategy (LMTS); a process flowchart for the approach is depicted in Figure 6-1. The three phases which have been followed to develop the lean manufacturing transformation strategy (LMTS) are described briefly in the following sub-sections.

6.2.1 Phase 1: Proposition of Lean Manufacturing Success Factors

Addressing lean manufacturing solely at tactical level (tools level) is usually ended with failure due to the exclusion of other factors that are essential to lean. Adopting lean tools is just one facet of the journey, there are several factors that organisations must consider to make the journey successful and sustain the obtained results. Therefore, the first phase of developing the lean transformation strategy is to focus on the critical success factors of lean which are regarded as prerequisites to successfully commence any lean project. The lean critical success factors have been extensively addressed in Chapter 3 in this study.

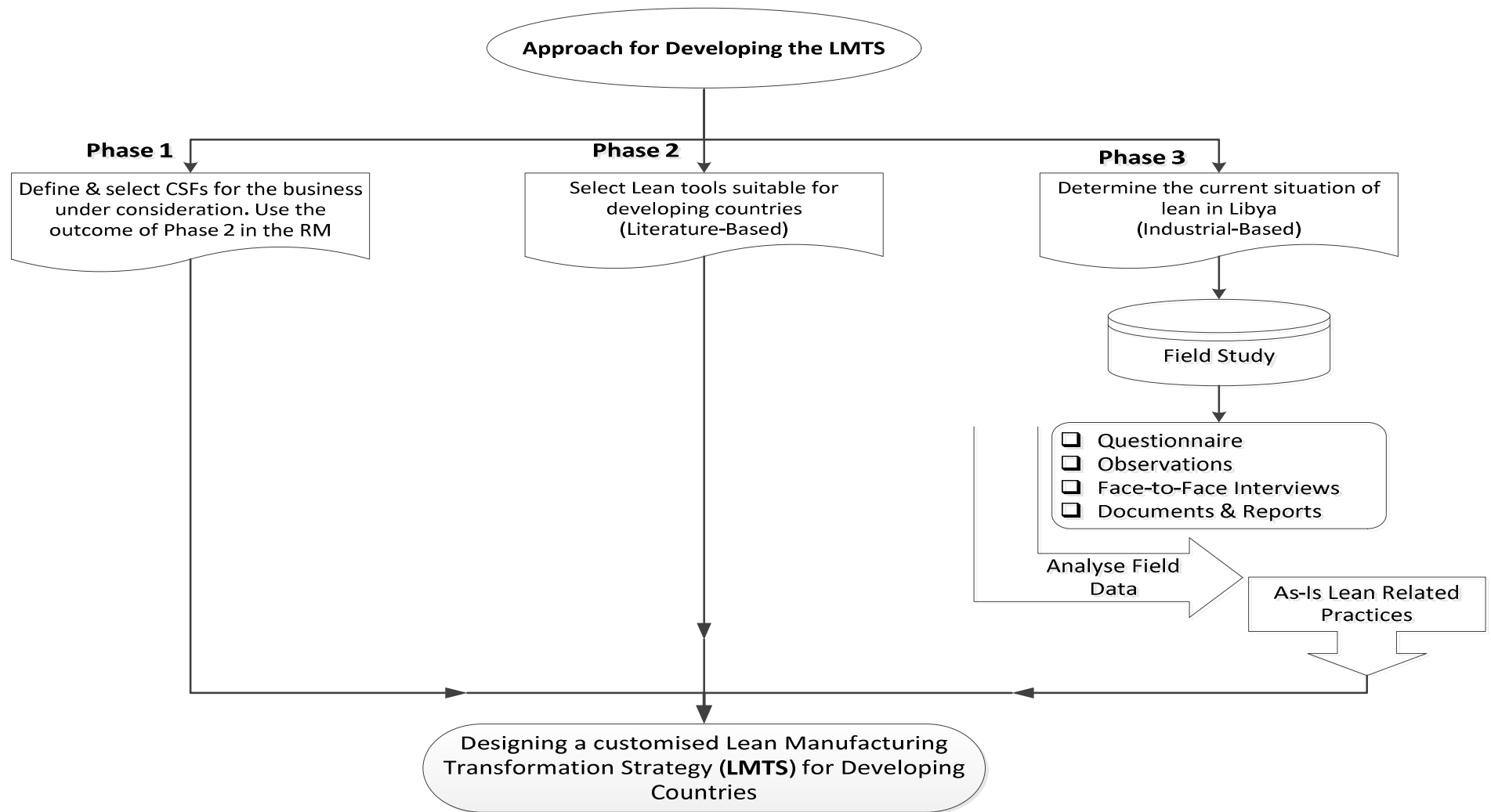


Figure 6-1 Approach for developing lean manufacturing transformation strategy for developing countries

The process of proposing a list of lean critical success factors for the developing countries was illustrated by the approach depicted in Figure 1-1. Firstly, the lean success factors in developed organisations have been identified from literature. Since this is a customised transformation strategy for developing countries, the lean barriers in developing countries were also identified from literature. Then, the two steps have been mapped by comparing different results and finally a list of lean critical success factors for developing countries was proposed.

The approach that has been developed and depicted in Figure 1-1 has produced a pool of lean critical success factors that companies – in general – in developing world could consult to select what factors are suitable to them and help them to define new ones. This could be considered as a good contribution this study has made to the field of lean manufacturing.

6.2.2 Phase 2: Selection of Lean Manufacturing Tools

The second phase of the LMTS development's approach is selecting the most appropriate lean tools. Lean manufacturing tools are the most part of the lean subject that has been addressed by researchers; hence the second step of the LMTS development's approach is focusing on the tools aspect.

There is a wide range of lean manufacturing tools that had been reported in literature by many leading practitioners and academics worldwide (Chen and Meng, 2010). However, the focus here will be on the most common and basic tools as the purpose of the intended transformation strategy (LMTS) is to introduce lean to an environment which is relatively new to lean (Libya and other similar developing countries). The tools and techniques that are widely and commonly applied in implementing lean have previously been addressed in Chapter 2 (sections 2.3 and 2.7) in this study. Moreover, a number of articles have been reviewed in order to identify the tools that are easy to understand and use by employees in a context such as Libya where the infrastructure and preparedness to lean has been found very poor as has been illustrated in many sections in Chapter 5 (field study data analysis).

The implantation of lean tools has demonstrated great improvements in operational performance. However, in practice, organisations face difficulties in terms of the suitability of the selected tools. The improper selection of lean tools has widely resulted in failure

(Tiwari *et al.*, 2007) and sometimes brings adverse results and creates other types of waste (Marvel and Standridge, 2009). This is because the effective selection of lean tools for a successful and an effective implementation is heavily dependent on how the process's issue is identified (Bayou and de Korvin, 2008). Therefore, intense attention should be given to what and how to apply lean techniques in a given environment; thus potential disruptions in manufacturing processes (due to improper selection of tools) could be prevented.

Since the core objective of selecting and implementing a particular lean tool / tools is to reduce or eliminate a particular type of waste / wastes, then the selection of tool / tools should be based on the type of waste identified in the manufacturing system. A number of authors have considered the importance of selecting lean tools based on the waste type. For instance, (Amin and Karim 2013) proposed a methodology to help companies identifying the proper lean tools that are suitable for a specific type/s of waste. In the same vein, Garbie 2010 argued that the process of lean tools adoption is time consuming as there is a wide range of those tools. He demonstrated in a case study that lean tools should be selected according to the identified non-value added steps (waste type). Lean manufacturing comprising a number of tools, each tool aims to identify and then eliminate or reduce some of the identified manufacturing waste. Each lean tool has a direct impact (high or low) on several types of waste. Table 6-1 presents a matrix relationship between the most common manufacturing wastes identified from literature and the specific lean tool / tools that use to handle the identified waste. This matrix has been developed as a result of the thorough research and investigation of the typical types of waste in manufacturing area and the well-established tools and methods. This investigation resulted in understanding the relationship between what the tools have been developed for and how they have been practiced to address the waste. Furthermore, examples have been provided to illustrate the effectiveness of the correlation between lean tools and waste types that has been demonstrated by the matrix. Finally, it is worth to mention that this matrix is just a general guide giving suggestions and hints when selecting lean tools. It is not a measuring tool and does not guarantee the success of waste removal through selecting certain tools.

Table 6-1 Correlation relationship of lean tools impact on the type of waste

Lean Tools	Type of manufacturing waste						
	Setup time	Over production	Rework	Unneeded transportation	Unnecessary motion	WIP	Waiting: machine or operator
Total productive maintenance (TPM)	✓		✓				✓
Pull / Kanban system		✓	✓			✓	
Production levelling		✓	✓			✓	
Just –in-time			✓			✓	
Visual management system					✓		
Standardised operations	✓	✓	✓	✓	✓		✓
Single minute exchange of dies (SMED)	✓						
5S	✓				✓		✓
Continuous flow / information & processing						✓	
Poka Yoke			✓				✓
Takt time		✓	✓				

As shown in Table 6-1 the rows in the matrix represent different lean tools and the columns represent waste types that are widely reported in literature (Shah and Ward, 2003; Doolen and Hacker 2005; Panizzolo 1998). The impact that a lean tool has on a waste type has been illustrated by a tick symbol in the matrix of Table 6-1. The “lean tools – waste type” matrix [Table 6-1] can be used as a decision support tool to help companies to make the most out of lean tools by selecting the tool or collection of tools that are most relevant to the identified type of waste within the manufacturing system. Therefore, the likelihood of lean success can be maximised.

As the “lean tools – waste type” matrix suggests, there are several levels of complexity in how lean techniques and tools could be implemented. On the most practical and pragmatic level, lean manufacturing techniques and tools are aimed to identify and then reduce or eliminate waste in a particular environment. These techniques and tools should be selected according to their suitability for addressing the identified waste in order to realise the expected benefits of these tools. For example Single Minute Exchange of Dies (SMED) is usually selected to address setup time waste as SMED has an impact on the different forms of setup time waste (e.g. processing time, machine or operator idle time, times for loading and waiting for raw materials). Also, as it can be seen from Table 6-1, 5s has an impact on setup time and it is regarded as an effective tool to handle this type of waste (setup time waste).

Moreover, the principles of 5S are aimed to organise shop-floor, as a result all tools necessary for a machine’s start-up are kept visible and easier to locate, and thereby setup time will be enhanced. Single Minute Exchange of Dies (SMED) is another lean tool that is regarded suitable for addressing setup time waste. The aim of SMED is to reduce parts waiting time by analysing all activities (internal and external) related to a machine setup and redesign processes.

It is notable that “lean tools – waste type” matrix (Table 6-1) shows a level of multiplicity of the role that lean tools can play in reducing waste. Every single lean manufacturing tool can drive a variety of improvements and contributes to performance improvement.

Unfortunately, this multiplicity of lean's tools role in reducing waste could lead to chaos if tools implemented concurrently because the "improvements – issues" of each tool will be difficult to analyse and further enhancements will also be difficult to sustain. Therefore, it is highly recommended that lean tools should be implemented in a right sequence for organisations to realise and sustain operational benefits. In line with that, many previously published studies – for example - (Anand and Kodali, 2010b; Wan and Chen, 2009; White and Kuo 2010) have argued that the sequence of lean tools' implementation should be regarded as one of the parameters that should be considered when implementing lean tools. In this study, the sequence of lean tools implementation has been addressed in Chapter 2 (section 2.9)

6.2.3 Phase 3: Determination of the Current Situation of Lean in Developing Countries

Since the sought goal was to develop a transformation strategy that is customised to the need of manufacturing organisations in developing countries (Libya as a representative), the identification of the current situation therefore was a must. The current situation has been investigated during the field study which was conducted within three Libyan manufacturing organisations. Several methods (e.g. questionnaire, interviews, observations & chatting with workers, analysing companies' documents) were employed to assess and identify the current situation of the lean manufacturing related practices within the Libyan companies. The details of the process of administering the questionnaire and the obtained results have been presented in Chapter 4 and Chapter 5 (Table 5-9) respectively. Furthermore, the lean manufacturing barriers within the case companies have been identified through interviews and observations and were illustrated and reported in Chapter 5 (section 5.4.3). It might be worth to mention that the identified lean barriers through the field study were found consistent with those reported in previous literatures, which gives credibility to the results obtained by this study. The proposed lean manufacturing transformation strategy (LMTS) contains several practices that will act as countermeasures to

effectively reduce the effect of those identified barriers and hence increase the chance of successfully adopting lean manufacturing.

Finally, the above three phases of Figure 6-1 were then combined to construct the lean manufacturing transformation strategy (LMTS). The details of LMTS are presented in the next section.

6.3 The Proposed Lean Manufacturing Transformation Strategy

As it has been highlighted in Chapters 3 and 4 in this study, the previous studies have indicated that a proper transformation strategy for introducing lean manufacturing to a developing country such as Libya is still a vital necessity. An effective strategy to introduce lean should link the concept of lean with its operational practices through some systematic means. In this study, a lean manufacturing transformation strategy (LMTS) has been proposed based on the most critical success factors linked with the concept of lean and tools associated with it, which is the main aim of this study.

Following the approach presented in Figure 6-1, the proposed strategy (LMTS) is depicted in Figure 6-2. The proposed strategy is hoped to facilitate the process of introducing lean manufacturing to the Libyan industry and other similar developing countries. There are no restrictions on the application of the proposed strategy (LMTS), as it could be adopted in any industrial sector in the developing countries that have a similar context to Libya, regardless the companies' size and the market in which they operate. However; the focus of the current study is the automobile sector in Libya.

In this proposed strategy (LMTS), lean manufacturing principles and its associated techniques and tools should facilitate and promote the reduction of non-value added activities within the business under consideration, resulting in the eventual creation of the mind-set of continuous improvement, which in turn should eventually lead to obtaining productivity gains in the specific area being the focus of the application of the lean manufacturing implementation strategy, LMTS.

The content of this proposed strategy, its implementation process, its respective phases and steps, and its sequence are addressed in more detail in the following sub-sections. As shown below, there are seven phases to run the entire process of introducing lean manufacturing through the proposed LMTS. They are as follows:

Stage 1: **Preparation**

Stage 2: **Establish target objectives**

Stage 3: **Current process map**

Stage 4: **Current process performance measurement**

Stage 5: **Action (commerce improvement process)**

Stage 6: **Overall system assessment**

Stage 7: **Kaizen**

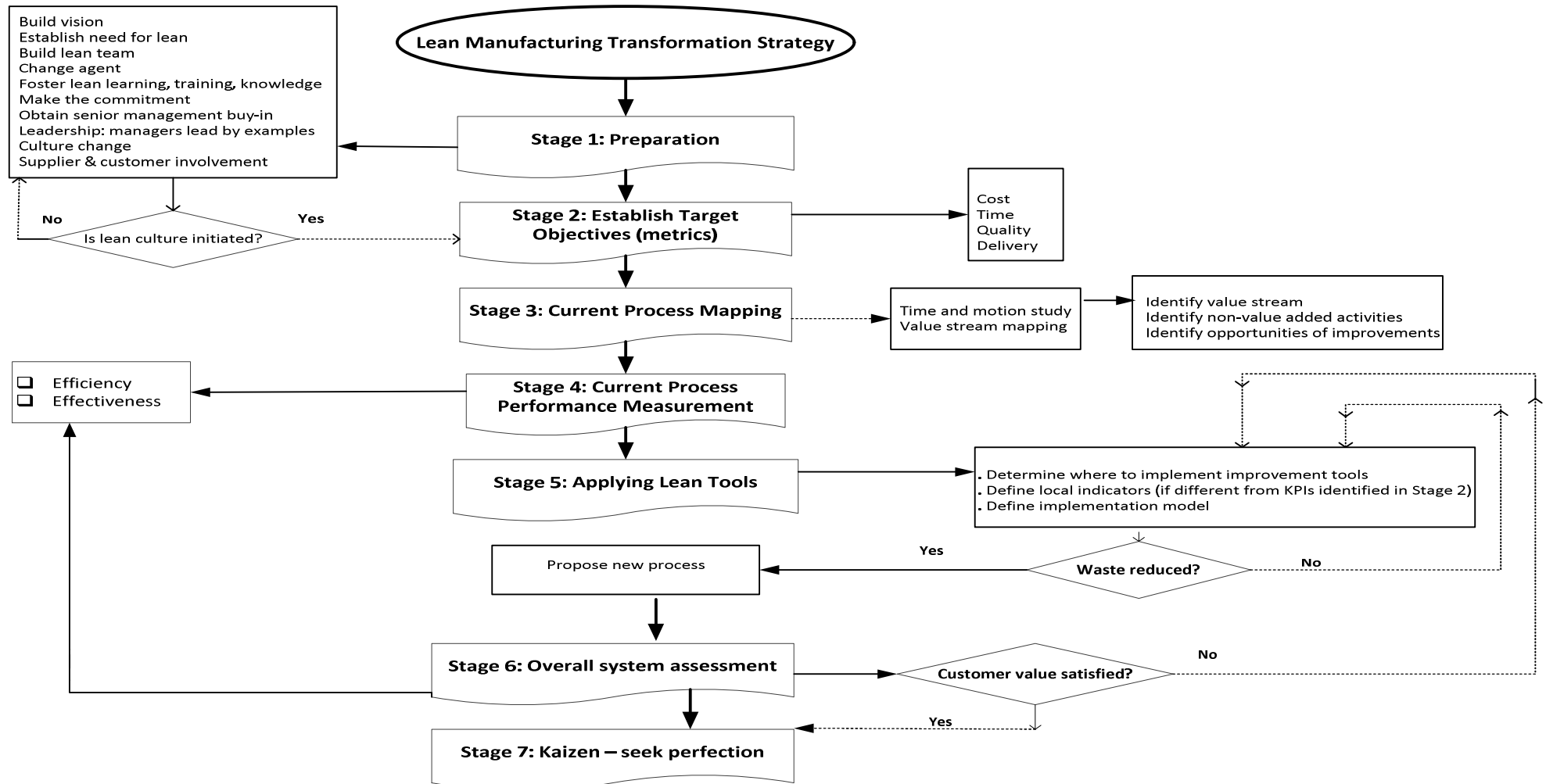


Figure 6-2 Proposed Lean Manufacturing Transformation Strategy (LMTS)

6.3.1 Stage 1: Preparation

The first stage of the developed LMTS is to create the infrastructure that is required for successfully transforming a company to better enhance its processes and gain more benefits through the adoption of lean manufacturing.

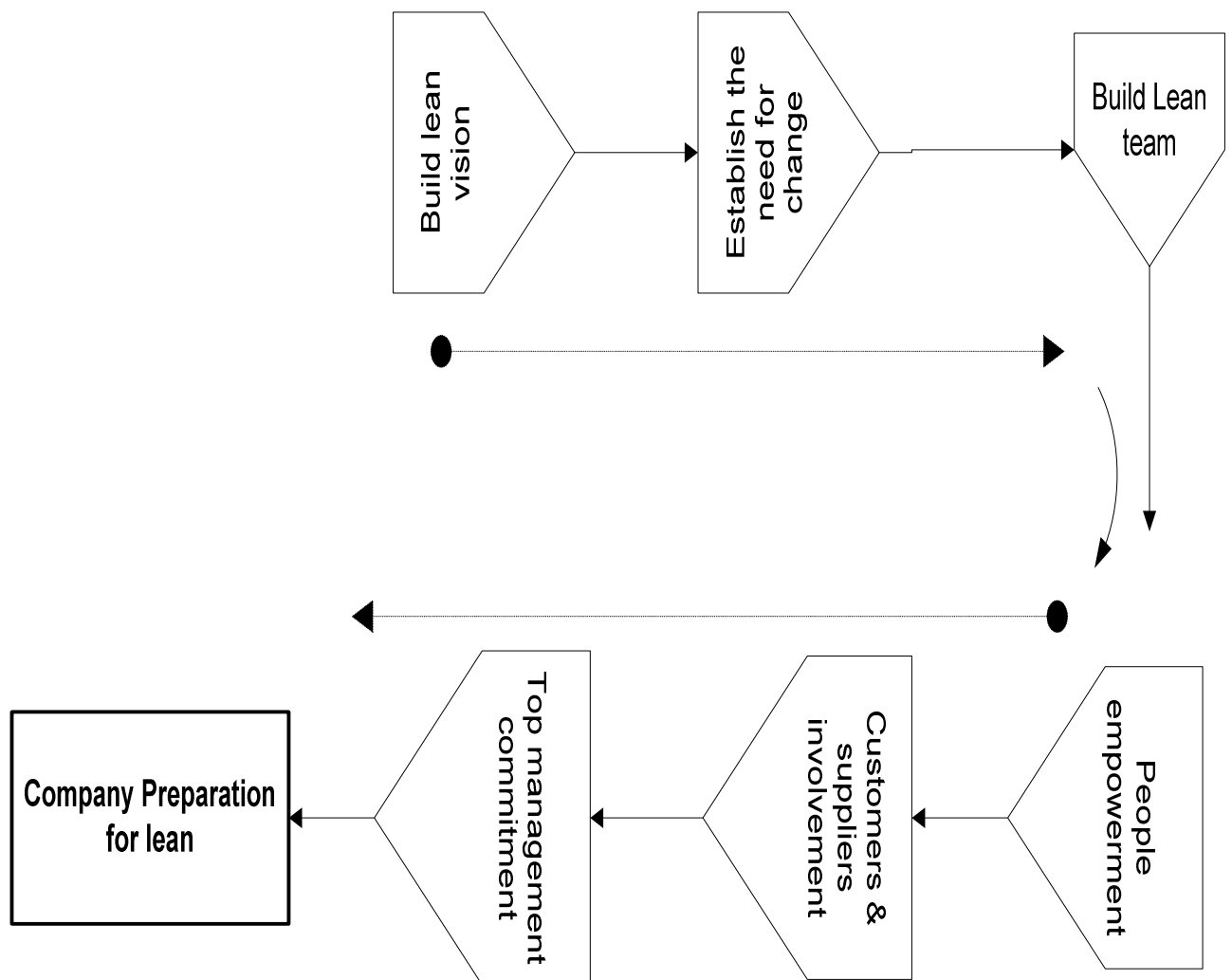


Figure 6-3 Preparation Steps for Adopting Lean

Figure 6-3 illustrates the most important activities that organisations should carry out in this stage in order to effectively adopt lean manufacturing. Those preparation activities are presented and discussed in the following sub sections.

6.3.1.1 Lean Manufacturing Vision Creation

The lack of an organisation's vision behind the reason of adopting lean is one of the most factors contributes to the initiative's failure. Therefore, as a first step towards lean, organisations are required to build and share a vision of what it means to them to be lean, what are the basic requirements for an organisation to become lean and how to change the organisation's context in order to drive the transformation to lean. Meeting customer value, enhancing employees working conditions, and reducing product costs can be achieved through radically redesigning an organisation's value stream processes for building the right products. Creating and sharing the lean vision is the senior management responsibility, therefore senior managers are required to obtain the necessary lean knowledge. It is therefore important to help a number of senior managers to be qualified to create the lean vision by – for example – organising seminars, workshops, or conferences.

6.3.1.2 Establish the Need for Change

One of the most important modules included in the proposed LMTS is the senior management's understanding and effectively demonstrating the compelling need for changing to lean manufacturing. Senior management should detail the need for change and the company's employees at all organisational levels must be aware why the company is moving towards lean. It has been illustrated that organisations are usually successful in making considerable and effective change only when they face serious challenges and threats. The process of transformation to lean usually fails when an organisation functions stably and normally. Therefore, senior management must find factors that act as motivation to change to lean.

Regarding the situation in the Libyan case companies, as highlighted within the section of semi-structured interviews, the interviewees (senior managers) have clearly stated that their companies see compelling need and urgency to adopt an improvement initiative such as lean manufacturing to reduce waste and enhance their processes. During the interviews sessions, a number of examples have been provided by the

interviewees to show the urgency for adopting lean manufacturing. For instance, some of the most common sources of waste were reported and have been regarded by the interviewees (during the field study) as main motivators for them to adopt lean manufacturing. As an example, the stoppage caused by internal suppliers' related issues in the year of 2013 in one of the case companies was accounted for 27% of the total lines stoppage time of 284,152.92 hours. Whereas, in the year of 2009 the total lines stoppage was 179,034.06 hours, and the delays caused by external suppliers issues comprised 24.29% of the total stoppage. Furthermore, in 2009 machines breakdown contributed by 22.13% of the total lines stoppage. In this regard, there are many studies (Alagaraja 2014; Kumar and Kumar 2015; Mcadam and Donegan, 2003) that highlighted the importance of the presence of urgency in stimulating organisations to embrace lean principles.

Furthermore, other researchers, for example (Hines *et al.*, 2004; Tischler 2006; Ulhassan *et al.*, 2013; Lee and Oakes 1996) demonstrated reasonably consistent association between the decision of changing to lean and the presence of urgency and the need for that change. For example, Hines *et al.*, 2004 stated that Toyota itself invented its system; "Toyota Production System" (TPS) due to shortage of its resources and because of the Japanese market increased competition that forced Toyota to find a way to cut waste and improve its processes

Moreover, studies such as Alagaraja, (2014) and Cooney, (2002) highlighted the importance of the presence of business conditions to successfully adopt and implement lean programmes. They argue that certain business conditions (e.g. strong competition, increased customer demand, governmental regulations for enhancing industrial sector) are very important for setting the right context and develop a sense of urgency for lean adoption. Based on the analysis of question one in the interviews section (presented in the sub-section 6.4.2), certain business conditions in the Libyan market are found to be supportive for Libyan companies to change to lean, since the interviewees have indicated that there is a critical need for adopting lean and have provided several examples to support that need.

6.3.1.3 Lean Team Building

The successful adoption of lean manufacturing necessitates the human-centred aspect of the manufacturing system. Setting up a lean manufacturing implementation team is vital while transforming to lean manufacturing. The size of the implementation team depends on the size of the company itself, but it ideally should consist of:

- A senior management from the targeted area
- Members from key departments such as: quality control, production, public relations, marketing, finance, engineering, maintenance, and
- Operators

There are specific attributes that are considered essential for effective lean team members. Team members should exhibit a level of enthusiasm; respect; sincerity; openness; interdependence; and trust. These qualities should play a vital role in enhancing the team performance. For example, the implementation team members would be more flexible to accept and value different points of view and respect the other members' views when they are open-minded. Teams in lean environment should also have open, honest communication and feedback among all members. Furthermore, the goals of the team should be aligned, and there should be a high degree of synergy and cooperation among the team members.

The lean team members should first establish and then increase their knowledge and familiarity regarding lean principles and their associated benefits, and the company leadership must provide the necessary time and efforts for that. To that end the company leadership might consult a lean expert to train the team members and familiarise them with lean principles and techniques. Moreover, the presence of appropriate communication channels enable the team members and workers to better understand lean manufacturing and therefore be much better in visualising the requirements and the potential benefits of the lean transformation process. The main aim of the implementation team is to organise the available resources and workers in order to drive the transformation process.

6.3.1.4 Top Management Commitment

The lack of top management understanding and commitment is usually behind the failure of lean manufacturing transformation process. It is crucial for lean transformation process that top management invests the required resource, time, effort, and commitment. It is vital - from the outset - after establishing and increasing the awareness of lean that top management address any doubts to wipe out any misconception or fear linked with the lean transformation process.

6.3.1.5 Workers Involvement and Empowerment

The workers' ability and desire to involve and effectively participate in lean manufacturing transformation activities will be likely affected if workers are put under close inspection by senior management. In fact, this might be considered as a normal behaviour of the workers because of the unsupportive work environment and the blame culture created by such behaviour from the top management. Therefore, workers involvement and empowerment is a vital factor for adopting lean successfully and thus should be considered during the transformation process. Employees' involvement and empowerment could be increased by implementing systems such as suggestion scheme, reward and recognition systems, and organise workers in quality circles (for example) to enable them generate and provide new improvements ideas.

Shop-floor workers' suggestions systems are usually fostered by entailing other human resources practices such as employees' education and training, employees' involvement, and ergonomics. These practices that foster workers' suggestions systems and thus improve workers' empowerment are vital in enhancing product design, decreasing changeover times and lead times, and enhancing the quality. For example, the more workers' suggestions on work practices are considered by management, the more likely is that poka-yoke solutions diffuse downward through the company.

Successful lean manufacturing companies usually encourage workers to participate in teamwork environment as the improvement ideas and suggestions are often

generated within teams. The successful lean companies usually introduce suggestions systems (e.g. quality circles, focus groups, and problem-solving small group sessions) where people are organised in groups to work collectively and suggest ideas for improvement. The investigated Libyan companies seem they are missing this supportive aspect of lean, therefore they should consider teamwork to take advantage of its benefit in generating effective ideas for improvement. When collaborating in teams, there are a lot of benefits that workers could acquire such as: more ideas and new ideas; multiple areas of expertise; shared workload; and stronger problem solving.

During companies visits it had been noted that the vast majority of workers are local people and the researcher had been informed that the employees' turnover is very low in general in the Libyan market. This point should be a motivator for the top management to invest in long-term human resources development by focusing more on education and training in order to leverage workers' desire to participate in teamwork where the improvement ideas should be generated. It might be worth to mention that low employees' turnover lead to increase the organisational learning which is necessary for Lean. The improvements ideas provided by workers should be recognised in order to keep workers motivated, hence the productivity can be enhanced.

6.3.1.6 Customers and Suppliers Involvement

Maintaining long-term and good relationships with customers and suppliers contributes to stabilising demand patterns and hence improving the consistency of demand as well as providing feedbacks on products' quality. Therefore, companies should address the possibilities of involving customers in the business activities and in some stages of product development processes. Customers' involvement is viewed as external resource that enhances the company's activities towards effective lean transformation. Moreover, the degree of customer involvement has widely been recognised as one of the key indicators of the level of processes' leanness, therefore it should be considered in any lean transformation process. One of the possibilities of aligning processes and products to meet customer requirements is involving customers

in the product design process. Therefore, customers' needs can be fulfilled and hence company can maintain customers for long time.

Once the company has established the required infrastructure towards lean manufacturing, the next stage in the LMTS is to establish the company's target objectives.

6.3.2 Stage 2: Definition of Performance Metrics

In this stage the lean implementation team should define and communicate a number of objectives (performance metrics) that all workers in the targeted area can visualise and contribute to. The importance of defining a set of performance measures stem from the need to justify the adoption and the implementation of lean manufacturing. Therefore, the set of performance measures is like the mechanism through which companies can demonstrate the achievements of performance improvement.

These performance metrics – that will be used later on to assess the lean performance – can take the form of a set of variables such as cost reduction, productivity improvement, quality enhancement, lead time reduction, processing time reduction, non-value added time reduction, and lead time improvement. It has been found that the time-related performance metrics are the most used indicators in assessing lean manufacturing performance. In this study, time, cost, quality, flexibility are selected among the many used performance metrics. The performance measures should be shared with all workers and constantly kept up to date.

6.3.3 Stage 3: Current Process Mapping

The purpose of this stage is to capture a clear picture of the targeted area which will be the focal point for the LMTS's improvement activities (where lean is intended to be implemented) in order to assess the current status of the manufacturing current processes and their interrelationships. The evaluation of the current state has two activities, namely analysing the performance indicators that have been defined in stage 2 (section 6.3.2) and mapping the flow of materials and information throughout

the process. The outcome of this stage will be the documentation of the value stream, in other words, identifying all manufacturing activities (value added and non-value added). The flow stream of manufacturing processes is identified by visualising those processes using tools such as value stream mapping (VSM) and time and time and motion study. By identifying all possible areas of removing waste, the opportunities of improvements would then be clear and visible which then would be the target of LMTS improvement activities.

6.3.4 Stage 4: Current Process Performance Measurement

The fourth stage in the LMTS is to measure the current performance of the manufacturing process (before implementing lean improvement tools). The performance assessment metrics that have been defined in stage 2 (section 6.3.2) might be used to assess the process's current performance in terms of efficiency, productivity, defect rate, and effectiveness. After implementing lean tools in the next stage (section 7.3.5), the process performance will be assessed again to compare the results of performance before and after applying lean tools.

6.3.5 Stage 5: Applying Improvement Tools and Techniques

This stage of the proposed strategy (LMTS) is where the company makes the actual process change and bring things about. There is no specific order for the implementation of the improvement tools. The tools, the targeted area of implementation, and the order of implementation will largely depend on the results of stage 3 above (section 6.3.3). However, since the subject of lean in the Libyan context has been found relatively new - as the results of field study has shown - the focus of this phase will be setting the right stage that is essential to successfully transform companies into lean manufacturing. It is to build a solid foundation for implementing a set of any future further improvement tools. These improvement tools should be applied constantly, again and again, until the wasteful activities are reduced and eliminated. This should result in enhanced performance and satisfied customers' needs, and therefore a new process is proposed.

One of the big issues companies usually face when starting lean initiatives, they start from this stage (implementing lean tools – stage 5 in here). Although, starting lean with implementing lean techniques can produce quick results, it would not have much impact on the overall performance as the company has not been prepared well from scratch. Therefore, preparing the foundation for lean is very important as illustrated in stage 1 above.

The generic template that would be followed within the proposed LMTS for defining and implementing lean manufacturing improvement tools is shown in Figure 6-4.

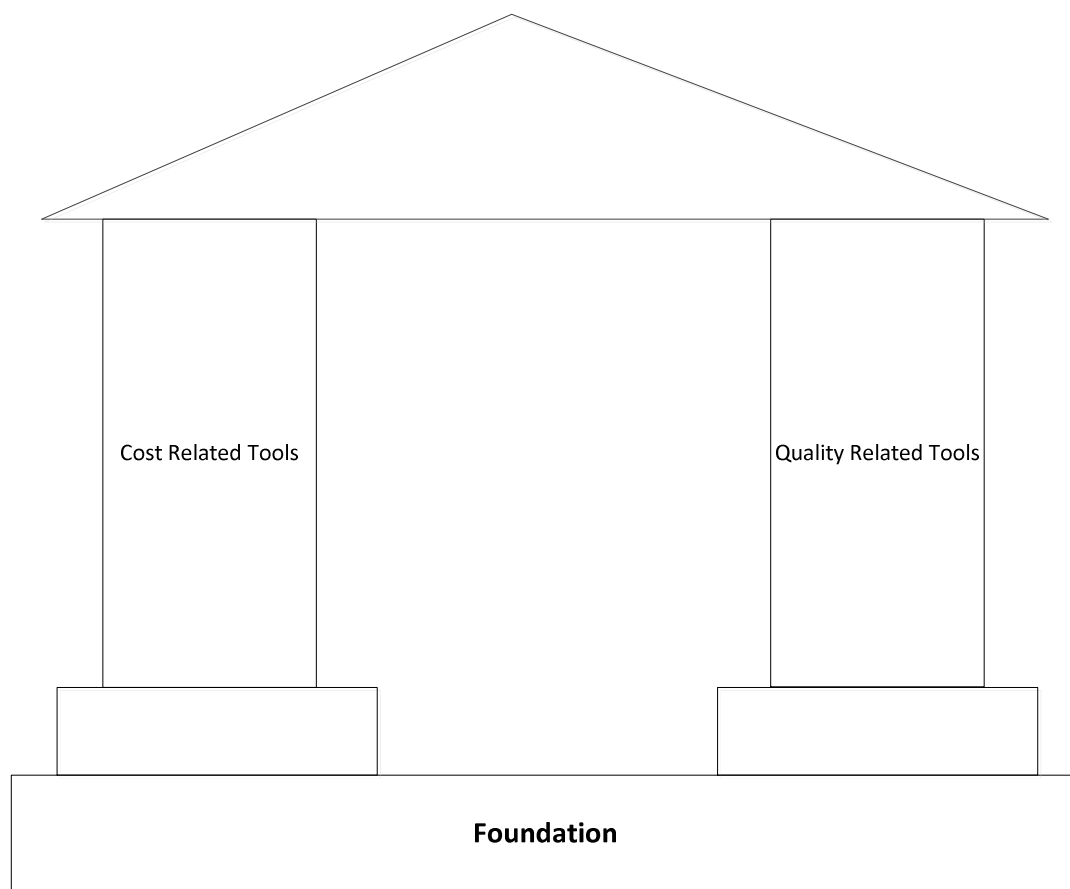


Figure 6-4 Template to be used to populate lean tools

The tools and activities that comprise each part of this template are presented in Figure 6-5.

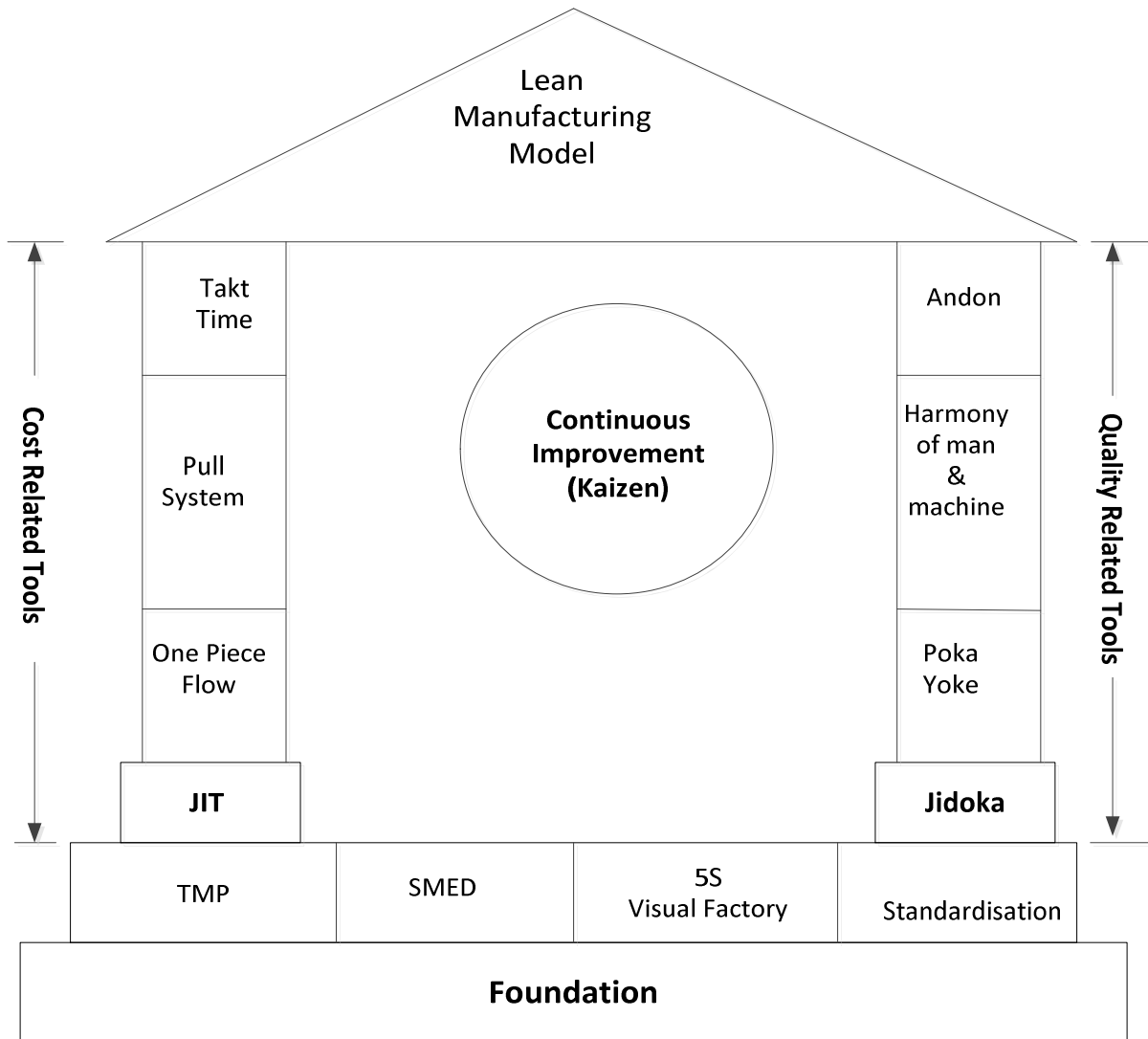


Figure 6-5 Lean manufacturing model with the tools to be implemented

6.3.5.1 The Foundation

The foundation of the model presented in Figure 6-5 consists of the basic requirements that should keep the manufacturing process function smoothly. The focus of the foundation will be on the most vital lean tools, which have been called in this research the *"MUST TOOLS"*. There are other several advanced tools that companies could adopt for further improvement projects. The *"MUST TOOLS"* that included within the proposed LMTS were already presented in Section 2.3.1 and

should be adapted to the revealed situation and actual culture of the business under consideration.

Regarding 5S, the results of the field study of this research have shown that the shop floors within the case companies were untidy and tools and equipment were thrown everywhere. This indicates that a lean tool such as 5S is highly recommend for Libyan manufacturing companies to get the workplace clean and organised in order to be more productive. Based on the literature review presented in Chapter 2 in this research, 5S is considered one of the tools that forms the foundation of lean manufacturing systems, which can be adapted to many different forms, one of which are equipment and items in the shop floor. 5s requires every tool and item to be labelled and located in the right place in the shop floor and requires work place to be equipped with necessary items only.

Moreover, total productive maintenance (TPM) is another basic tool that must be considered in this stage of any lean journey. As it was shown in section 5.2.2.1, during the field study, it has been found that the Libyan companies do not practice the approach of autonomous maintenance (AM) which has negatively affected the adoption of total productive maintenance (TPM) concept. The neglecting of autonomous maintenance and total productive maintenance has eventually resulted in affecting those companies' readiness level for lean manufacturing. The absence of the autonomous maintenance within the case companies has been attributed to the type of organisational culture in those companies where there is fixed divisions between responsibilities of the organisations' different departments. In addition to that, another reason for the lack of operators' empowerment to perform basic maintenance activities was due to the absence of trust in operators' capabilities to carry out maintenance activities. This obviously raises the issue of knowledge and training provision to enhance operators' basic maintenance skills which is a vital in developing autonomous maintenance.

The behavior of restricting the maintenance to maintainers only is considered as main barrier to successfully implement total productive maintenance (TPM) which in turn

hinders the successful adoption of lean manufacturing. The fundamental innovation of total productive maintenance (TPM) is to establish the environment where workers are being able to develop ownership of their machines by being able to operate them as well as perform basic maintenance tasks to keep their machines in good conditions. Thereby, operators evolve their skills to discover the possible existence of equipment issues before they become real failure that eventually might lead to stop the equipment completely.

As to single minute exchange of dies (SMED) or quick change over (QCO), the investigation of the field study has shown that the manufacturing environment type within the case companies makes it inevitable that the tooling or moulds during production processes will be changed frequently. In such manufacturing environment more than likely that most of production equipment will be stopped for long times. These machines stoppages will increase machines idle time which will lead to increasing delivery times, creating much waste, and eventually reducing production efficiency and productivity. Therefore, a lean tool such as single minute exchange of dies (SMED) or quick change over (QCO) is a must for reducing wasted time and enhancing production efficiency.

The investigation of field study has shown that such tool is not practiced within the case companies. Therefore, it must be addressed in order to effectively transform organisations to lean manufacturing.

6.3.5.2 Lean Quality Related Tools (Jidoka)

The pillar of Jidoka in the lean manufacturing model is based on the standardisation block within the foundation of the model. The purpose of Jidoka is to reduce or eliminate the defective items being processed during production processes. Therefore, prevents production lines from frequent stoppages, which should eventually improve the flow and pull principles throughout the entire system. There are several tools by which product quality could be ensured and the opportunity of producing defects

could be eliminated as much as possible (e.g. Poka Yoke, Andon, Automation). These tools are to enhance the operators' and the machines' ability to detect defects or abnormalities within the production system and to immediately respond and take corrective actions. For example, Poka Yoke or mistake proofing is the use of design or process features to prevent mistakes or the negative impact of mistakes, therefore the production operation functions correctly. It is also prevents operators injury and promotes job safety. Furthermore, mistake proofing systems prevent faulty products as well as machine damage. It is an important tool of lean manufacturing that should be considered when adopting lean.

Andon is also one of the quality related tools in lean manufacturing. It is a visual control tool that is helpful in identifying the statue of the process at a single glance. Andon is usually be in the form of a group of lights system; giving managers information about the shop-floor at a first glance. Each colour in the system indicates something different about the statue of the process. "Green" means the factory goes fine; "Red" means there is serious issue (e.g. machine broken), and action is required; and "Yellow" means the process might be behind a bit little and it tells the managers what to worry about in order not to encounter sudden serious issues.

The importance of adopting lean quality related tools have already been covered in section 2.3.2 (Chapter 2) in this research.

6.3.5.3 Lean Cost Related Tools

The purpose behind adopting the tools within this pillar is to produce and ship only the necessary items based on actual customer demand. This is to save manufacturing resources by using only the necessary manufacturing materials and times. There are a number of tools that are helpful in reducing the inventory levels and work in process (WIP) in manufacturing systems, thereby enhancing the just in time manufacturing activities within the system.

Manufacturing companies usually tend to build up inventories to compensate for having some production issues such as, defects rate, and machines idle times. These

created and accumulated inventory levels hide the need to pre-empt those production issues and prevent their recurrence. In order to reduce inventory levels and hence reduce the related production issues, pull system is one of the important elements that is very vital in this regard as it provides opportunities to address those issues and reduce the chance of creating space for inventories. The mechanism of pull system has already been shown in Figure 2-6. Other important lean cost related tools were also presented in section 2.3.2 in this study.

6.3.6 Stage 6: Overall System Assessment

After applying lean tools in the previous stage (stage 5), and a new process was proposed following the reduction and elimination of the identified waste, the purpose of the current stage (stage 6) in the LMTS is to measure the performance of the new proposed process. It is to compare the system performance after implementing lean tools with the performance before applying lean tools. The same performance metrics that have been used in stage 4 will be used here in this stage (stage 6).

6.3.7 Stage 7: Seek Perfection

Following the result of stage 6, and once the customer value is satisfied, the last stage within the proposed lean manufacturing transformation strategy (LMTS) is to seek further improvements through Kaizen (continuous improvement) as always there is something to improve and a chance to go for the better. The principle of perfection is to constantly endeavour to satisfy customer requirements and needs, visualise non-value added activities, enhance the process, and reduce defect rate.

If adopted properly, the proposed strategy would be functioning like a structured approach that provides companies with the possibility of improving the performance of their manufacturing processes. Thus, enable companies to obtain operational gains in both the short and long-term run

Chapter 7 Industrial Case Study Validation

For purpose of validation, the proposed lean manufacturing transformation strategy (LMTS, presented in Figure 6-2) has been applied in a real environment in a Libyan manufacturing company – that is - Trucks and Buses Company (TBCo). The TBCo is operating within the automotive sector in the country.

7.1 An Overview of Trucks and Buses Company

The TBCo is one of the three organisations participated in the field study reported in Table 4-4, Chapter 4. TBCo is a joint venture between Libyan government and the Industrial Vehicles Corporation (IVECO), Turin, Italy. It was established in Tripoli (the capital of Libya) in 1980. Currently there are 700 employees working for TBCo. The company produces trucks and buses for industrial uses as well as aftermarket services and spare parts. The leadership in the TBCo is centralised and the management is formalised as a result of the functional organisational structure. The organisational structure of the TBCo consists of a board of directors where the hierarchy is clearly defined. All the company's executive directors are being members of the board with the CEO being the chairman. The TBCo organisational structure is presented in Figure 7-1.

TBCo vision is to become the largest regional partner (in North Africa) for the leading trucks and buses manufacturers and to be one of IVECO's prime suppliers, whereas, the company mission is to provide value to their customers in Libya and in its region. TBCo aims to establish a work environment of values and ethics that should encourage their employees to be more productive. Furthermore, TBCo strives to build and maintain a long term partnership with their suppliers. Finally, TBCo has made considerable efforts to enhance its environmental safety, transfer knowledge and thus contribute to the prosperity of Libyan society as a whole. Moreover, TBCo strategy aims to leverage its existing capabilities and expand market share by reducing manufacturing costs in order to enhance its growth and profitability. This is to be well

prepared for the competitive market environment, towards achieving its defined vision and mission.

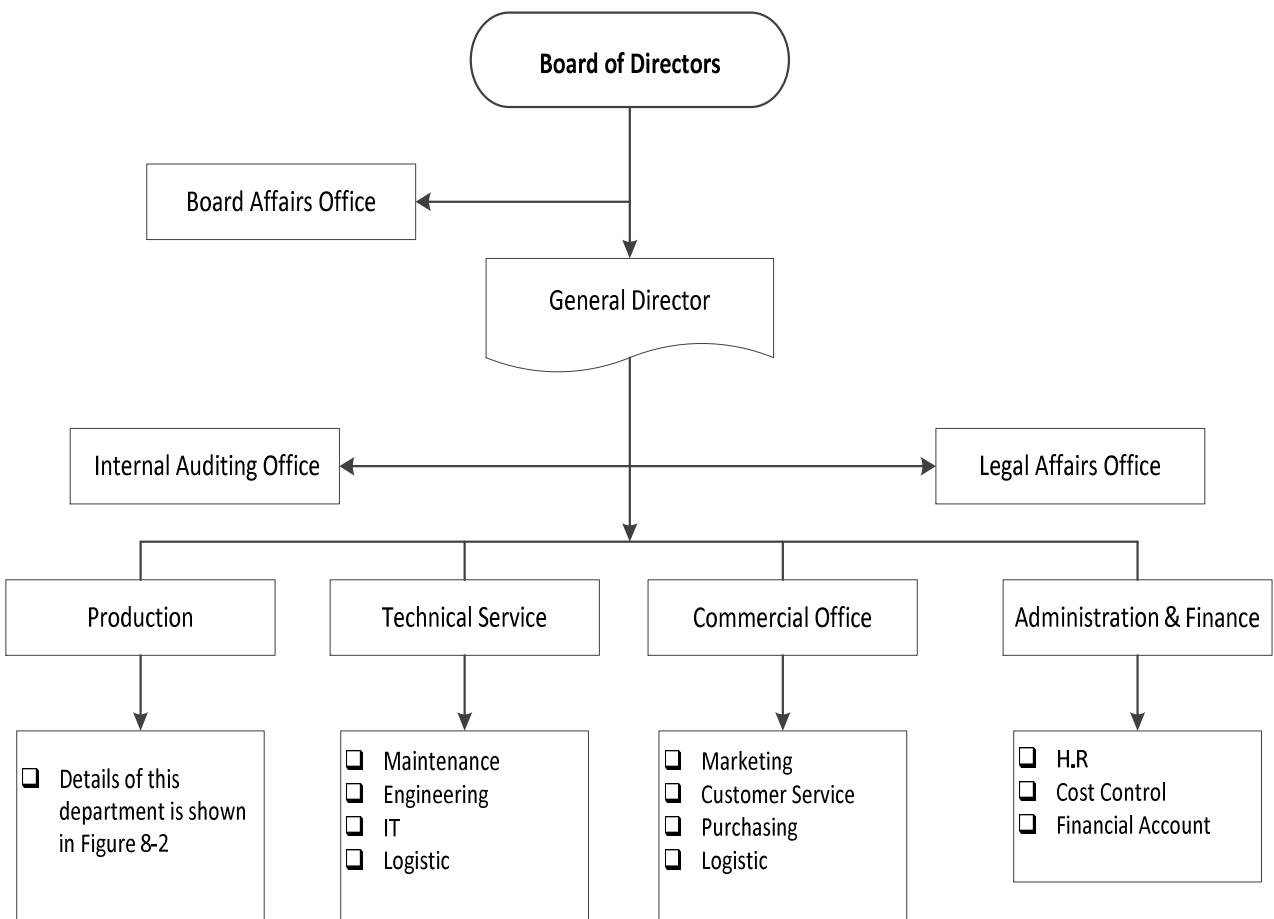


Figure 7-1 TBCo Organization Structure

Since the focus of this study is the production area, the structure of production department in TBCo is illustrated in Figure 7-2.

The TBCo is certified by TÜV (an independent German technical inspection association) for both quality system and environmental management system (ISO 9001:2008 and ISO 14001: 2004); copies of the certificates are illustrated in Appendix 6 and Appendix 7 respectively.

The Trucks and Buses (TBCo) is located within an industrial complex that occupies a total area of 65 hectares in the west of Tripoli. The company has good capabilities, majority of which are used in achieving its manufacturing objectives. These capabilities are distributed among several factories consisting of a number of production lines as follows:

1. Off-road truck assembly
2. Medium-weight truck assembly
3. Light- weight truck assembly
4. Truck's cabin trimming line 1
5. Truck's cabin trimming line 2

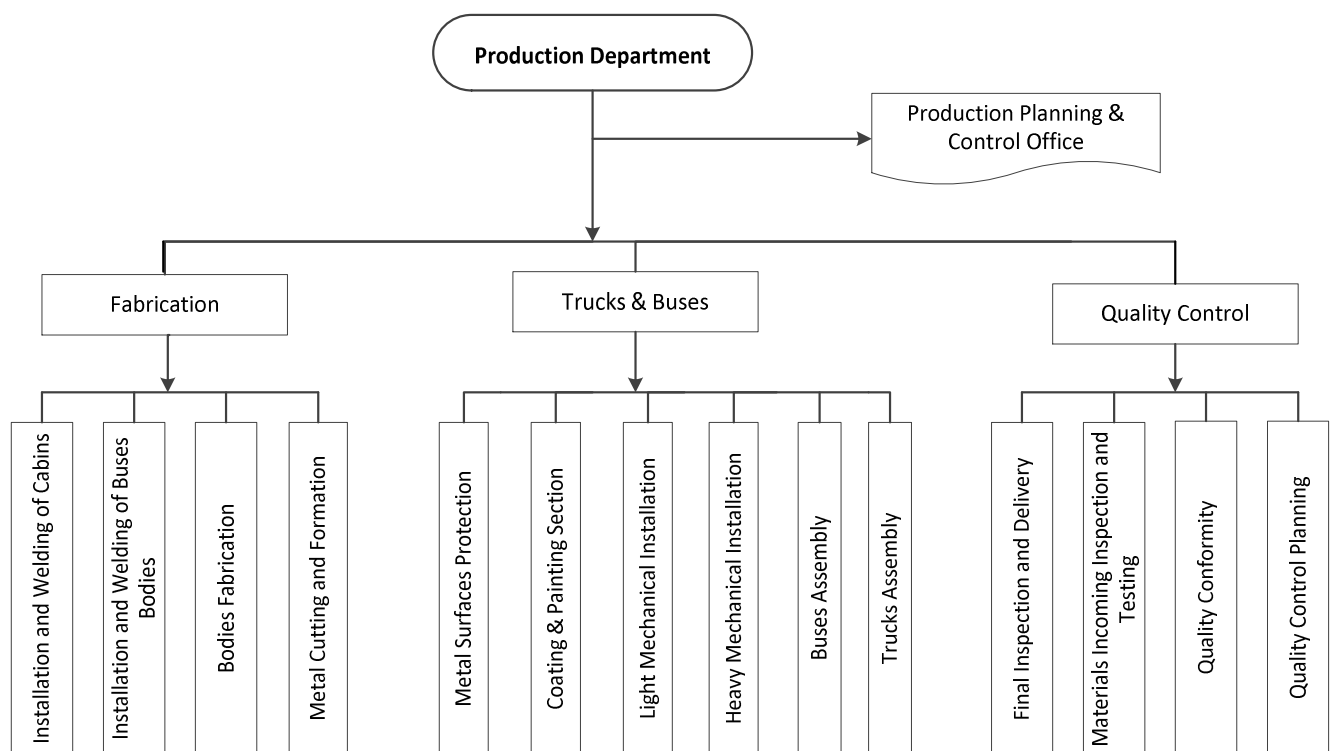


Figure 7-2 TBCo Production Department Structure

6. Fabrication of body and cabin components
7. Welding of body components

8. Truck body assembly
9. Cabin fabrication
10. Truck cabin painting
11. Buses painting
12. Fabrication of bus's body components
13. Welding and assembling of bus's body components
14. Buses trimming line
15. Fabrication of plastic components (front and rear lights for buses and trucks)
16. shock absorber line
17. Chassis trimming line
18. Engine drop unit
19. Truck body and its components painting

7.2 Implementation of the Proposed Lean Manufacturing Strategy

The main focus of the case study validation was the process of truck cabin painting. In particular the heavy duty truck of 6X4 "TRAKKER AT-N" was selected as shown in Figure 7-3. This process is performed manually. The reason for selecting the painting process was the substantial amount of waste within the process. The team leader was quite certain that demonstrating fast positive results such as, the reduction of processing time; reducing the amount of waste (e.g. the long travelled distance of the cabin within the painting process) would be a positive motivation for the top management to extend the lean project to different areas in the company.

In order to validate the proposed lean manufacturing transformation strategy (LMTS), the different stages of the strategy (Figure 6-2) have been implemented in the TBCo (Trucks and Buses Company). The LMTS requires the following considerations:

- I. First stage, this is where the company should be prepared to adopt lean. Many vital activities are performed in this stage (e.g. building the vision, establishing the need for change to lean, obtaining top management buy-in, providing lean

knowledge and training ...etc.). Furthermore during this stage a lean team who would then lead the transformation initiative is formed.

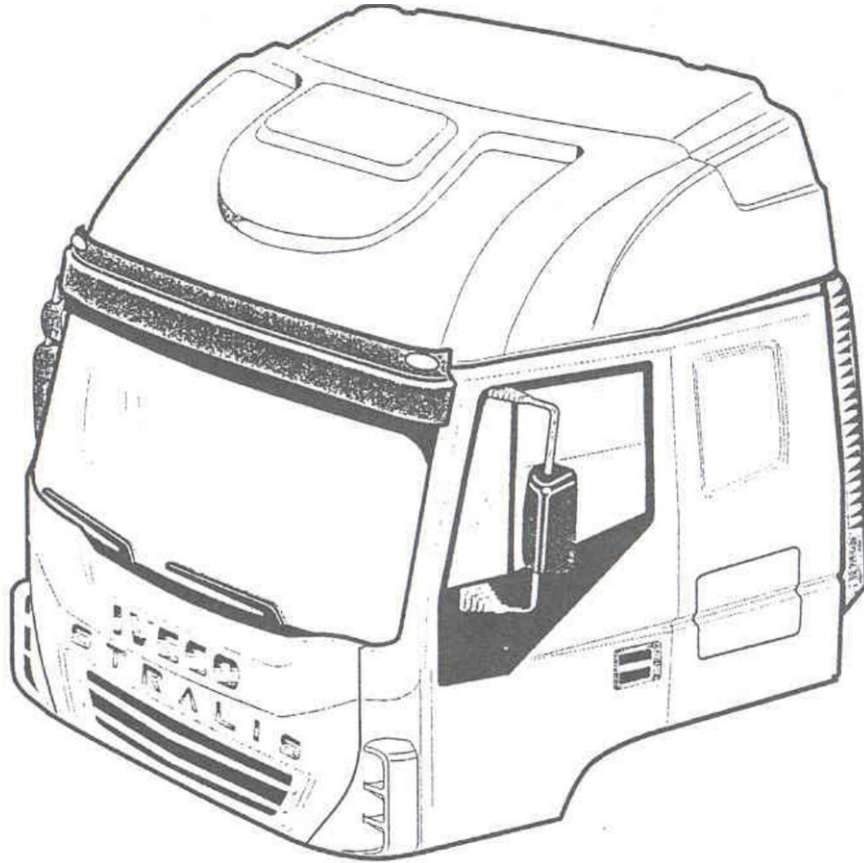


Figure 7-3 Case study: The painting of the heavy duty truck cabin (6X4 TRAKKER AT-N)

- II. Second stage, in this stage the team defines performance indicators based on cost, processing time, and production quality.
- III. Third stage of the LMTS, here where the waste is identified by mapping all process activities using time and motion study and value stream mapping (VSM).
- IV. Fourth stage, this is where the current performance of the process is measured by calculating the efficiency and effectiveness of the current process.
- V. Fifth stage, lean tools are applied in this stage; also, improvement ideas are suggested and should be implemented.

- VI. Sixth stage, the overall system performance will be evaluated to compare the process state before and after applying lean tools.
- VII. Seventh stage, this is the last stage within the LMTS, where the company should seek perfection by setting the principle of “always there is something to improve” through continuous improvement culture.

The following sub-sections are presenting the implementation of the LMTS on the case study of the truck cabin painting as shown in Figure 6-2.

7.2.1 Stage 1: Preparation for Implementing the LMTS in the Painting Line

The following are the first steps in the implementation of the LMTS in TBCo as shown in Figure 6-2:

- I. **Establish a need for a lean**: The TBCo provided reports about the current production data, performance and issues. This led to arrange workshop between the researcher and the head of the production department and his key engineers and supervisors as well the logistic manager. This was a good opportunity where the researcher presented formally the concept of lean manufacturing to the engineers who attended the workshop whom all showed full appreciation and support to the lean idea. This resulted clearly the need for considering lean manufacturing as a mean to address all these problems. The head of the production department and logistic manager took the responsibility to present this request to the CEO of the TBCo.
- II. **Obtain senior management buy-in**: The CEO was presented with a case of the need to introduce lean manufacturing to the company. The decision was taken to perform a pilot case study with the help of the researcher in order to learn more about lean and evaluate its benefits to the company. The CEO left the decision to the production department to select the suitable area to implement lean manufacturing. In addition the CEO stressed his full support to this initiative and to inform the rest of the top management.

- III. **Define new lean vision:** The following is proposed for the company in order to highlight the lean thinking philosophy with the strategy and the operations of the TBCo:

Vision: The Truck and Buses Company focus on value creation for its end customers with the process of continuous improvement in order to meet their expectations in producing high quality products in shorter time and lower possible manufacturing cost.

Mission: TBC is committed to deliver high quality truck and buses to its customers with greatest possible value. The company considers the expenditure of its resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination.

Build lean team: A lean implementation team to apply the proposed strategy (LMTS) was built up and it consists of people with varying positions within the company. The team members were from different organisational levels within the company, production; engineering; maintenance; front line workers; and top management. In addition to that, the researcher also took part in the team activities. The structure and hierarchy of the team is illustrated in Figure 7-4.

The role of the researcher within the implementation team was restricted to providing the necessary lean manufacturing related knowledge. The lean manufacturing concept, its principles, and associated tools and techniques were presented by the researcher over a number of in- house workshops.

- IV. **Foster lean education and training:** Although the researcher managed to give several formal workshops and awareness seminar about lean manufacturing, this area is in need to develop formally for the company to educate and train all

the stakeholders. As first step, the company hired a member of staff from Tripoli University with lean manufacturing experiences as a consultant to support them in this journey which includes formal training.

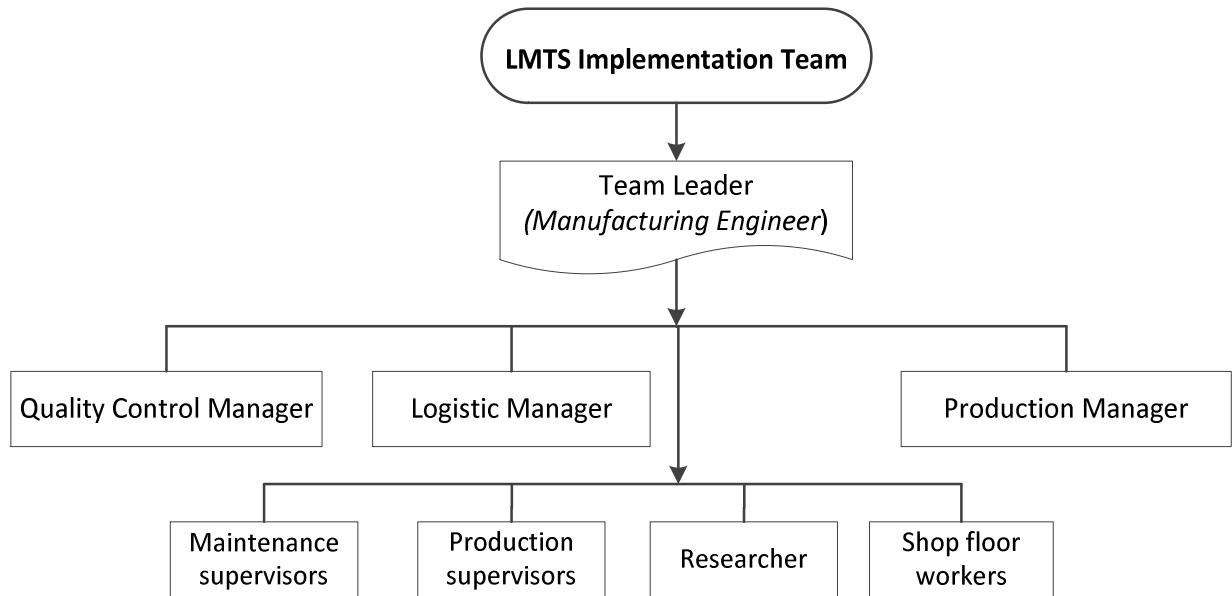


Figure 7-4 LMTS implementation team members

- V. **Culture change and commitment:** This will take some good time through the lean journey, however, the researcher did observe the interest and the commitment of the different engineers and supervisors while performing this particular case study in the painting process. This is a positive indication for the future of lean implementation in the company.

- VI. **Suppliers and customers involvement:** This is outside the scope of this case study.

7.2.2 Stage 2: Establish Target Objectives (Metrics) for the Painting Process

The implementation team has defined two performance indicators; 1) processing time and 2) lead time, to be used later in measuring the efficiency and effectiveness of the painting of truck cabin process.

7.2.3 Stage 3: Current Painting Process Map

The painting process of the truck cabin progress through four main phases is as follows:

1. Painting by Immersion
2. Initial Painting
3. Final Painting
4. Ceiling Installation

These painting phases are presented in details as follows:

(1) Painting by Immersion

This stage includes several operations starting with loading the cabin on its carrier to simplify the handing process including lifting and pulling out the cabin of the treatment, cleaning and painting basins. Following this the cabin door beams are installed manually to keep the door in cracked open position to ease cleaning, treatment, and painting of the doors and their holes. Thereafter, any rust is removed manually from the cabin body. Once this is completed, the cabin will be lifted from programmed crane station by manual control.

1.1 Treatment Process

Treatment process consists of the following stages, removal of the existing lubricants on the cabin body by spraying of or immersion into acidizing solutions, washing the cabin whether by spraying or immersion, ionization of the metal surface until it becomes ready to absorb the paint when it is immersed and cleaning of the cabin by immersion into full basin of phosphate solution, and then is washed by distilled water to remove impurities.

1.2 Painting by Immersion process

This process includes the following activities including immersing the cabin into the painting basin plus spraying process by using Ultrafiltration (UF) solution, then spraying it with new pure solution of the same substance, removal of the cabin to mobile land trolley in which is moved by the crane, drying cabin into a furnace at 180 °C for a 15 minute and finally cooling of the cabin.

1.3 Cabin Installation Station

Prior cabin installation, thickness of painting layers must be according to the following standards: thickness of the outer paint layer is 25 micrometre / 15. In addition, the inner paint thickness layer is 20 micrometre/10. Furthermore, thickness of holes painting layer shall be more than or equal to 8 micrometre. Afterwards, loading of the cabin manually on the crane and finally moving the cabin to its own ground trolley of the painting line.

1.4 Inspection of Painting by Immersion process

Inspection of any consequential defects caused due to painting by immersion should be carried out. All defects are removed by using abrasive sanding papers with a smoothness coefficient of 400, then cleaning of the rasped area by using a wet piece of fabric with thinner.

(2) Initial Primary Painting

The cabin will proceed through different stations during this phase of painting. There are 6 stations which will be individually defined in details.

2.1 Initial Sanding Process

The cabin should be located on the trolley by crane to transfer it to the first station of the initial painting line. Then sanding of the cabin outer surface will be conducted. This might contain some defects due to paint flow during painting by immersion process. One of these defects is the appearance of paint grains and lumps due to paint flow.

Furthermore, manual sanding can be carried out to flourish the narrow places, such as drainage holes and tank side while the automatic method will be efficient in flat areas. In addition, cleaning of the cabin should be carried out by using a wet piece of fabric with a cleaning liquid, and then dried by air jet. Eventually, the cabin will go through quality inspection to identify any further defects.

2.2 Application of Insulating Silicone

Isolating silicone will be applied to cover the inner and outer sides of the metal cabin, and such process will be conducted by using large and small spraying guns. The places that will be covered by silicone are as follows (shown in Figure 7-5):

- The outer space of the upper side of the cabin (A)
- The inner frame of the entry side (B)
- The crescent shaped space of the upper front side (C)
- Door's frame and the inside piece of door anchor (D)
- Spraying isolating silicone into the outer space of the back crescent shaped of gear box track (E)
- Spraying isolating silicone along the space of the back side of the cabin (F)

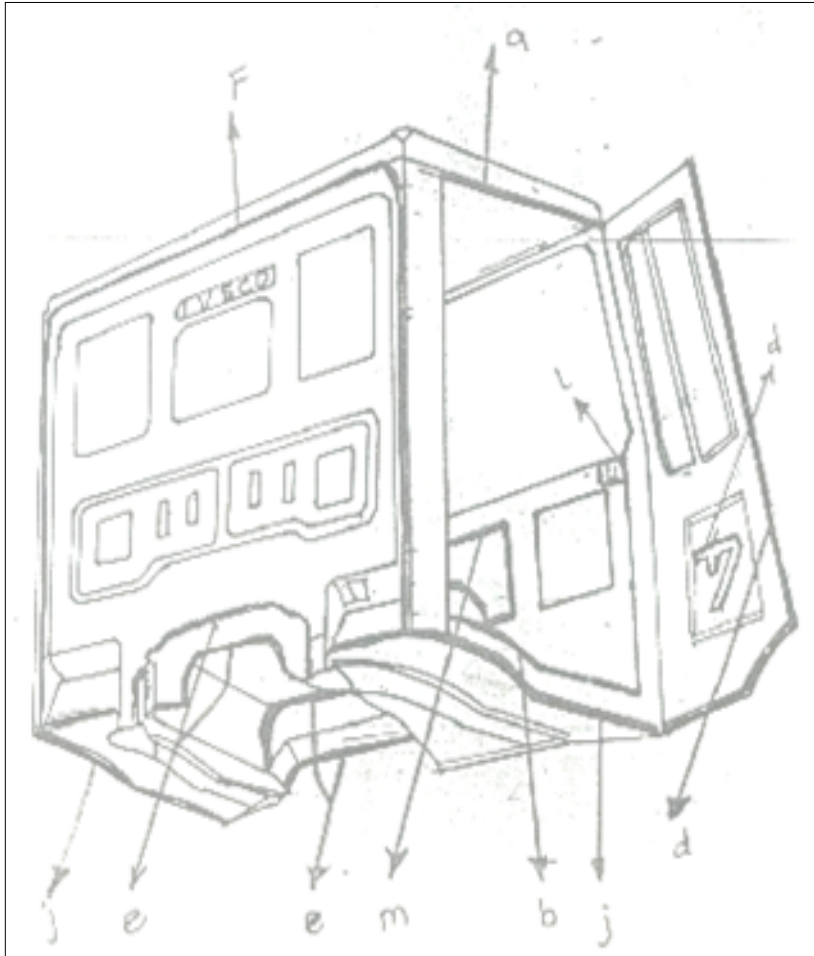


Figure 7-5 The application of silicone on different areas of the cabin

- Spraying isolating silicone in the outer spaces of both crescent shaped areas of the front side (G)
- Spraying isolating silicone in the lower spaces of the front side (H)
- Spraying the entire screw positions of the front side with isolating silicone (I)
- The lower space side of the entry door as (J)
- The inner places of the squares' edges (K) which are located in the front side
- Spraying isolating silicone into the edges of the front anchor located in the front side of the cabin dashboard (L)
- Spraying isolating silicone into the edges of the located square in the front side (M)
- Spraying of an isolating silicone into the bottom spaces (N)

An Inspection of the above stated areas that were covered by silicone should be conducted by making sure any extra amount of silicone is removed by using a brush for correction.

2.3 Coating the inner and lower surfaces of the cabin with tar

Using of sticky tape on the entire screws and their holes within the area which will be painted by tar, as well as covering the side squares with tar. In addition, the lower side of the cabin will be covered with tar as well as the spaces of the inside back areas of the cabin. Afterwards, an inspection process is conducted to ensure that the entire body of the cabin is covered up with tar. Using a sticky tape is essential as part of it must be left sagging within sensible height in order to prevent tar to reach the parts which should not be covered up.

2.4 Coating with Polyvinyl Chloride (P.V.C)

The entire parts of the cabin should be covered with PVC glue by using spraying guns and also by using putty knives. Then an inspection process shall be conducted in order to make sure that the entire body of the cabin was covered up with (PVC).

2.5 Drying Process

The entire cabin will be entered into a furnace of 150 °C for half an hour; this operation shall be divided into three stages of 10 minutes each.

2.6 Final sanding process of the cabin body

Lowering the cabin shall be done in order to be located on the mobile trolley by using crane to be sent to the final painting line. After that sanding of the outer places of the cabin is conducted in areas which may contain some defects due to the flow of the paint during the initial painting process. Finally, manual sanding will be utilised to correct the narrow places, such as tank and drainage area, while other flat surfaces will be sanded automatically. Cabin then will be cleaned with wet fabric of cleaning

solution and later dried by air jet. Quality inspection of the cabin should be carried out to prevent defects.

(3) Final Painting

3.1 Coating with insulating materials

The floor of the cabin will be coated with isolating anti-shock, heatproof and soundproof substances (as shown Figure 7-6). Cleaning of the entire cabin then will be done with a piece of fabric.

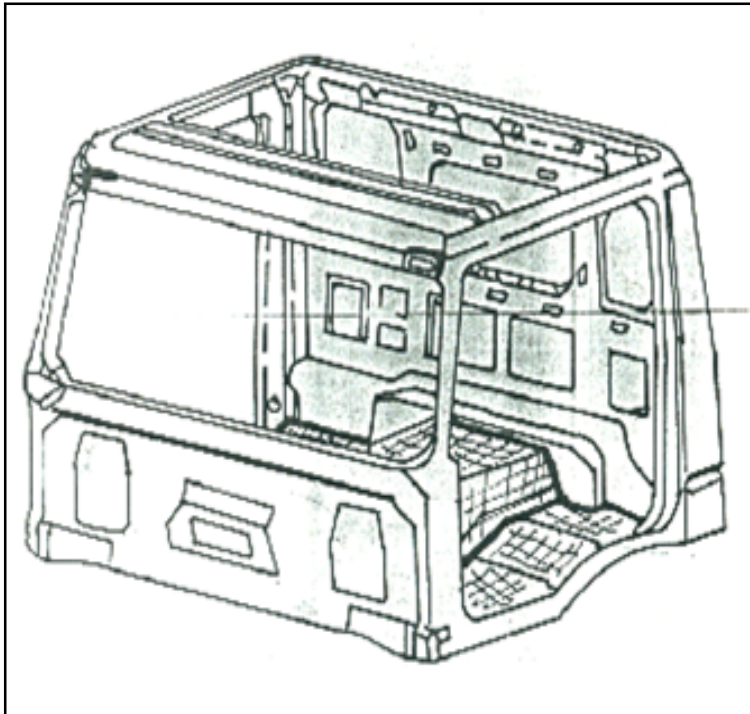


Figure 7-6 Coating the floor of the cabin

3.2 Application of final painting

The entire parts of the cabin shall be covered up with paint in separate stages by using painting guns. Then quality inspection shall be conducted to make sure that the entire body of the cabin has been fully covered up with paint.

3.3 Final drying process

The cabin is placed in a furnace at a temperature of 150°C for a period of 30 minutes. This process is divided into three stages, each stage takes 10 minutes time.

3.4 Handling and inspection of the cabin

The cabin is taken out of the furnace and then is lifted by crane in order to be transferred to the final inspection. The final inspection of the cabin is the last stage before the commencement of ceiling installation. Eventually, handling of the cabin from the painting line should be conducted in order to be sent to the ceiling installation unit.

(4) Completion (ceiling installation)

The ceiling shall be mobilised to the work site by programming section. Then it is turned upside down and located on suitable cushions in a position that should facilitate its installation on the cabin. Secondly, the cabin should be placed in the operation area. Thirdly, cleaning the edges of the ceiling surface as well as the targeted outer surroundings for taping and fixture shall be carried out carefully. In addition, the cleaning process shall be conducted by using a fully saturated paper with Heptane or any other similar substance. Fourthly, drying the processed area is done by utilizing cleaning paper. Fifthly, cleaning of the edges of the cabin surface is carried out. Sixthly, hammering the edges of the cabin shall be conducted by rubber hammer to smooth the inner surface. Seventhly, a sticky tape is fixed on the edges of the cabin. Eighthly, painting the edges of the cabin is carried out with primer by using a brush. Ninthly, painting the edges of the ceiling is carried out with primer by using a brush. Tenthly, drying primer by leaving it exposed to air for more than 5 minutes.

Next step is to apply the isolating silicone in the edges of the cabin by using special type of guns and then positioning the ceiling on the cabin. In addition, fixing, pressing and hammering the ceiling is carried out by using metal fixers. Then locating sticky tape on the edges of the cabin and spraying more isolating silicone again on the outer

edges of the ceiling by using special type of guns, in order to cover any remaining holes in the spaces of the edges from outside.

Afterwards, grading the surface of the isolating silicone and removing the sticky tape from both the cabin and the ceiling shall be completed. The flow and layout of the current cabin painting process is depicted in Figure 7-7.

7.2.3.1 Waste Identification

In order to better understand the cabin painting process, time and motion study was carried out as shown in

Table 7-1. It is a method of documenting the current processing times and thus, identifying drivers of inefficiency in painting work processes and the current layout of the process. The performed time and motion study included the following main activities:

1. Capturing the individual activities of each task and sub-process of the truck cabin painting process and break them down into single motions
2. Documenting the time for each motion
3. Identifying any non-value added activities
4. Calculating the overall process time

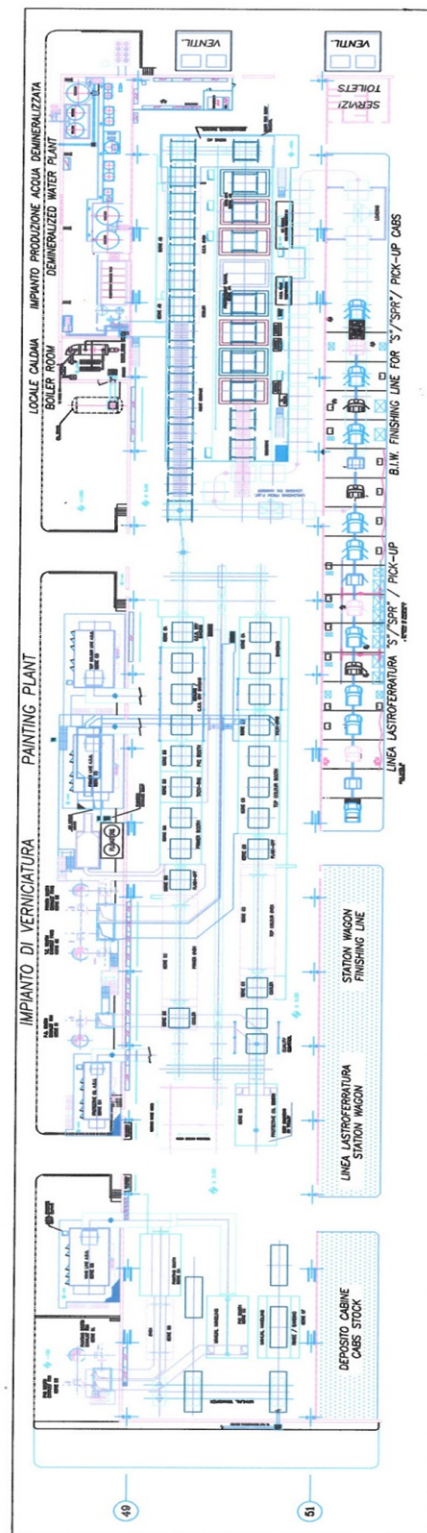


Figure 7-7 Layout of the cabin painting line

Table 7-1 Time and motion study for cabin painting process

		TRUCKS AND BUSES Co. Cabin of Heavy Duty Truck (QMS-CA-WI-04)	
Time and motion study for cabin painting process			
Task No	(1) Painting by Immersion	Time min	
Station 0			
1	Loading the cabin on the carrier	2.00	
2	Installing doors beams	2.00	
3	Removing rust	6.00	
4	<ul style="list-style-type: none"> • Removing the existing lubricants • Washing the cabin • Ionization of the metal surface • Cleaning of the cabin by immersion 	10.00	
5	<ul style="list-style-type: none"> • Immersing the cabin into the painting basin • Immersing the cabin into Ultra Filtration (UF) solution • Removing the cabin and placing it on trolley • Entering cabin into a furnace • Cooling of the cabin. 	22.00	
6	<ul style="list-style-type: none"> • Loading of the cabin manually on the winch • Moving the cabin to its own ground trolley 	5.00	
7	<ul style="list-style-type: none"> • Performing inspection 	3.00	
(2) Initial Painting			
Station 1: Initial Sanding Process			
1	<ul style="list-style-type: none"> • Locating the cabin on the trolley • Transferring the cabin to the first station in this stage 	0.86	
2	Sanding the cabin's outer surface	16.00	
3	Cleaning the cabin	3.00	
4	Performing inspection	2.00	
Station 2: Application of insulating silicone			
1	Applying silicone to outer space of the upper side	1.5	
2	Applying silicone to inner frame of the entry side	1.7	
3	Applying silicone on the crescent shaped space of the upper front side	1.9	
4	Applying silicone to door's frame and the inside piece of door anchor	2.00	
5	Applying silicone into the outer space of the back crescent shaped of gear box track	2.8	
6	Applying silicone on the space of the back side of the cabin	2.7	
7	Spraying silicone into the outer spaces of both crescent shaped areas of the front side	1.8	
8	Spraying silicone in the lower spaces of the front side	1.45	
9	Applying silicone on screw positions of the front side	2.3	
10	Applying silicone on the lower space side of the entry door	2.22	
11	Applying silicone on the inner places of the squares' edges	1.65	
12	Applying silicone on the edges of the front anchor located in the front side of the cabin dashboard	1.53	
13	Spraying silicone into the edges of the located square in the front side	2.55	
14	Applying silicone on the bottom spaces	2.00	
15	Inspection of the above stated areas	1.4	
Station 3: Coating the inner and lower surfaces of the cabin with tar			
1	Using a sticky tape to prevent tar to reach unwanted parts	3.66	

2	Sticking sticky tape on the entire screws set	5.9
3	Covering the lower side of the cabin with layers of tar	7.66
4	Covering the spaces of the inside back areas of the cabin with layers of tar	6.9
5	Performing inspection to ensure that the entire body of the cabin is covered up with tar.	0.88
Station 4: Coating with polyvinyl chloride (P.V.C)		
1	Covering the entire cabin's body with PVC	27
2	Performing quality inspection	1
Station 5: Drying Process		
1	Entering cabin into furnace	30
Station 6: Final sanding of the cabin body		
1	Lowering the cabin on the trolley via crane	0.86
2	Sanding of the cabin's outer surface	12.20
3	Cleaning the cabin via wetted fabric	5.60
4	Carrying out quality inspection	0.70
(3) Final Painting		
Station 7: Coating with insulating materials		
1	Coating the floor of cabin with isolating materials	15
2	Cleaning cabin	5.5
Station 8: Application of final painting		
1	Covering up the cabin by paint	28.75
2	Performing quality inspection	2.00
Station 9: Final drying process		
1	Entering cabin into furnace	30.00
Station 10: Handling and inspection of the cabin		
1	Taking the cabin out from the furnace	1.40
2	Conducting final inspection	8.75
3	Sending the cabin to ceiling installation workstation	3.65
(4) Ceiling Installation: Station 11		
1	Bringing the ceiling to the final workstation	1.1
2	Entering the cabin into the workstation.	1.26
3	Cleaning the edges of the ceiling surface	1.00
4	Drying out the treated area	6.00
5	Cleaning of the edges of the cabin surface	1.5
6	Hammering the edges of the cabin	2.00
7	Sticking a sticky tape on the edges of the cabin	1.00
8	Applying a layer of primer on the edges of the cabin	2.00
9	Applying a layer of primer on the edges of the ceiling.	2.00
10	Drying the primer	6.00
11	Applying silicone on the edges of the cabin	1.4
12	Positioning the ceiling on the cabin	1.5
13	Fixing the ceiling in its place on the cabin	2.5
14	Putting sticky tape around the edges of the cabin	1.00
15	Applying silicone again on the outer edges of the ceiling	3.5
16	Smoothing the silicone application	2.00
17	Removing the sticky tape	1.00
18	Taking the cabin out of the line	1.24
19	Performing final quality inspection	3.00

The total time required to complete the entire painting process was recorded and summarised in Table 7-2. This task was performed by one member of the lean team who spend one working shift to observe and record the time using a stop-watch. He also recorded the none-value added time of each step of the painting process.

Table 7-2 Time required to complete cabin painting process

Workstations of truck cabin painting process	Station Time	NVA Time	Waste Percentage
(Stage 1): Painting by Immersion	50	20.5	41%
(Stage 2): Initial Painting			
<i>Station 1: Initial Sanding Process</i>	21.86	7.29	33.35%
<i>Station 2: Application of insulating silicone</i>	29.5	8	27.12%
<i>Station 3: Coating with tar</i>	25	9	36%
<i>Station 4: Coating with polyvinyl chloride (P.V.C)</i>	28	8.6	30.71%
<i>Station 5: Drying Process</i>	30	8.6	28.67%
<i>Station 6: Final sanding of the cabin body</i>	19.36	6	30.99%
(Stage 3): Final Painting			
Station 7: Coating with insulating materials	20.5	5.1	24.88%
Station 8: Application of final painting	30.75	11	35.77%
Station 9: Final drying process	30	7.5	25%
Station 10: Handling and inspection of the cabin	13.8	8.5	61.59%
(Stage 4): - station 11 - Ceiling Installation	41	14	34.15%
<i>Total time required to complete one cabin</i>	339.77	114.09	33.58%

The total painting process took a 339.77 minute to be completed and required a 12 worker to bring it to the end. As shown in Table 7-2, 33.58% of the total process time has been found as waste. The proportion of value-added time to non-value added is shown in Figure 7-8.

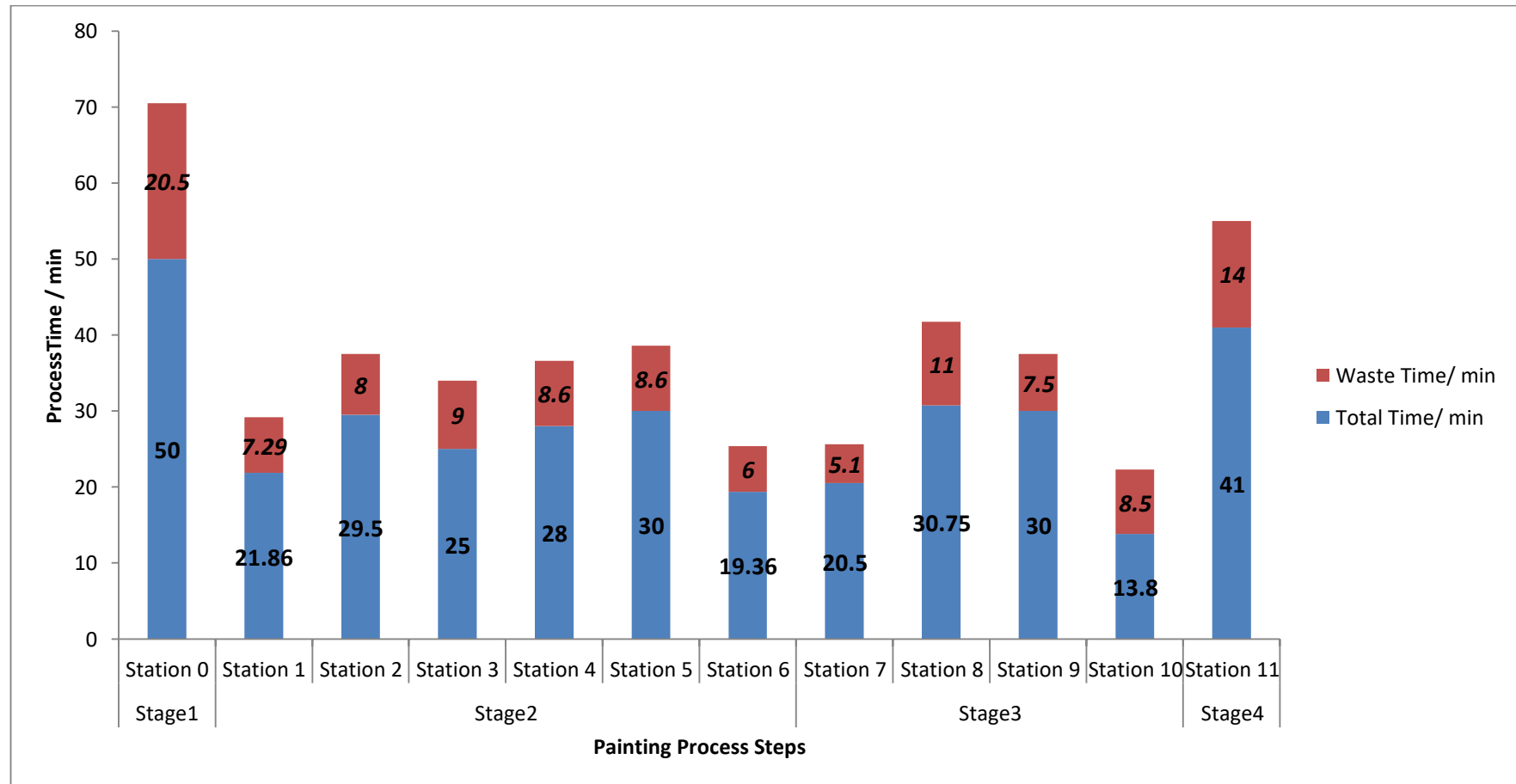


Figure 7-8 Proportion of waste to value added activities within cabin painting process

7.2.3.2 Waste Analysis

The implementation team had analysed the painting process stages and tasks to identify any activities that does not add real value to the process performance. It has been found that about 33.58% (114 minutes) of the process lead time is spent doing activities that did not add value to the final product. The tasks that add value to product flow, on the other hand, represented about 66.42% of the total process lead time (about 225.68 minutes). Therefore, there is room for improvement concerning waste elimination or reduction, thereby lead time and overall performance are improved. The waste activities were a result of doing unnecessary things such as, waiting due to equipment breakdowns, items handing, or items being travelled between the various workstations. For example, according to the present painting process layout (shown in Figure 7-7), the cabin is travelling about a 2000.00 meter throughout workstations. The non-value added activities had been analysed and were classified into two groups as follows:

1. Resource related waste: Manufacturing resources such as workers or machines are behind this category of waste. These wastes are:
 - Waste due to downtime (e.g. equipment failure / breakdown, setup and adjustment)
 - Waste due to quality issues (e.g. defects and rework)
2. System related waste: The activities that relate to this category of waste are more difficult to handle as they are usually looked at from different perspectives. These activities are:
 - Material handling
 - Inventory
 - Layout

Table 7-3 presents a detailed analysis of the identified types of waste associated with the process of cabin painting. Moreover, the percentage of each identified type of waste to the total identified waste (114 min) is also displayed in Figure 7-9.

Table 7-3 Non-value added time analysis for the current layout of the cabin painting process

waste category	Sources of Waste		Time Taken/ min	Percentage
Resources Related	1	Equipment failure	12	10.5%
	2	Setup and adjustment	10	8.8%
	3	Defects and rework	11	9.6%
	4	Line blocking (station 10)	4	3.5%
	5	Insufficient buffer size at step 2, stage 4	8	7.0%
	6	Delay in material supplying	4	3.5%
System Related	7	Material handling	11	9.6%
	8	Redundant inventory	6	5.3%
	9	Quality check	7	6.1%
	10	Demand fluctuation at station 4, stage 2	4	3.5%
	11	Operators unnecessary movement	17	14.9%
	12	Cabin travel distance	20	17.5%
Total of non-value added time			114	100%

As it can be noted from Table 7-3, a greater amount of the total wasted time (about 57 %) is system related. Furthermore, the vast majority of this percentage of waste (around 42%) is due to the existing stations' layout (e.g. product travel distance, operators' movement, materials handling). In fact, considerable amount of waste was contributed to the poor current process layout. For instance, about 17.5% of the total identified waste was due to cabin travel distance between stations, whereas operators' unnecessary movement contributed to around 15% of the total waste (see Figure 7-9). In addition, about 9.6% of waste time was related materials handling activities.

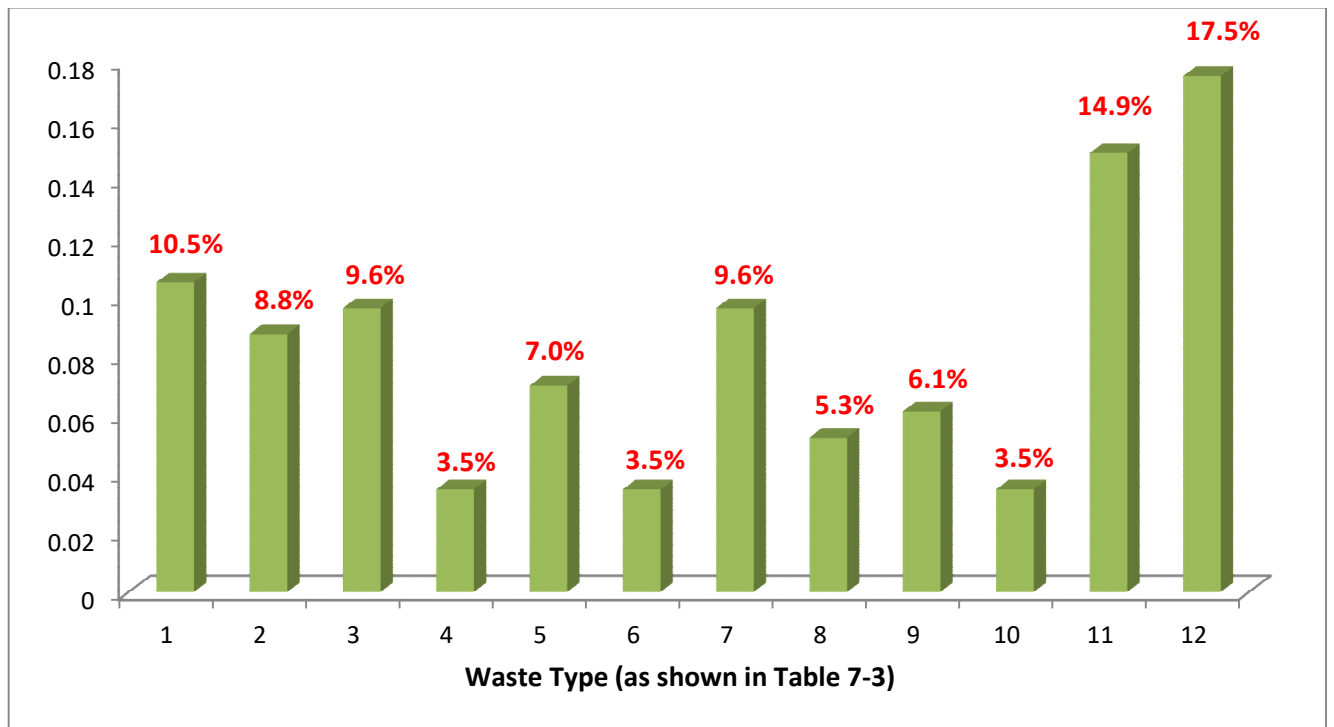


Figure 7-9 Percentages of each waste type identified in cabin painting process

Furthermore, equipment failure and rework due to defects have also contributed to the generated waste, 10.5% and 8.8% of the total waste respectively. The importance and necessity of analysing and identifying the waste is to provide help in tracing the results of improvement measures that would be adopted in Stage 5 in this proposed strategy (LMTS).

7.2.4 Stage 4: Current Painting Process Performance Measurement

In this stage of the case study, the current performance of the cabin painting process is measured in terms of efficiency and effectiveness. The data that have been collected from time and motion study during current process mapping (section 7.2.3) are used to estimate process efficiency which compares the process output to its input.

Currently there are 12 operators to finish the job of painting one truck cabin. The entire painting line runs 6.5 hours (390 min) every day. At the time of this case study the line production capacity target was set to 13 units per day. However, in the real situation the average output of the painting line was only 5 cabins every day. Also, every finished cabin took about 339.77 minutes to be completed, as it was shown in

Table 7-2. This amount of time included setup time, changeover time, maintenance, and scheduled downtime. Based on the above information the painting line efficiency is calculated as follows:

$$\text{Line Efficiency} = \frac{\text{output}}{\text{input}} * 100 \%$$

$$\text{Line Efficiency} = \frac{\text{no of output*time to complete one unit}}{\text{number of operators*daily working hours}} * 100\%$$

$$\text{Line Efficiency} = \frac{5*339.77 \text{ min}}{12*390 \text{ min}} * 100\% = \mathbf{36\%}$$

Moreover, the overall effectiveness of the line is computed based on the target efficiency of the line and its actual efficiency, as follows:

$$\text{Line Effectiveness} = \frac{\text{Actual output}}{\text{Target output}} * 100 \% = \frac{5}{13} = \mathbf{38\%}$$

The calculated line efficiency and effectiveness (36% and 38%) respectively, revealed a great drawback in the painting process which needs to be addressed. Therefore lean manufacturing is a good approach to significantly enhance the productivity of the process.

After the application of suitable lean tools and improvement ideas in the following sub-section, the calculated values of efficiency and effectiveness will be used to compare the process performance before and after lean.

7.2.5 Stage 5: Application of Suitable Lean Tools in the Painting Process

In this stage of the proposed LMTS, improvement ideas are to be suggested and proper lean tools to be adopted to eliminate or reduce the identified waste. It has been found that 42% of the total wasted time was related to the current process layout (see Table

7-3). Therefore, the LMTS implantation team focused more on redesigning the current workstations' layout. Since the major causes of waste have already been identified over time and motion study, the team directly addressed those particular workstations (bottlenecks stations) to reduce the non-value added times (e.g. waiting, reworking, transporting times).

According to the identified types of waste (shown in Table 7-3), a range of appropriate lean tools have been recommended to improve the current painting process. Those lean tools are shown in Table 7-4 and are briefly explained.

Table 7-4 List of recommended lean tools for TBCo

No	Identified types of waste	Recommended lean manufacturing tools
1	Equipment failure	Total productive maintenance (TPM)
2	Setup and adjustment	Quick changeover, 5S
3	Defects and rework	Poka-yoke, 5S
4	Line blocking (station 10)	One piece flow, pull, Takt time
5	Insufficient buffer size at step 2, stage 4	Pull system
6	Delay in material supplying	One piece flow
7	Material handling	One piece flow
8	Redundant inventory	Pull system
9	Quality check	Poka-yoke, 5S, standardised work
10	Demand fluctuation at station 4, stage 2	Pull system, Heijunka (production levelling)
11	Operators unnecessary movement	5S, standardised work
12	Cabin travel distance	One piece flow, standardised operations, 5S

The following are justifications of the recommended lean manufacturing tools in order to eliminate (or reduce) each of the Identified types of waste that were listed in Table 7-3.

Total Productive Maintenance (TPM): The industrial visit and the data collected for the painting process case study showed a clear evidence of equipment failure which contributed to 10.5% of the total waste as shown in Table 7-3 and illustrated in Figure 7-9.

Therefore, TPM has been recommended as a lean tool to address this issue. This is because TPM is set of activities for restoring equipment to its optimal possible condition and changing the work environment to maintain that condition. As such, the TBCo is making efforts to enhance its traditional maintenance performance. The company is introducing standardised maintenance procedures and making sure those procedures are holistically carried out by capable and motivated operators to gradually realise a level of TPM. Moreover, TBCo is now considering small maintenance activities to be delegated to line operators as part of their daily routines. The standardised maintenance procedures embody step by step and detailed how-to directions that should enable the operators to execute the maintenance activities in a consistent manner. Those maintenance procedures should act as instructional resources that should enable the operators to respond without being in need for guidance or instructions from other party. Furthermore, the LMTS team has advised TBCo that the standardised maintenance procedures should be effectively shared with all operators by being posted on the shop-floor (for example) to realise the potential of those procedures. In addition, the results of those maintenance procedures should also be shared with all operators who involved in the programme. By performing such activities, the machines should continuously be in good conditions and then their reliability should be increased.

Quick Changeover: As shown in Figure 7-9, a remarkable amount of waste (about 9%) was generated due to setup time and adjustment activities. The LMTS implementation team at TBCo has noted that a great portion of the setup time was taken in changing over the noses of the paint spraying guns and other adjustments activities. Accordingly, the LMTS team has considered that time is waste and hence a

target for reduction. Therefore, quick changeover has been suggested as a lean tool to handle this identified type of waste within the cabin painting process. This is because quick changeover is a method of analysing and then reducing the time required to change a machine from producing one good part to another good part. In addition, reducing set up times is an important element for most of lean manufacturing other elements such as: TPM; JIT; WIP; small lots; and Kanban. The reduction of set up time should lead to reducing processing time, optimising equipment usage time; thereby the equipment idle time should be reduced. Most importantly the reduced set up time provides chance to run small lots, hence improving flow. This means product flows only when it is needed, in the smallest increment, the case which is consistent with the core principle of lean manufacturing.

As an effort to reduce the drying furnace setup time at TBCo, LMTS implementation team has videoed the current set-up activities (e.g. preparing, handling the tools, mounting, and adjust ...etc), then the total time based on those activities was analyses. Finally, the team has developed an action plan to eliminate the ineffective time in order to enhance the overall processing time. Eventually, by implementing the lean tool of quick changeover, the setup time will be reduced and become more frequent.

Poka-yoke: Based on the analysis of non-value added activities (shown in Table 7-3), rework activities due to defects consumed 11 minutes (around 10% of the total wasted time) during cabin painting process. Accordingly, Poka-yoke has been recommended to address this issue. Poka-yoke aims to put controls in place to prevent an error from producing a defect or to prevent a defect from ultimately passing on to the customer.

One of the identified mistakes that caused rework later was the cabin exceeding the required drying time inside the furnace. In order to prevent this error, the LMTS team has suggested using a system that automatically forces the furnace door to open as soon as the requested drying time is elapsed.

Furthermore, cabin sanding activities require the operators to use sanding papers with varying coefficient of smoothness. The operators' usage of improper sanding papers has contributed to the wasted time related to rework due defects. To prevent this human error, the LMTS team has suggested storing different sanding papers in different shaped bins on the shop-floor, so operators can easily locate the proper papers. Therefore, this suggestion is expected to positively contribute to waste reduction.

5S: The focus of 5S activity is to keep the shop-floor organised in order to make it more productive. The activities of 5S play an important role in optimising the overall productivity and the quality of products. Therefore, 5S was one of the tools that was recommended by the LMTS implementation team in TBCo.

Because of the importance of tidiness and cleanliness in painting process, the 5S tool was recommend to be adopted, particularly in station number 8 (final painting station). As it can be noted from Table 7-1 the final cabin painting step (Station No. 8) has taken a 30.75 minute; out of this processing time, there was 11 minutes has been considered as waste (as presented in Table 7-2). That wasted time (11 minutes – about 35.77% of the station total time) was attributed to the existing process neatness and orderliness standards. Therefore, the implementation of 5s is expected to provide a good opportunity to improve the current process time and hence contribute to overall company performance.

The pictures presented in Figure 7-10 show typical bad and good examples of shop-floor area with a level of 5S.

Moreover, several improvement ideas were suggested by the team to address the identified waste. For example, in the current process layout, the cabin was transported about 250 meters to reach the ceiling installation station (from station 9 to station 11). However, in the new proposed layout, the ceiling station is now relocated just above the station 10 and a lift is now used to transport the cabin.



A: A typical bad example of an area



B: A good example of an area with a level of 5S

Figure 7-10 5S implementation in painting line at TBCo

The new distance the cabin now travels (from station 9 to 11) is only a 15 meters which used to be around about 250 meters. Eventually, the redesign layout of station 11 (ceiling station) should now reduce a good amount of the overall painting processing time.

7.2.6 Stage 6: Overall System Assessment

Taking into consideration the improvements that the company should gain from the implantation of lean tools, and the suggested improvement ideas, the process performance is to be re-evaluated in this stage. The performance is to be measured as it was done in Stage 4 (section 7.2.4). Eventually, any possible performance increase will be estimated by calculating the efficiency and effectiveness of the process.

7.3 Expert Judgment Validation

The researcher approached a lean manufacturing practitioner who has more than 15 years' experience including training and working with Japanese while he was working in Denso. This expert is also has lean manufacturing small projects and training in Middle East. Currently he is the director of *"Coaching For Change"*

www.coachingforchange.co.uk). Therefore he was the right person to invite to provide expert judgment for the work presented in this thesis.

The researcher sought the opinion of the expert on two fronts: a): the Lean Manufacturing Transformation Strategy (LMTS) and b): the industrial case study. The overall opinion of the actual research topic of this PhD is its very relevance to the developing countries such as those in Middle East and North Africa. The expert believes there is a real need and many opportunities to introduce and implement lean in the different sectors of this region. However, there is a lack for a framework to help them to start the lean journey as part of their manufacturing strategy. Therefore, he sees that the proposed Lean Manufacturing Transformation Strategy (LMTS) is a good step toward filling this gap. The following sub-sections are presenting the expert judgment of the proposed LMTS and the industrial case study.

7.3.1 Expert Judgment of the Lean Manufacturing Transformation Strategy

The expert provided the following opinions on the current LMTS that was shown in Figure 6-2:

- The title is good as we should move away from focusing on only lean tools implementation to have strategy that will help the transformation of a company into lean environment.
- **Stage 1 Preparation:** The expert supports the “preparation stage”; however he provided certain feedback that helped the researcher to improve the detailed activities that should be performed within this stage. This is shown in Figure 7-11.

Build vision Establish need for lean Build lean team Change agent Foster lean learning, training, knowledge Make the commitment Obtain senior management buy-in Leadership: managers lead by example Culture change Supplier & customer involvement	1. Establish need for lean 2. Obtain senior management buy-in 3. Define new lean vision 4. Build lean team 5. Foster lean learning, training, knowledge 6. Culture change & commitment 7. Supplier & customer involvement
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A: Before expert judgment

B: After expert judgement

Figure 7-11 The modification of the “Preparation” activities of the LMTS

- **Stage 2 Establish Target Objectives (metrics):** The expert sees the importance to establish target to work toward achieving them. However, he recommended using the common languages used in manufacturing area which is “Key Performance Indicators”. He endorsed the proposed metric; “cost and time” and recommended to change “quality” to “Defect Rate” and remove “Delivery”.
- **Stage 3 Current Process Mapping:** The expert endorsed this stage and also emphasised the importance of performing value stream mapping and recommended it to be before the activity of “time and motion study”.
- **Stage 4 Current Process Performance Measurement:** The expert endorsed it as it is.
- **Stage 5 Applying Lean Tools:** The expert was pleased to see the proposed “Lean Manufacturing Model” shown in Figure 6-5 and agreed with the model structure of having 3 key elements: 1) the foundation, 2) quality related tools, and 3) cost related tools. He provided small modification for example “Standardisation” should be called “Standardised Work”. In addition, the expert highlighted the importance of calling “Jidoka” as “Bulid-in Quality” rather than just “Quality”. He also mentioned that the model should be regarded just as a guide and no need to be rigid in following it. Furthermore, the lean tools

implementation should be performed step by step where no tool implementation should be done without having adequate training and support for it. Finally, the expert advised to change the output of this stage from “Propose new Process” to “Improved Process”.

- **Stage 6 Overall Systems Assessment:** He endorsed this stage as it is.
- **Stage 7 Seek Perfection:** The expert endorsed this stage, however, he reminded the researcher that the transformation is a long and continuous journey and the manufacturing companies in the developing countries should be aware of that.

The feedback and the recommendations of the expert judgement helped the researcher to improve the proposed LMTS. The new modified version is shown in Figure 7-12. Finally, the modified version of lean implantation model is shown in Figure 7-13.

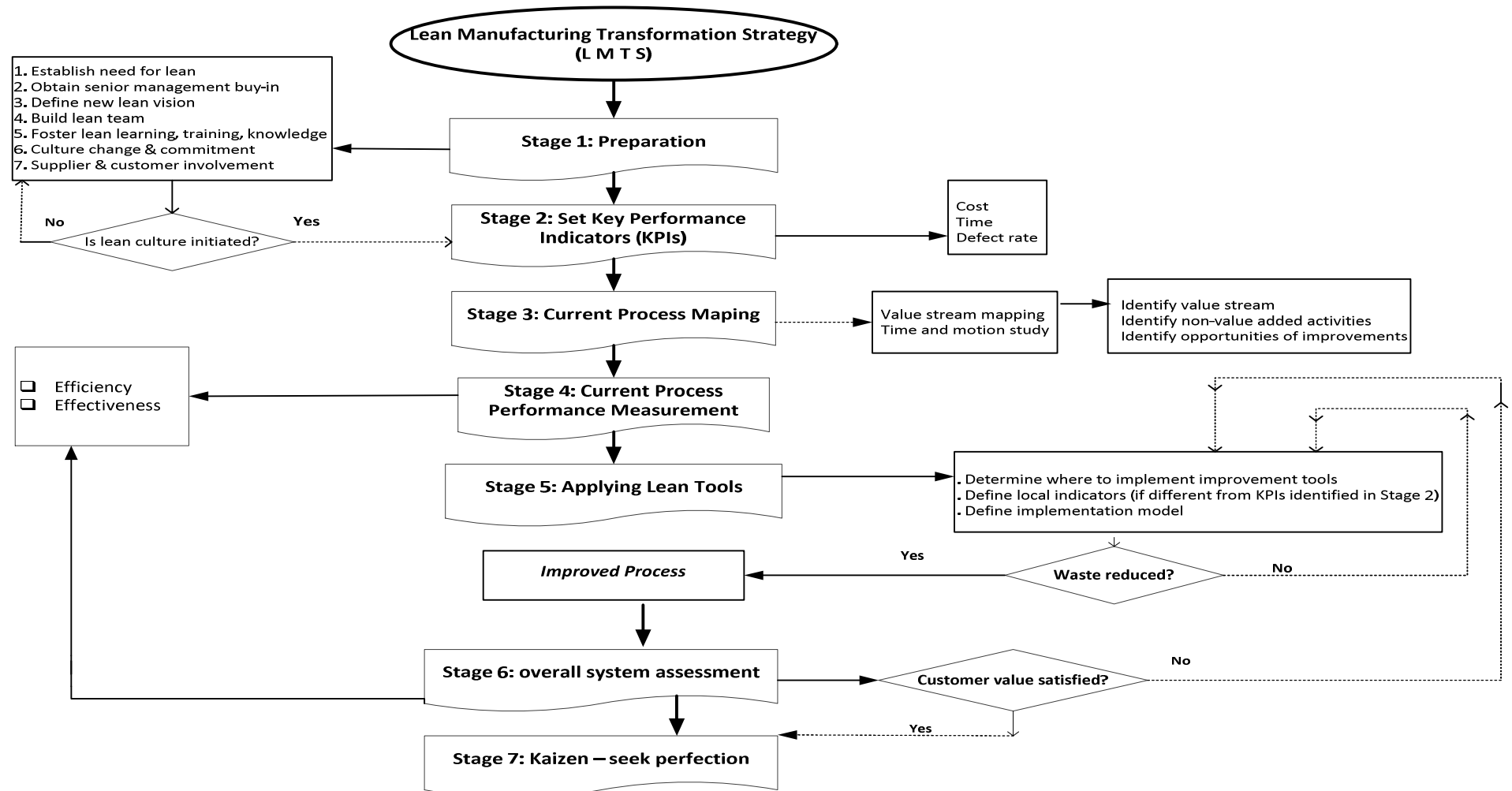


Figure 7-12 Modified version of the lean manufacturing transformation strategy (LMTS)

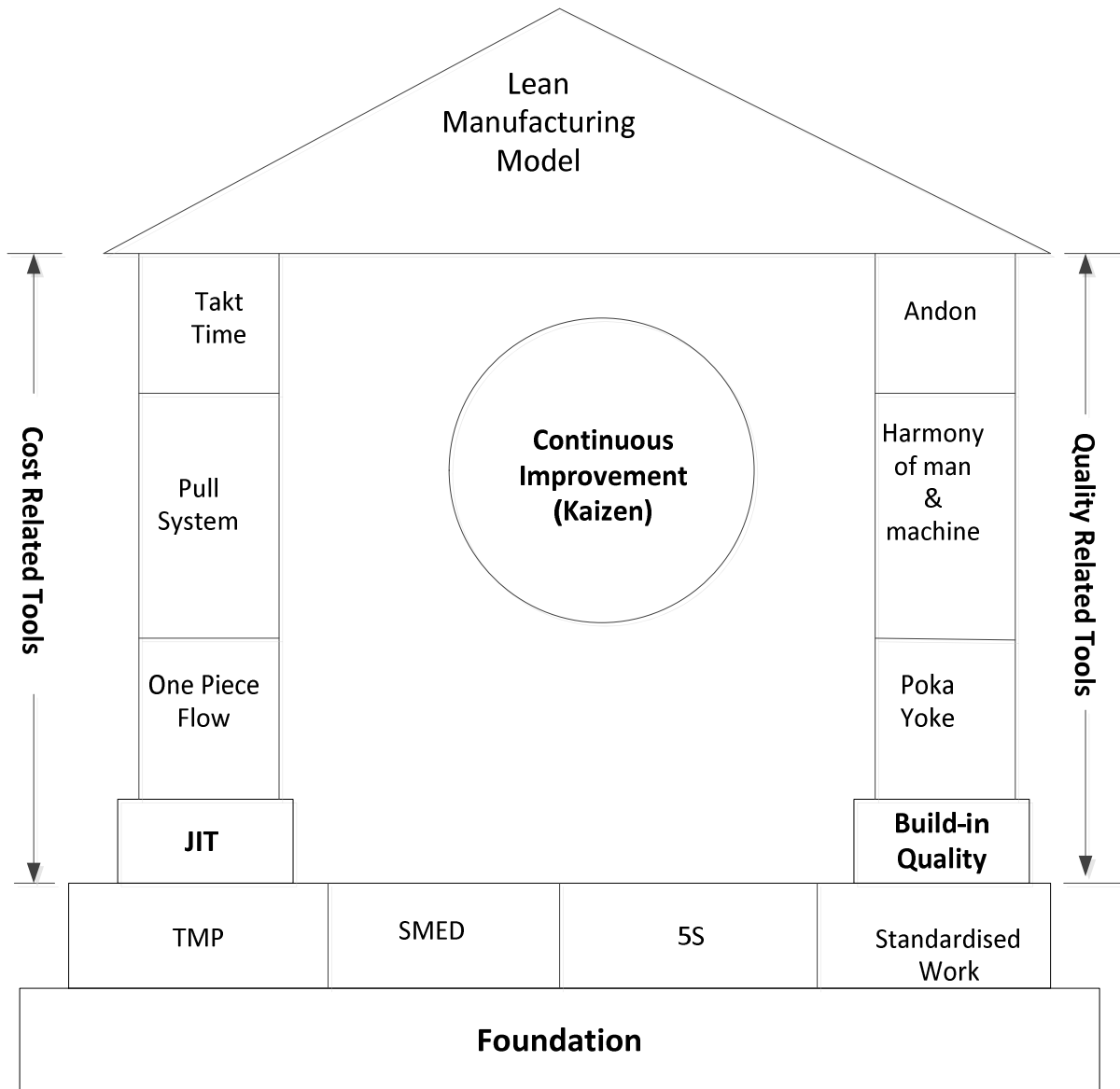


Figure 7-13 Modified lean model

7.3.2 Expert Judgment of the Industrial Case Study

The expert has stated that the painting process is a good case study to validate the LMTS as the process has different elements to demonstrate the benefits of lean manufacturing via following the proposed LMTS. He found the LMTS implementation logical and easy to follow and understand. Furthermore, he appreciated the fact that due to security and political situation in Libya, several issues have hindered the full

implementation and collecting the right data in more accurate manner. However, with current level of the collected data, the expert could see the value of this work from both sides of validating the proposed LMTS and for making the company “TBCo” aware of the importance of lean manufacturing.

The expert provided the following opinions on the industrial case study presented in section 7.2

- The implementation of Stage 1 “Preparation”: The expert endorsed all the performed activities as they presented section 7.2.1
- The implementation of Stage 2 “Establish Target Objectives (metrics) for the painting process”. This is OK for the sake of this type of demonstrating case study.
- The implementation of Stage 3 “Current Painting Process Map”. The expert appreciated the detail description of the painting process presented in section 8.2.3. The expert mentioned that having VSM is in general important in lean manufacturing application, however, the detail of the painting process layout shown in Figure 7-7 and the detail description of the process helped to have good understanding of the current painting process map. Furthermore, the expert considered the work on value added and none-value added activities shown in Table 7-2 as a major to appreciate the value of lean for the collaborating company as well as to demonstrate the effectiveness of the proposed LMTS. The expert did like very much the analysis of the none-value added activities shown Table 7-3 and Figure 7-9.
- The implementation of Stage 4 “Current Painting Process Performance Measurement”: The expert endorsed it as it is.
- Stage 5 “Application of suitable lean tools in the Painting process”. The expert found the presented work an interesting and easy to follow where he agreed about the list of recommended lean tools shown in Table 7-4. Also, he agreed of the style of putting recommendations as the actual full work might take up to 12 months.

In general the expert sees this case study has demonstrated - in satisfactory level - the value of the proposed Lean Manufacturing Transformation Strategy.

Chapter 8 Conclusion

8.1 Research Contribution to Knowledge

The contribution of this research to knowledge on lean manufacturing is expected to be of importance mainly in developing countries (e.g. Middle East and North Africa). Considering the lack of lean manufacturing studies within that region of developing countries, this research added a new value to the very little efforts being made toward transferring lean to those countries.

This research investigated the transfer and adoption of lean manufacturing which is widely accepted as a source of competitive edge. The work shed more light on how companies (in developing countries) can successfully be transformed into lean environment. Toward that end, the study emphasised the need of adapting to lean culture along with adopting its principles and techniques. As a typical developing country, this work has investigated the readiness of lean in the Libyan manufacturing industry; the automotive sector was the target in particular.

Following comprehensive investigations, this work has identified the factors that hinder lean transfer to the manufacturing industry in Libya. The identification of those factors was very helpful in developing the core output of this study, namely the lean manufacturing transformation strategy for developing countries (LMTS). The proposed LMTS is considered as a major contribution to lean literature in the developing countries context, particularly in Middle East and North Africa, as those countries share similar characteristics of culture and other organisational features. Therefore, the proposed LMTS can be adopted as an instructional model by other companies in that region of developing countries in order to help them start their lean journey.

Furthermore, the questionnaire developed in this study could be used by companies as a diagnostic tool to figure out their readiness to lean before embarking on the initiative. All lean manufacturing requirements were addressed in that questionnaire, thus it is expected to be a good diagnostic tool for companies to understand their

capabilities and limitations to adopt lean. Therefore, chances of failure could be analysed and then mitigated from the outset.

Moreover, this study has comprehensively investigated the lean critical success factors, therefore, it offers some important insights on how companies could maximise their chances of success.

Finally, the variety in data collection techniques used in this study (i.e. literature review, conducting questionnaire, interviews, performing case study validation, and seeking expert judgement) has enabled the researcher to achieve a level of triangulation and thus being able to ensure the validity of the obtained results.

8.2 Research Limitations

The outcomes of this study are relevant only to manufacturing organisations that are in a specific geographic region (i.e. Middle East and North Africa). However, considering the similarities of organisational culture and other organisational features those countries share with each other, the findings of study could be generalised to a huge number of organisations within that region.

Furthermore, the number of companies participated in this research is relatively small. However, this was as a result of selecting only one sector (i.e. automotive manufacturing sector) as a target for this study, in which there were only three companies operating in that sector within the sponsor country of this research, namely Libya. However, the drawback of small sample size was mitigated by the large number of people who were participated in the questionnaire phase and those who were interviewed in person during the interviews phase. The researcher has been able to conduct a total of 21 interviews within the three participated companies (7 people in each company). In addition, a total of 99 people from different organisational levels were successfully participated in the questionnaire as presented in Appendix 5.

Another possible limitation of this study is the likely occurrence of social desirability bias. Because this study used questionnaire and interviews as main data sources, respondents might have dishonestly replied to some questions which can influence

the accuracy of findings. However, the researcher believes that the obtained findings reflect the reality of the situation within the participated companies. This is because several research methods were used in data collection, such as observations made during plant visits and also the official reports provided by the participated companies. Furthermore, the content of the provided manufacturing reports is accurately reflecting the observed practiced within the participated companies. Therefore, the information provided by the respondents and the interviewees is of high quality and reflects the reality to a significant extent. Thus, drawback of bias in the findings is kept to minimum.

8.3 Conclusion

- Lean manufacturing showed a great success all over the world; however manufacturing companies in certain developing countries are still lagging behind others in the market. This work has contributed toward filling this gap.
- The identification of lean critical success factors has produced a pool of factors that companies in developing world could consult to select what factors are suitable to them and help them to define new ones.
- The questionnaire has been a good tool to communicate the idea of lean thinking in a developing country such as Libya. In addition, it helped to clearly capture the current manufacturing practices in different automotive companies in Libya.
- The interaction of the Libyan manufacturing companies during the field study showed their great interest and appreciations to lean manufacturing. This eventually will help to have wide spread of lean manufacturing good practices in the different manufacturing sectors.
- The data analysis of the field study has aided to identify the gap of the applications of lean manufacturing good practices then helped to make a case about the need for introducing and implementing lean.

8.4 Future work

Due to time constraints there was no chance to apply the proposed LMTS in different sectors. It is recommended to test the LMTS with other industries for purpose of validation. Also, the researcher recommends using LMTS in other similar developing countries on bigger scale.

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Appendixes

Appendix 1: Summary review of lean critical success factors in developed countries

Country where research conducted	References	Focus of Research	Research Design / Methodology	Key Findings / Remarks
1. UK	Achanga <i>et al.</i> (2006)	Identifying critical factors required for lean implementation in SMEs	<ul style="list-style-type: none"> • Literature review and • semi-structured questionnaire • visitations and observation of firms practices • personal interviews • a ten case study 	Lean critical success factors: <ul style="list-style-type: none"> • Leadership & management • Financial capabilities • Skills and expertise • Organisational culture
2. Netherlands	Timans <i>et al.</i> (2012)	Gather in-depth information on CSFs and impeding factors and their impact on lean deployment	<ul style="list-style-type: none"> • short questionnaire to select companies familiar with lean manufacturing • comprehensive questionnaire to select companies for case studies • six case studies • semi-structured interviews • open-ended interview protocol 	The heights ranked critical success factors of lean are: <ul style="list-style-type: none"> • Linking to customer • vision and plan statement • communication and management involvement and participation • development of the project leader's soft skills • supply chain focus • personal lean experience of top management The strongest impeding factors are: <ul style="list-style-type: none"> • Internal resistance • the availability of resources • lack of leadership
3. USA and China	Hofer <i>et al.</i> (2011)	Exploring the interaction among different institutional factors that drive the adoption	<ul style="list-style-type: none"> • survey of Chinese's manufacturing companies executives • administrating the same survey among 	<ul style="list-style-type: none"> • Insights into the drivers and barriers to lean adoption. • Lean adoption process is driven by several economic, socio-cultural, and regulative factors • some economic factors

		process of lean manufacturing practices in China as compared to the USA context	randomly chosen members of The Association for Operations Management (APICS) in the US.	facilitate the lean adoption process <ul style="list-style-type: none"> • social processes and cultural traits may hinder the full adoption process
4. UK	Crute <i>et al.</i> , (2003)	key drivers for Lean and examine the assumption that cross-sector transfer may be difficult.	<ul style="list-style-type: none"> • primary data: In-depth longitudinal two case studies • semi-structured interviews with managers and workers • literature review on lean adoption process criteria • secondary data: monitoring developments on lean processes 	key factors affecting the rate of lean change: <ul style="list-style-type: none"> • management commitment • change strategies • organisational cultural • focusing on a specific product value stream • time and space for change
5. Sweden	Göthberg and Simonchik, (2013)	Understanding the effect of chosen lean change factors on employees' attitudes during the early stage of lean manufacturing adoption process	<p>A case study was conducted and data were collected through:</p> <ul style="list-style-type: none"> • observations • focus group sessions • semi-structured questionnaire 	several change factors affect employees' attitude, it could have negative and positive impact: <ul style="list-style-type: none"> • change training programmes have highest influence on the affective component of attitude • workers participation showed more connection to the cognitive component • change vision will affect the behavioural component mostly
6. US and German	Czabke <i>et al.</i> (2008)	Identifying the difficulties and challenges that faced in lean adoption.	<ul style="list-style-type: none"> • Lean manufacturing conceptual framework • four case studies, two in the USA and two in Germany 	Lean adoption main challenges: <ul style="list-style-type: none"> • Organisational cultural • Communicating the vision and plan for lean initiative to all employees • Adherence to the new work conditions,

			<ul style="list-style-type: none"> questionnaire different interview protocols 	practices, and principles
7. USA	Motwani (2003)	Exploring the critical factors involved in the implementation of lean	<ul style="list-style-type: none"> Literature review Case study Interviews Observations Archival documents 	<ul style="list-style-type: none"> Lean process change requires the following success factors: <ul style="list-style-type: none"> Strategic initiative of top managers acting as leaders in defining and communicating the vision of change Willingness to learn Culture readiness Knowledge sharing
8. USA, eight EU countries, Japan, China, and India	Mefford (2009)	Presenting a production paradigm (management philosophy & tools) to increase productivity, this paradigm is drawn up based on the experiences of companies practicing lean manufacturing. Transferring best practices methods to developing countries	Interviewing managers in 12 developing and developed countries (India, China, eight EU countries, Japan, USA)	<ul style="list-style-type: none"> The successful adoption requirements of this paradigm is discussed. The role of CEO in successful adoption of this productivity paradigm and how to transfer it to developing countries was also addressed. Soft technology (management and process skills) is vital in transferring lean to developing countries Political and economic instability, infrastructure shortage, and lack of skilled workers are example of factors that may hinder transferring lean Before successfully implement lean, two things must be changed: the organisational cultural and manager's philosophy of management The CEO vital components required to successfully adopt lean The main barriers to lean is resistance to change and inertia Top management commitment is vital in

				lean adoption
9. Belgium and Norway	Bakås <i>et al.</i> (2011)	addressing the challenges the face EU SMEs and identifying the success factors	<ul style="list-style-type: none"> • Literature review • Seven case studies in Belgium • Industrial cooperation with four case companies in Norway • Joint workshops between researchers and selected team from each case company 	<ul style="list-style-type: none"> • critical success factors were suggested: <ul style="list-style-type: none"> ○ strong leadership and management involvement ○ employee involvement and participation ○ sufficient time for preparing the organisation and cultural change ○ creating motivation and learning ○ Communication of lean goals and objectives ○ performance evaluation system ○ Linking lean to business strategy and customers
UK	Näslund, (2013)	reviewing the critical success factors (CSF) for lean and analysis these factors as compared to previously productivity continuous improvement initiatives	<ul style="list-style-type: none"> • literature review • comparative analysis complemented with examples from previous case studies 	<ul style="list-style-type: none"> • It has been shown that there is a general consensus on the success factors for all improvement initiatives. Moreover, these factors seem to be fairly unchangeable over time. • The CSFs are: <ul style="list-style-type: none"> ○ management support & commitment ○ organizational culture ○ strategic alignment ○ project management ○ training
US	Kundu and Manohar, (2012)	Identifying lean critical success factors in IT support services sector	Conceptual discussion of success factors applicable to IT support service companies	<ul style="list-style-type: none"> • a comprehensive model of CSFs for lean implementation in IT services sector: <ul style="list-style-type: none"> ○ management leadership ○ management support ○ top management commitment ○ organizational culture ○ communication ○ training and skill

				<ul style="list-style-type: none"> building <ul style="list-style-type: none"> financial capability measurement framework
10. Different EU countries	Laureani and Antony (2012)	Identifying the critical success factors for adopting lean manufacturing	<ul style="list-style-type: none"> Analysing the recent literatures on the success factors for all continuous improvement initiatives Designing a survey questionnaire based on literature returns 	<ul style="list-style-type: none"> The most vital factors are: <ul style="list-style-type: none"> management commitment cultural change linking lean to business strategy leadership styles
11. Belgium	Dora <i>et al.</i> (2012)	Exploring the effect of lean manufacturing successful factors	<ul style="list-style-type: none"> multiple case studies 	<ul style="list-style-type: none"> Determining factors of lean manufacturing adoption process <ul style="list-style-type: none"> top management commitment organisational culture the culture of team work skilled workforce
12. UK	Bhasin, (2011a)	Exploring the importance of an appropriate systematic change strategy leading to the probability of successful lean adoption. Discussing the significance of embracing lean as an ideology which allows companies to obtain the full benefits of lean	<ul style="list-style-type: none"> questionnaires interviews case studies lean meticulous audits were conducted in selected companies as validation 	<ul style="list-style-type: none"> Extensive audits with companies showed the importance of a systematic and well planned change strategy for embracing lean initiative. A strategy in which a company clearly communicates what objectives to be sought and how these objectives will be achieved Barriers to lean implementation: <ul style="list-style-type: none"> inadequate understanding of the potential benefits insufficient funding senior management skills supervisory skills lack of skilled workforce the cost of the

				<ul style="list-style-type: none"> investment <ul style="list-style-type: none"> organisational culture issues Key pre-requisite factors facilitating lean adoption <ul style="list-style-type: none"> Lean sustainability: measuring the commitment to lean culture treating lean as a profitable initiative a strategy of embracing lean
13. UK	Kumar <i>et al.</i> (2009)	Investigating the quality initiatives practiced by UK manufacturing SEMs. Comparing these practices in Six Sigma firms and its Non Six Sigma counterparts	<ul style="list-style-type: none"> Literature review Short questionnaire 	<ul style="list-style-type: none"> Lean critical success factors: <ul style="list-style-type: none"> management involvement and commitment communication leadership skills link lean to employee culture change education and training link lean to customer project selection link lean to supplier project management skill organization infrastructure vision and plan availability of resources link lean to strategic organisation objectives Barriers to lean: <ul style="list-style-type: none"> Lack of knowledge and training Internal resistance Poor employee participation Changing business focus
14. Belgium	Mothersell <i>et al.</i> (2008)	Opel Belgium transformation from mass to	<ul style="list-style-type: none"> Review of internal documentation 	<ul style="list-style-type: none"> Lean Successful Factors <ul style="list-style-type: none"> Leadership

		lean production.	<ul style="list-style-type: none"> of the mass-to-lean conversion. Plant tours. Open discussion with team members in the plant. Extensive interviews with key organisational leaders. 	<ul style="list-style-type: none"> understanding of lean ○ Changing organisational behaviours ○ Changing infrastructures and routines ○ Changing organisational cultures ○ Pilot project ○ Champion
15. Switzerland	Scherrer-Rathje <i>et al.</i> (2009)	Identifying the success and failure conditions and criteria in adopting lean	<ul style="list-style-type: none"> Case study in a large, global European manufacturer of food processing machines. Interviews with members from different functional areas ranging from shop-floor workers to management members. Three plant tours. Two discussion workshops within the business unit 	<ul style="list-style-type: none"> Lean will not pay off without management commitment Encourage and enable employees autonomy Full communication of lean's tactical and strategic goals with all employees affected by changing to lean Ensure the sustainability of lean and prevent employees from backsliding to pre-lean work conditions Communicating the benefits of, and lean successes from the outset Develop measurement and Continual evaluation system to ensure the organisation is on the right path
16. Denmark	Pedersen and Huniche, (2011)	Determining the success and failure factors of lean	<ul style="list-style-type: none"> Literature review Interviews with 29 senior managers 	
17. UK	Angelis <i>et al.</i> , (2011)	Examining the relationship between lean manufacturing and employees commitment and associated practices	<ul style="list-style-type: none"> Questionnaire plant tours interviews 	
18. Australia and Switzerland	Fraser <i>et al.</i> , (2007)	See the paper in folder: papers—		

		recent—factors : it is under this title Fraser <i>et</i> <i>al.</i> , 2007		
	Panizzolo, <i>et</i> <i>al</i> (2012)	Lean in developing countries		

Appendix 2: Lean manufacturing barriers in developing countries

Country where research conducted	References	Focus of Research	Research Design / Methodology	Key Findings / Remarks
1. Malaysia	Jeyaraman and Teo, (2010)	Analysing the critical success factors for lean and Six Sigma and measuring the impact of those factors on companies performance	<ul style="list-style-type: none"> quantitative survey structured questionnaire six case studies statistical methods were applied to validate results 	<p>A model of lean six sigma critical success factors:</p> <ul style="list-style-type: none"> Management engagement & commitment Organisation belief and culture Effective lean training Project success stories, best practices sharing and benchmarking Project prioritisation, selection, review and tracking Communication Financial capability Reward and recognition
2. Mexico	Suárez-Barraza and Ramis-Pujol, (2010)	Providing a successful example of how lean is adopted	<ul style="list-style-type: none"> A case study direct observation documentary analysis semi-structured interviews 	<p>Lean enablers:</p> <ul style="list-style-type: none"> Commitment to and wish for improvement Clear resolve to improve Focus on the simple and practical Active leadership The service is outcome/customer/stakeholder-oriented Holistic and transversal thinking Creating a performance measurements system <p>Lean inhibitors:</p> <ul style="list-style-type: none"> Resistance to change by employees A lack training classical bureaucratic mode, organisational structure, creating small fiefdoms The influence of trade unions with little interest in change A lack of credibility of certain middle management lack of a strong link between lean efforts and the HRM best practices

				required to consolidate them
3. Malaysia	Roslin <i>et al.</i> (2012)	Report on a successful lean initiatives taken by a manufacturing firm and discussing the factors led to that success	<ul style="list-style-type: none"> • Literature review • Case study in a manufacturing company • Plant tour observations 	<ul style="list-style-type: none"> • lean adoption process is a top-down holistic approach • Adaptation to lean is a knowledge-intensive process, hence top management is required to have clear vision and strategic initiatives, and sufficient level of education & training • Success factors: <ul style="list-style-type: none"> ○ top management support & continuous commitment ○ organisational and cultural change ○ motivated and empowered employees ○ involving people as teamwork is the heart of lean organisation ○ investing in lean activities and focus on long-term benefits • Barriers to lean: <ul style="list-style-type: none"> ○ lack of leanness understanding (conceptual idea of lean and its application and tools) ○ resistance to change ○ lack of financial resources
4. Kuwait	Al-Najem <i>et al.</i> (2013)	Measuring the readiness to lean within manufacturing SMEs	<ul style="list-style-type: none"> • Extensive literature review • questionnaire • semi-structured interviews 	<ul style="list-style-type: none"> • Lean CSFs in the Kuwaiti context are not very supportive. • There is a notable lack of Kuwaiti companies' preparedness for lean. • Factors affecting adopting lean successfully: <ul style="list-style-type: none"> ○ language barriers ○ level of worker education and skills ○ effective communications between workers and departments ○ workers' empowerment and

				<p>involvement</p> <ul style="list-style-type: none"> ○ lack of urgency / pressure to convert to lean due to the lack of competitiveness in the market ○ lack of training and recognition ○ lack of government support
5. Saudi Arabia	Karim <i>et al.</i> (2011)	Evaluating the main lean barriers and investigating lean implementation levels	<ul style="list-style-type: none"> • Literature review • Semi-structured questionnaire 	<ul style="list-style-type: none"> • Barriers of lean manufacturing implementation: <ul style="list-style-type: none"> ○ Organisational culture ○ Lack of management commitment ○ Lack of skilled workers
6. Pakistan	Bhutta <i>et al.</i> (2013)	Exploring the diffusion of lean manufacturing practices in eight textile firms	<ul style="list-style-type: none"> • Structured interviews • plant tours 	<ul style="list-style-type: none"> • Pakistani firms are in the early stages in implementing lean manufacturing • Much work have to be done to truly implement lean manufacturing • Opportunities are available for Pakistan firms to improve their operating performance by properly adopting lean practice.
7. India	Singh and Ahuja, (2013)	examining the factors that influencing the lean	<ul style="list-style-type: none"> • Literature review • Questionnaire tested with 50 manufacturing companies 	<p>Lean success factors are:</p> <ul style="list-style-type: none"> • Culture transformation • Top management commitment • Cross training programmes • Employee involvement and commitment • Long-term relations with suppliers • Communicating lean goals with all employees • Introducing incentive system • Empower employee in decision making process
8. India	Garza-Reyes <i>et al.</i> , (2012)	Empirical investigation of the statues of lean manufacturing in India	<ul style="list-style-type: none"> • Questionnaire • Literature review 	<ul style="list-style-type: none"> • The adoption of lean manufacturing is very limited within Indian companies. •

Appendix 3: Studies that assessed the degree of lean manufacturing adoption

Study	Investigated Area	Data Collection Method	Assessed Lean Manufacturing Practices
1. Sezen <i>et al</i> , (2012)	Shop-floor	Questionnaire	Pull production, one piece flow, value stream mapping, process improvement, preventive maintenance, cellular manufacturing, 5 why, employee suggestion system, continuous improvement, Poka-yoke, waste elimination
2. Shetty <i>et al</i> , (2010)	Shop-floor	Questionnaire	Standardization, supplier management, reducing WIP, using Kanban, employee empowerment, reward and recognition, 5S, TPM, cycle time reduction, Poka-yoke, one-piece flow
3. Shah and Ward, (2007)	Shop-floor	Questionnaire	Supplier feedback, supplier JIT deliver, supplier development, customer involvement, pull, flow, low setup, TPM (total productive maintenance), employee involvement, SPC (statistical process control)
4. Wan and Chen, (2009)	Shop-floor	Questionnaire	Pull, line balancing, standard work, automation, SMED, VSM, visual control, worker flexibility, concurrent engineering
5. Saurin <i>et al</i> , (2011)	Shop-floor	Interview and Observations	Teamwork and leadership, continuous improvement, cross-training, employee's autonomy, work standardisation, visual management, pull, production levelling, quick set up, TPM
6. Bhasin (2011a)	Shop-floor and administrative	Questionnaire and Observations	Safety, flow, pull, reduce WIP, visual management, mistake proofing, continuous improvement, top management support, need for change strategy, lean champion, organisational culture
7. Soriano-meier and Forrester (2002)	Shop-floor	Questionnaire	Elimination of waste, continuous improvement, zero defect, JIT delivery, pull, decentralisation, integrated of functions, vertical information system,
8. Lasa, <i>et al</i> , (2009)	Shop-floor	Interview and observations	Takt time, continuous flow, pull system, levelling production, SMED
9. Karlsson and Åhlström (1996)	Shop-floor	observations	Waste elimination, continuous improvement, zero defect, just-in-time, pull system, multi-functional teams, responsibilities decentralization, integrated function, vertical information system,
10. Panizzolo (1998)	Administrative areas and shop floor	Interviews	This study assessed 48 lean practices, which have been categorised under six main constructs: process and equipment, production planning and control, human resources, product design, supplier relationship, customer relationship.
11. Gurumurthy and Kodali	Administrative areas and shop	Observations	Job rotation, communication between employees, cross functional team working,

(2009)	floor		rewards and recognition, employee participation, long team employee, safety programmes, supplier relationship, customer relationship, information exchange with suppliers, training programmes, flat organisation, TPM, one piece flow, SMED, WIP reduction, cycle time reduction, quality circles, layout change, ensuring quality at source, load balancing, pokayok,
12. Doolen and Hacker (2005)	Administrative areas and shop floor	Questionnaire	This questionnaire assessed the use of 30 lean practices came under six impact areas: manufacturing equipment and process, shop-floor management, new product development, supplier relationships, customer relationships, workforce management
13. Sánchez and Pérez (2001)	Administrative areas and shop floor	Questionnaire	36 lean practices have been grouped into six categories: elimination of non-value activities, continuous improvement, teamwork, JIT production & delivery, supplier integration, flexible information system

Appendix 4: Questionnaire

Construct 1: Process and Equipment

1.1 Visual Management

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE01	Your company follows active policy to help keep shop floor tidy, clean and uncluttered.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE02	A visual labelling system is in place to locate tools in shop floor and ensure they are in the right place.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

1.2 Cellular Manufacturing

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE03	Dissimilar machines are grouped together and dedicated to process collections of items that have similar production requirements (e.g. tolerance, machine tool capacities, required operations, etc.).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE04	The processes used within similar operations are located and carried out in close proximity to each other.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE05	There is very little delay between task completion time at one workstation and the start time at the next workstation.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE06	People and equipment responsible for workstations activities have access to timely, accurate information about the disposition of work (e.g. order status, part availability, equipment function, procedures, production goals, specifications).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

1.3 Total Productive Maintenance (TPM)

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE07	Your company emphasises more on preventing machines sudden-breakdown (preventive maintenance) rather than machine failure repairing (breakdown maintenance).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE08	Your company follows standardised operating procedures to efficiently perform maintenance activities.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE09	Maintenance programmes are performed in partnership between several departments' workers (e.g. maintenance, production, and engineering) as part of their daily jobs.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

1.4 Setup Time Reduction

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE10	Your crews use techniques that are helpful in minimising machines setup and tools/mould changeovers.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE11	Most of your internal setup time has been converted to external setup time while the machine is running.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

1.5 Pull Production system (JIT Flow)

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE12	Upstream production processes are triggered only by actual demand initiated by downstream processes (actual production is demand-driven).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PE13	There are visual methods (such as cards) with relevant information being attached, communicating production requirements between work stations to support PE12 practice.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

1.6 Commitment to Quality

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PE14	All machines have devices either for preventing or detecting abnormalities. These devices – for example – are: warning lights; colour codes; limit switches; toggle switches; jig devices; or sensors.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Construct 2: Planning and Control

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
PC01	Your company conducts regular focus group meetings to identify wastes and solve problems by creating new ideas.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PC02	Your company benchmarks its performance with similar industry companies in the region.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PC03	There are up-to-date charts displayed on the shop-floor. These charts (Key Performance Indicators) showing important information to communicate current progress against the targeted plan. These information such as: defect per unit, error per unit, cycle time (hours per unit), and / or schedule adherence (i.e. 2 hours behind or ahead of plan).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
PC04	Your company uses analysis techniques such as “Cause and Effect Diagrams”, “Quality Circles” as a tool attempting to identify a potential root causes of quality problems to address them before the problem escalation.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Construct 3: Human Resources Management

Item Code	Best Practices	Scale of Agreement / Disagreement				
		<i>Strongly Disagree</i>	<i>Somewhat Disagree</i>	<i>Neutral</i>	<i>Somewhat Agree</i>	<i>Strongly Agree</i>
HRM01	Shop-floor workers are encouraged to bring manufacturing related issues to problem-solving small group sessions to clearly determine these issues in order to find solutions.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
HRM02	Your company makes efforts to utilise the different abilities of shop floor workers (e.g. physical, creative, mental, abilities).	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
HRM03	Shop-floor workers are trained in a variety of tasks to develop workers with cross-functional skills within production area.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
HRM04	Workers are moved from a job to another within the plant in order to ensure they are capable to carry out different tasks.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
HRM05	Reward and recognition system is initiated to motivate workers to do their best in order to generate ideas for improvements.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
HRM06	Shop floor workers have the decision making authority to stop the production line if abnormalities occur.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Appendix 5: The sample size of the questionnaire respondents

Position	Number of Respondents			
	Company A	Company B	Company C	Total
Chief Executive Officer	1	1	1	3
Production Director	1	1	1	3
Planning & Control Manager	3	2	3	8
Production Manager	4	4	4	12
Quality Manager	2	2	2	6
Logistic Manager	2	1	1	4
Human Resources Manager	2	1	2	5
Engineering Manager	4	5	5	14
Maintenance Manager	2	3	3	8
Cost Control Manager	1	1	1	3
Shop-floor workers	2	3	1	6
Sales Manager	1	2	2	5
Stores manager	1	1	1	3
Technical Service Supervisor	3	3	3	9
R & D Manager	1	1	1	3
Line Supervisor	2	2	3	7
Total Respondents	32	33	34	99

Appendix 6: TBCo Certification of ISO 9001



CERTIFICATE

The TÜV CERT Certification Body
of TÜV Rheinland Cert GmbH

certifies in accordance with
TÜV CERT procedures that



Trucks & Buses Co.

Tajura km 19, Sidi Karim St.
LAR - Libya

has established and applies a quality management system for

Production of all Types of Trucks & Buses

An audit was performed, Report No. **083012**.

Proof has been furnished that the requirements according to

DIN EN ISO 9001:2000

are fulfilled.

The certificate is valid until **2011-07-16**.

Certificate Registration No. **01 100 083012**



Cologne, 2008-07-24

A handwritten signature in black ink, likely of a representative from TÜV CERT.

TÜV CERT Certification Body of
TÜV Rheinland Cert GmbH



Appendix 7: TBCo Certificate of ISO 14001



CERTIFICATE

The TÜV CERT Certification Body
of TÜV Rheinland Cert GmbH

certifies in accordance with
TÜV CERT procedures that



Trucks & Buses Co.

Tajura km 19, Sidi Karim St.
LAR - Libya

has established and applies an environmental management system for

Production of all Types of Trucks & Buses

An audit was performed, Report No. **087248**.
Proof has been furnished that the requirements according to

ISO 14001:2004

are fulfilled.

The certificate is valid until **2011-07-16**.

Certificate Registration No. **01 104 087248**



Cologne, 2008-07-24



TÜVRheinland®

A handwritten signature in black ink, likely belonging to a representative of TÜV Rheinland Cert GmbH.

TÜV CERT Certification Body of
TÜV Rheinland Cert GmbH

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