An Analytical Investigation into Lead-Time Reduction in the Manufacturing Sector:

A Study of Discrete Manufacturing in Kurdistan Region of Iraq

A thesis submitted for the degree of

Doctor of Philosophy

By

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November 2016

Abstract

The dynamic business environment has prompted the companies to improve their competitiveness in terms of manufacturing efficiencies by exploring faster, better and cheaper modes of product development. In this concern, different approaches are configured such as lean manufacturing, just in time and lead time reduction. The study focuses on a critical investigation into the reduction of Lead Time within discrete manufacturing in Kurdistan region of Iraq and the reasons behind this research, that area has evolved gradually as well as the government has an action plan for national recovery and development of reconstruction, where lead-time has become a major issue in manufacturing industry. Specifically, current research study aims at contributing to the strand by focusing on a critical investigation into the reduction of lead time within discrete manufacturing in Kurdistan region of Iraq, where lead-time has become a major issue in manufacturing industry. Mainly, the study has the goals of developing reliable techniques for reducing the lead time through application of assessment survey, capacity planning and key performance indicators in order to implement and control the manufacturing processes. The rationale behind the present study is consisted of economic development within the region, which has attracted a large number of foreign direct investments, but the expanded lead time is causing hurdles with the lack of a strategic plan for resolving the issue which has not keenly addressed in literature so current study would be beneficial for both the stakeholders such as researchers relying on literature and for practitioners as well.

In order to conduct the analysis, current research applies the mixture of quantitative and qualitative research. Specifically, for quantitative analysis, a survey is conducted using questionnaires as data collection tool and SPSS analysis for exploring the cause and effect relationship. Mainly, the data are collected from eight Kurdistan based manufacturers. On the contrary, the qualitative analysis is conducted through the case studies. The development of a comprehensive conceptual framework has been applied for focusing on quick response manufacturing both at batch and mass production level. The framework is a contribution to academic knowledge.

Through the outcomes of the study, specific factors which are explored to be the main causes of extension in lead time include ineffective forecasting for material requirements, capacity planning, inaccurate demand analysis, decreased resource efficiency and shipment delays. As the most effective solution to these issues, the findings explained that the lot for lot technique is much better than the fixed period requirements which are mostly used in the Iraq region. Moreover, just in time manufacturing strategy and closed loop capacity is also proven to be fruitful along with the splitting order tactic. It is concluded from the findings of this study that the basic issue lies with management in different areas like in human resource, quality, information acquiring, technological developments and operational efficiency. So, it is recommended to the practitioners to higher efficient management squad at the most basic level to eradicate the root cause of the lead time issue. This research will provide new simple strategies for reducing manufacturing lead-time because this is particularly important, as it can be used to provide guidance to industry practitioners on how to reduce manufacturing lead time.

Key words:

Manufacturing Lead Time Reduction, Throughput Time Reduction, Quick Response Manufacturing, Operation Management

Acknowledgement

I would like to express my gratitude to the people who have helped and supported myself to realise this project.

Firstly, I would like to thank my supervisor, Dr Atanas Ivanov, for his guidance, time, effort, encouragement and endless patience to make this project a success.

Also I would like to thank Prof Kai Chang and Dr. Susan Grant

I am grateful for the support of Brunel University and the DDS department who have encouraged me to realise this project

I dedicate this project to those mentioned above.

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List of Abbreviations

- CMM Coordinate Measuring Machine
- CO Confirmed Order.
- CONWIP CONstant Work In Process,
- EMA Exponential Moving Average
- ERP Enterprise Resource Planning
- EVA Economic Value Added
- FCFS First-Come, First-Served
- FCS Finite Capacity Scheduling
- FGI Finished Goods Inventory
- FOQ Fixed Order Quantity
- FOQ Fixed Order Quantity
- FPR Fixed Period Requirement.
- HDPE High-density Polyethylene
- JIT Just-in-Time
- KPIs Key Performance Indicators
- L4L Lot-of-Lot
- LDPE Low Density Poly
- M/G/1 Queuing Model
- MLT Manufacturing Lead Time
- MPS Master Production Schedule
- MRP Manufacture Resource Planning
- MRP Material Requirement Planning

- MTBF Mean Time Between Failures
- MTO Make To Order
- MTTP Manufacturing Throughput Time per Part
- MTTR Mean Time To Repair
- OEE Overall Equipment Effectiveness
- OTD On Time Delivery
- PLCs Programmable Controllers
- PLT Product Lead Time
- PLT Production Lead time
- POLCA MANAGERIAL FUNCTIONS defined as: Planning, Organizing, Leading, Controlling, Assurance
- POLT Planned Order Lead Time
- PPRC Polypropylene Random Copolymer
- QRM Quick Response Manufacturing
- QVM Quick View Manufacturing
- R&D Research and Development
- RCCP Rough Cut Capacity Planning
- SIC Standard Industrial Classification
- SMED Single Minute Exchange of Dies.
- SPC Statistical Process Control
- TBC Time-Based Competition
- TDO Technology Development Organisation
- TOC Theory of Constraints

- TPM   Total Productive Maintenance
- TQM   Total Quality Management
- VSM   Value Stream Mapping
- WIP   Work In Progress
- ZX   Plastic Factory

List of notations

μ	Service rate units per hour
λ	Arrival pipes rate units per hour
rho	Traffic intensity
Ws	Average time in the system
Wq	Average waiting time in the queue
P	Average server utilisation
Po	Probability (% of time) system is empty
Pn	Probability number units in system
Tsu	Setup time for each process
H0:	Null hypothesis
Ha:	Alternative hypothesis
Asymp. Sig. (2- sided)	P- Value: 0.025 < **ά** > 0.025
Chi-square Statistic	P-value > Level of Significant
CV	Coefficient of Variation
T_{MP}	Manufacturing planning time (hours /item)
T_{MC}	Manufacturing control time (hours /item)
T_{PD}	Product Design time (hours /item)
MLT	Manufacturing Lead Time (hours /item)
PLT	Product Lead Time (hours /item)
To	Operation (processing) time per item per process
Tno	Non- Operation (processing) time per item per process
Ls	Average number of unites in the system

Lq Average number of units waiting in the queue

Lead Time Hour: Day: Week: Month

Ws Equal to MLT (hour) if queuing system that has a steady state.

Chapter 1- Introduction and Background Information

1.1 Background

Currently, most modern manufacturing companies need to improve their manufacturing competitiveness in terms of better, faster and cheaper products, which has led to a range of approaches including 'just in time', lead time reduction, lean manufacturing, using social networks, and knowledge sharing, in order to be the first to get products and services to a customer faster. The aims for this thesis to cover the competencies required for carrying out lead time analysis. It involves adhering to the applicable principles and it also involves carrying out the processes of manufacturing lead time analysis for selected processes, as well as collecting information of data on manufacturing processes of different factories.

This research proposes a study on reducing manufacturing lead time (MLT) in factories in the Kurdistan region of Iraq, where lead time has become a major issue for the manufacturing industry because most of the factories inform the customers when orders are expected to arrive late. Also, they have a poor history of meeting their demand on time; they often have high demand that is backordered and also have excessive inventory due to poor forecasting and scheduling. Most of the manufacturers need to be sure and ask if their products met the target the customer has set for them. Therefore, companies seek to reduce manufacturing lead time (MLT) in order to reduce the cost of production; short lead times are a major source of potential competitive advantage, and a reduction in manufacturing lead time (MLT) is significant for any manufacturing firm.

This study deals with a review of various tools and techniques to reduce lead-time. The researcher will make recommendations to identify any problems or conditions with the work area/process where improvements could be made and make recommendations for the production which is revised lead time profiles, identifying the improved process. The researcher's responsibility was to comply with different organisational policies and procedures for the activities undertaken, and to report any problems that were outside the researcher's responsibility.

Newer research has stated that 'the impact of customer order and lead time are of crucial importance on the firm's ability to earn money' (Ketokivi & Heikkila, 2003). Lead time has several definitions. It can be regarded as the time from when a customer makes an order to when that customer receives the finished product. However, others claim it is the time that elapses between the placement of an order and receipt of that order into an inventory (Gaither, 1994) and (Silver et al., 1998). Various lean tools are available for reducing lead-time such as Single Minute Exchange of Dies (SMED), 5S, Poka-yoke, Kanban, Just-in-time (JIT), Value Stream Mapping (VSM), Jidoka, Cellular manufacturing etc., which are applied to reduce lead-time. In production systems, lead-time is equal to the sum of the wait, set-up, queue, move, and run times (Heizer & Render, 2008). Little's Law shows that by maintaining the same production rate, a reduction in lead-time will reduce work in process (WIP), or identifying the largest component of lead-time is to find the largest inventories and work to reduce them. Little's Law mentioned that WIP is throughput multiplied by cycle time (Hoppe, 2001), while Little's Law for a Kanban team is WIP equal throughput multiply to lead time (Lowe, 2014). Groover (2001) stated that "manufacturing lead-time (MLT) and work-in-process (WIP) can both be determined for a particular production facility". (Groover, 2001) defined that MLT as the total time required to process a certain part or product through the plant; it includes all lost time due to production equipment failures, delays, rework, storage time, etc. Groover (2001) also stated that production usually consists of a series of individual processing and assembly operations and that between the operations are material handling, storage, inspections, and other non-productive activities. Therefore, the activities in production are divided into two main categories: operation and non-operation elements. MLT is the sum of set-up time, processing time, and non-operation time (Groover, 2001) (see Figure1.1). (Warren, Reeve, & Fess, 2004) stated that lead-time, sometimes called throughput time, is a measure of the time that elapses between starting a unit of a product at the beginning of a process and completing the unit of the product; also, the components of lead time are conversion time, wait time, movie time and down time (Warren et al., 2004); therefore, total lead-time is the sum of value-added and non-value added times (Warren, et al., 2004) see (Figure1.1). By focusing on non-value added activities, the production planner can reduce lead-time, thus, the researcher will apply for reducing movie time and down time. This is because the proper approach to reduce MLT is focusing on non-value added lead-time while respecting customer satisfaction.

Therefore, the two main contributions in this thesis will apply and explore the causes of excessive non-value added lead-time such as move time and down time, which will be suggested as practical and inexpensive strategies for reducing MLT. It also should be considered because '90–95% of the time spent in a factory is spent waiting (non-value added lead time)' (HOPP et al., 1990, pp. 78-84; Groover, 2001, p. 24). Therefore the non-operation elements are handling, storage, inspections, and other sources of delay (Groover, 2001) because the activities of production have two main categories: operation and non-operation. Thus non-operation times are a major component of MLT (Groover, 2001). It is important and a reasonable factor that leads to increase manufacturing lead-time and should be considered by practitioners or production planners before making a decision for manufacturing planning in order to reduce lead-time.

The major components of non-value added lead-time are: wait time, move time and down time (Warren et al., 2004) see (Figure1.1); therefore, the manufacturers or practitioners should understand the relationships between operation time and non-operation time in order to find potential methodologies that could reduce lead time in the manufacturing process. There are many methods to reduce lead-time; various methods are described in this research study. There are various methods have been applied by several researchers to reduce lead-time or the components of MLT, as follows: process time, wait time, set-up time and move time. Therefore, reducing manufacturing throughput time can be a daunting task due to the many factors that influence it and their complex interactions (Johnson, 2003).

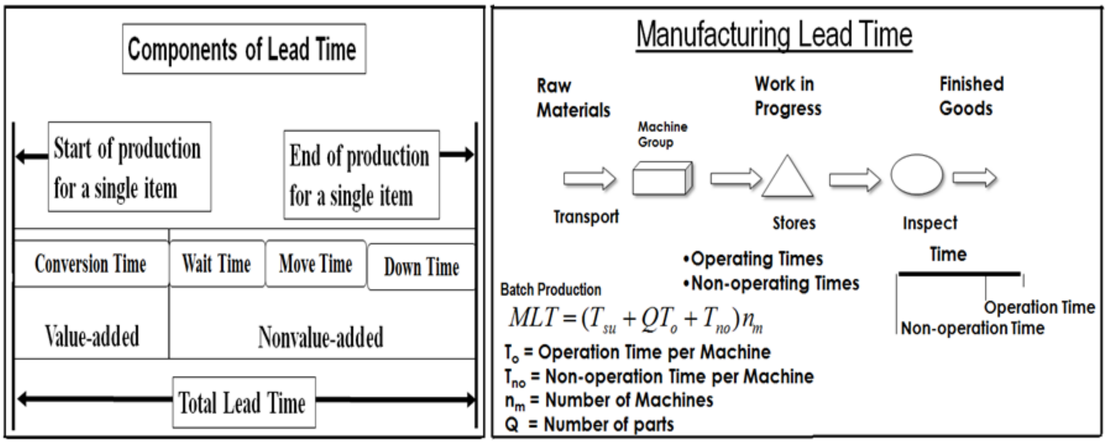

Figure1.1 Components of Lead Time and Manufacturing Lead Time (MLT)

(*Warren, et al., 2004) and (Groover, 2001)*

1.1.2 Statement of the Problem

Most of the factories in the Kurdistan region have maintained high work-in-process (WIP) inventory, leading to long manufacturing lead time (MLT) because they have a poor history of meeting their demand on time, high demand back ordered as well as excessive inventory, due to poor forecasting and scheduling. The MLT and work in process (WIP) were the result of many factors, including manufacturing inappropriate quantities of their products (i.e. little to no forecasting was done), poor utilisation of the machines, running inappropriate lots sizes, and a lack of formal scheduling methodology. Quick response manufacturing (QRM) focuses on reducing lead time in manufacturing operations. Other researchers have defined the time-based competition (TBC) for both concepts and advantages, (Stalk & Hout, 1990; Suri, 2003. Suri (2003) stated that the traditional beliefs about TBC must be replaced by QRM principles; therefore, this study determines the gaps in the literature, which could be identified as follows.

The first is the lack of quantitative studies showing the benefits of TBC and QRM, but using a manufacturing assessment questionnaire is the best research method for designing the survey as face to face for successful in reaching the intended target. Secondly, there are some principles and assessment tools of TBC/QRM paradigms that are rarely studied, such as the principles related to lot size, utilisation under times, available capacity, and performance measures focused on time. The third is that the application of principal and traditional beliefs of TBC/QRM in practice may be risks also QRM was focused on lead time reduction and not on tools and methods; therefore, in order to develop and use performance measures of lead time reduction is critical within the TBC/QRM thus the researcher thought that the proper an effective assessment tool is manufacturing assessment tool which provides a preliminary analysis of a firm’s strengths and weaknesses benchmarked against comparable manufacturing firms.

The study also thought about and asked questions concerning how a manufacturer can find the best alternative method to the principles of QRM—as well as to traditional beliefs for TBC—before reducing lead time. Therefore, the researcher felt that it would be best to start by looking up a manufacturing assessment and consider how to convert a manufacturing assessment into survey questionnaires. What are the simple strategies used before reducing lead time? What kind of steps should be taken into account before reducing MLT? Should all traditional beliefs be replaced by the 10 principles of QRM? Therefore, the research proposed that the quick-view manufacturing assessment is effective assessment tools that can help manufacturers reduce lead time, instead of the 10 principles of QRM. Therefore, a quick view will help manufacturers to better understand the problems and opportunities confronting their operations in order to develop and use performance measures of lead time reduction, which is critical within the TBC/QRM. This research study will convert the principle of QRM to Quick View as a manufacturing assessment questionnaire so that these gaps represent an opportunity for future research.

Why is the survey procedure needed? Because the survey questionnaire will be an expert system-based assessment tool that will provide a preliminary analysis of a firm’s strengths and weaknesses once it is benchmarked against comparable manufacturing firms. Also, it will help to investigate, track (defects and delays), evaluate and measure nine key areas of management for the manufacturing sector to be a focal point for strategic discussion towards reducing MLT.

Material requirement planning (MRP) is a production planning system used to ensure that the parts and materials required are available at the right time in the correct amounts. Beasley (OR-Notes, 2012) demonstrated that MRP should estimate and fix the lead time between releasing an order to the shop floor and producing a finished product. MRP is a technique that assists a company in the detailed planning of its production. Beasley (2012) and Heizer and Render (2008, pp. 560-583) stated that ‘the master production schedule sets out an aggregate plan for production thus MRP translates that aggregate plan into an extremely detailed plan’. Beasley (OR-Notes, 2012) mentioned that the production planner should avoid a stock-out; therefore, Beasley asked the question, ‘in each and every period, should I order in this period and if so how much?’ However, he did not mention that determining the system’s available capacity involves only two related decisions about ordering; in his example solutions, Beasley used lot-for-lot and fixed-period requirement (FPR) techniques for the quantity decision. Both are termed lot-sizing decisions. Also Beasley (2012) did not mention such key issues raised during the manufacturing process in filling an order when production time is greater than demand time.

There are some principles of technical tools that are rarely studied, for example, a lot-sizing technique that is exactly what is required to meet the plan in terms of smoothing the load and minimising the impact of changed lead time include splitting order (lot splitting) when the workload exceeds work-centre capacity, available capacity and performance measures focused on time. Also, gaps in the literature could be identified for finding simple strategies to cope when the production time is greater than the demand time in terms of using time to measure supply chain performance. Hoppe and Spearman (2001) stated that MRP has, for many years, been utilised by businesses to improve production efficiency and product delivery. On the other hand, one of the limitations of MRP has been its deterministic, fixed view of lead time—it does not take into account, for example, the capacity of each factory's machinery. According to Hoppe and Spearman (2001), 'The materials order placement, a fundamental feature of MRP, is most of the time, performed much earlier than necessary resulting in an exorbitant increase in inventory'. In production management terms, this is called infinite capacity scheduling. These shortcomings of MRP have been successfully corrected by finite capacity scheduling, but Hoppe and Spearman (1990) did not mention how to apply this or which technical tools should be used. Therefore, this study will be focused on rescheduling capacity planning, MRP and optimising the current layout strategy, which are potentially needed to create a model in order to develop step procedures with effective technical tools such as lot for lot for lot-sizing decision, splitting the order, managing line (queuing theory) and overall equipment effectiveness (OEE) in order to find sources and causes of delays, to control lead time and to find an opportunity for reducing MLT and move time.

Hopp and Spearman (1990) explored the causes of excessive lead time and suggested practical, inexpensive strategies for reducing lead time. Their recommendations and their systematically-reviewed potential methods for reducing lead time are to reduce mean flow time and/or flow-time variance. The practical strategies presented by Hopp and Spearman (1996) to reduce flow time fall into five general categories: (1) look for the WIP; (2) keep things moving; (3) synchronise production; (4) smooth the work flow; and (5) eliminate variability. However, this leads to the following question: Which technical approach could yield lead time reduction strategies? Thus, the researcher focused on two general areas: keeping things moving faster and eliminating variability (Hopp and Spearman, 1990).

Other researchers have demonstrated that the variability in process times caused by rework, downtime and lack of consistency in production methods increase both mean and the variance of flow time. This brings us to thinking about which kind of technical tool could be used to identify the variable controllable and random variation for process time to failure or time to repair in order to analyse defects to get their root causes which is not mentioned by (Hopp and Spearman, 1990, p.79); this is the 'gap in the knowledge'. Very little research has been done on monitoring the system in terms of the variability, reliability of machines and/or processes and their maintainability, yet they play a crucial role in ensuring that there is no downtime and guarantee the successful operation of production processes. They could be used to determine production availability and to increase speed and quality, as well as monitoring reliability of processes. This will help with the design of a preventative maintenance schedule to keep operational time and the production rate on schedule.

It is not easy to predict the outage of operation time without a reliable reason or evidence. The question is how to monitor manufacturing processes regularly for a period of time in order to check and record the reliability of machinery. This is because measuring the reliability factor is very important to discover the probability that a machine part or product will function properly for the specified time under the stated conditions. Thus, high reliability means no delays or stoppages and less non-operational time. Groover (2001) has stated that MLT is the sum of the set-up time, processing time, and non-operational time; also, less variability will occur to reduce throughput time, so consequently MLT will be reduced.

This research will focus on key performance indicators (KPIs). This is the best technical tool because KPIs such as overall equipment effectiveness (OEE) can identify the root cause of production losses such as: availability, performance and quality loss also allows effective targeting of resources for accelerated efficiency gains and best machine utilisation also can be used to determine equipment reliability, the number of incidents (stoppage), downtime and maintenance cost index. OEE must have a method to measure progress in improving reliability and to set future targets. As a minimum, the plant should be targeting the utilisation factor and the reliability factor. OEE can monitor the system in order to ensure manufacturing processes and that machines are available. This is because availability is an important factor associated with WIP. Little's Law defines WIP as throughput, ‘Although the most of companies track machine availability, some do not track the. The researcher considered how to track root cause of long MLT and production losses, and how they should be identified via a simple strategy prior to the reduction of lead time; this is the best area to research in more depth. Therefore, downtime and availability are important factors that should be considered in order to reduce lead time in terms of non-operational time—one of the main components of MLT. Hopp and Spearman (1990) do not mention the OEE tool for monitoring the system because this is one of the simplest strategies for reducing MLT. The researcher has suggested that this new conceptual framework will contribute to KPI tools, which are the best technical tools for monitoring a system, and for identifying opportunities to reduce lead time, as well as for supporting the production planner to utilise capacity more effectively. This makes it possible to meet the order requirements, leading to production orders being delivered according to the right time schedule. Therefore, a more important, related topic will help us answer our research questions.

This research proposes a study on reducing MLT in factories in the Kurdistan region of Iraq, where lead time has become a major issue in the manufacturing industry. This study deals with a review of various tools and different techniques that are available, and that should be considered in the manufacturing sector to find or suggest practical, inexpensive strategies to reduce lead time, and some of the gaps identified in literature. Various methods have been described by several researchers to reduce manufacturing lead time; therefore they have significant support approach for this research background. The purpose of the review is to develop a framework that enables the discovery of factors that affect MLT, throughput time and various tools and techniques to optimise QRM in order to conduct an analytical investigation into lead time reduction in the manufacturing industry. The aim is to provide guidance to industry practitioners and technicians on how to reduce MLT. For more detail, see section 2.6 (Scope of the Review and Gaps); for aims and objectives with research questions to create a framework see section 2.6.1 (Summary).

Manufacturing lead time reduction is important because lead time has a direct impact on customer satisfaction and also provides a competitive edge for product manufacturing companies. It is, therefore, imperative for any industry to keep improving their lead time, and for a company to offer significantly shorter and more reliable delivery times. However, there is very little research that has been done and no method has previously been published related to MLT reduction based on a dual approach that is both technical and theoretical. This is important for manufacturers to consider; research strategies for lead time reduction in the manufacturing sector is shown in Figure 1.2

The main point is finding a simple strategy for reducing manufacturing lead time based on two of the following questions. What opportunities do manufacturers have to reduce lead times? What major procedures should be considered before reducing lead times?

Research Methodology Strategies:

- **Qualitative research**
- **Quantitative research**

Based on Survey and Case Study Insights to:

- **Developing new methods for reducing MLT**
- **Reducing lead time**
- **Capacity Planning**
- **Providing the guidance for practitioners**
- **Continues improving**
- **Quick defect detection**

Survey questionnaire: Based on manufacturing assessment tool (Quick Review), QRM, TBC and TQM.

Modification: Converting manufacturing assessment questionnaire to survey questionnaire to identify areas of:

- **Capital, Defects, Wasting time and Delays**
- **Current performance of competitive factors**
- **Waste analysis**
- **Areas of improvement**

Manufacturing lead time

Case Study: Batch Production

Based on creating a model of reschedule capacity planning by using several technical tools are: Lot for lot, Splitting order, OEE, Queuing theory (waiting line) and Process-Oriented Layout

Modification: Converting push system to pull system and reducing MRP ‘buckets’ from weekly to daily to perhaps hourly

The aims and objectives are:

- **To utilise the capacity system more effectively**
- **To evaluate and minimize the impact of changed lead time.**
- **To reduce MLT**
- **To reduce move time**
- **To improve demand**
- **To do better forecasting**
- **To minimise machine downtimes and MLT**
- **To investigate non-operation time**
- **To increase OEE**

Figure 1.2 Two research strategies for lead time reduction in the manufacturing sector.

1.2 Aims and objectives

This research aims to assess the issues pertaining to manufacturing lead-time in in the factories of Kurdistan region of Iraq including cause of delays and defects in the production. Additionally, it aims to develop techniques for lead-time reduction through application of assessment survey, capacity planning and key performance indicators aimed at implementation and control of manufacturing processes.

This research will provide simple strategies for reducing manufacturing lead-time because this is particularly important, as it can be used to provide guidance to industry practitioners on how to reduce manufacturing lead time.

The research aims are demarcated to the following objectives:

- To investigate the causes of delays, areas of inefficient management and defects in the current manufacturing process and consider how these impact the manufacturing lead-time.
- To assess the capacity planning process of manufacturing companies at both batch and mass production level.
- To evaluate the various variables associated with production line and their relationship with performance parameters of manufacturing.
- To provide a consistent approach to reducing lead-time in the manufacturing sector encompassing an easy-to-use tool that manager can use to determine a course of action to reduce manufacturing throughput in their production plants.

1.3 Research Hypothesis and Questions

The formulation of the research problem of this thesis is based on problems related to manufacturing lead time and quick response manufacturing. Understanding the current state of the manufacturing and the emerging opportunities to improve manufacturing lead time and delivery date, the study established and proposed the following two hypotheses for this dissertation:

‘A significant opportunity exists to reduce the manufacturing lead time in the manufacturing sector with the application of survey questionnaires to provide

guidance to the industry practitioner on how to reduce manufacturing lead time, in order to provide products and services to the customers more quickly'.

Based on the first hypothesis of this research developed the following general research questions:

- What opportunities do manufacturers have to reduce lead times?
- How can we systematically review the potential methods for reducing lead time?
- What major procedures should be considered before reducing lead time?

The above questions are designed to illustrate these problems more clearly through a comparison between the literature and the survey questionnaire.

'A significant opportunity exists to reduce the manufacturing lead time in the manufacturing sector with the implementation of various tools and techniques in order to provide products and services to customers more quickly'.

Based on my second hypothesis, the researcher developed the following general research questions:

- How can manufacturing companies make use of different bundles of manufacturing practices or different technical tools to develop certain sets of capabilities, with the ultimate goal of delivering orders to the customer?
- What is the proper tactic for smoothing the load and minimising the impact of a changed lead time?

These questions are designed to utilise the capacity system more effectively and still meet the order requirements or customer demands, as well to smooth the load and minimise the impact of a changed lead time, which will, consequently, reduce the delivery time towards achieving lead time reduction.

- What is the best technical tool that should be available for the task of monitoring the system in order to reduce lead time and variability?
- How can practitioners eliminate variability to support their plant to achieve better performance?

These questions are aimed at determining the availability of operation time, the number of stoppages, MTBF and downtime loss, and also to identify performance (speed loss) and reliability of machines and equipment towards achieving MLT reduction.

1.4 Key contributions

This thesis contributes to the existing body of knowledge by taking a novel perspective on manufacturing lead time and different operational performances. This study provides an easy-to-use tool that managers can use to determine a course of action to reduce manufacturing throughput in their own plants as well as this study provides the major procedures should be considered before reducing lead time.

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The main contributions of this thesis are highlighted below:

- A thorough review of current manufacturing lead-time, tools and techniques being practiced in the manufacturing companies of Kurdistan, Iraq is carried out. This work provides a review of issues existing in a geographical area of Iraq on which past literature does not reflect in depth, which is valid in general. The gap in past literature is bridged through complete analysis of issues pertaining to the manufacturing processes.

- Development and application of methods for lead time analysis including design of panel data sets and identification of value addition points throughout the process.

- The development of a comprehensive conceptual framework focusing on quick response manufacturing both at batch and mass production level. The framework is a contribution to academic knowledge.

- Identification of the variables in business environment which may need changes to positively reflect firm-level productivity and manufacturing lead-time.

- Contribution to research and development referring to the need for strategic planning of companies to improve manufacturing performance and discovering solutions to existing problems associated with lead time and capacity planning.

Scope of research strategy

1-The principles of survey questionnaires as a face-to-face procedure were applied as well as the survey form designed and published in Web Google Docs. Survey will identify to: staff opinion, monitoring, tracking defect detection, the causes of variability in manufacturing lead time, the characteristics of the factors have a great impact on MLT, sources of delays, symptoms and problems in the eight factories of Iraq have been carried out. Moreover, the practical methods and workshops involve visiting the factories, watching the production line and learning of the current situation in the factories, and then analysing a practical and theoretical approach. Proper decisions about the guidelines for solving the defects, problems and reducing MLT have also been carried out. The modification for this study's survey was by converting manufacturing assessment (Quick View) to a survey questionnaire.

A. This Quick view approach was developed in 2001 by TDO solution for manufacturing and technology in USA then published in Quickview@tdo.org and also TDO solutions (2014). The effects of the application of principles and traditional beliefs of time based on competitive (TBC) and quick response manufacturing (QRM) in this survey questionnaire are considered. This research method was published as a technical report for the Centre for Quick Response Manufacturing, May 2003 in the USA by Suri (2003).
B. This approach leads to identify those areas of operation management which may need some attention. It is critical within the TBC/QRM in practice may be risked without manufacturing assessment tools (Quick View) in this research survey. This is one of the alternative approaches in this research study that has been applied. The survey was properly designed and has a uniform sampling methodology, which provides a preliminary analysis of a firm's strengths and weaknesses benchmarked against comparable manufacturing firms out.

2-Research methodology strategies are based on dual approach of qualitative research and quantitative research studies, which are surveyed, and case study have been applied. This is a hybrid exploratory-explanatory approach to balance theory with practice. This combination method enhances validation and verification of the collected data and hypothesis.

A. The case study was designed and located in a plastic pipe factory, the interview was face-to-face and workshop procedure has been carried out. The case study uses an interpersonal interaction to elicit answers pertinent to the research hypothesis by creating a model that provides the production planner to move the work between the time period to smooth the load, or at least to bring the manufacturing system within capacity. The determination of an accurate capacity plan and lead time estimates were done by using lot splitting as a tactic for smoothing the load, reducing the impact of changed lead time, reducing MLT, improving delivery date adherence out as well as utilising capacity more efficiency to meet the order requirements
B. Reducing MRP 'buckets' from weekly to daily under the capacity available (minutes) has been made. This approach is proved analytically—lot splitting improves the reliability of delivery for the supplier, and hence, the production schedule stability of shipping to customer. Estimation for delivery reliability in terms of a lot splitting policy and system characteristics has been carried out. This is one of the modifications for this model that was applied.
C. Changing the production system from a push system to a pull system was applied. Using lot-sizing decisions to change the fixed period requirement (FPR) to the optimal size of lots, such as lot-for-lot technique has been carried out. A lot-sizing technique used to meet the plan also to reduce MLT. Capacity planning and designing a work balance chart have been carried out. These are two of the modifications for this model that have been applied.
D. Validation and verification of the system have also been carried out by using two technical approaches involve in queuing (or waiting line model) and overall equipment effectiveness (OEE). The OEE reduce complex production problems into a simple, intuitive presentation of information and help the manufacturer systematically to improve the process and manufacturing lead time with easy-to-obtain measurements. OEE is monitoring the system and the effects of random variation in manufacturing processes as well as tracking defects were demonstrated. This was done through technical indicators such as key performance indicators (KPIs) such as OEE. This approach is similar to what was published in Manufacturing Review (Hopp and Spearman, 1990; 3(2),78-84) demonstrated practical strategies for lead time reduction but Hopp and Spearman (1990) did not consider the OEE tool

for monitoring the system. It is one of the simplest strategies for reducing MLT in term of reducing variability in the manufacturing process. Also Hopp and Spearman (1990) did not consider how to determine the downtime and manufacturing performance through monitoring the system reliability for improving machine and equipment reliabilities for the purpose of defect prevention.

E. This approach is similar to published papers for operation research (OR-Notes); there are a series of introductory notes (OR- Notes) at the Brunel University presented by professor Beasley (2012) in term of MRP and lot-sizing decisions. He did not consider or apply the logic of lot splitting in order to smooth the load and minimise the impact of changed lead time. Also he did not consider how to utilise capacity more efficiently to meet the order requirements for the available capacity of the system.

F. Optimising the current layout was to reduce move time by reducing move distance. This proposed procedure leads to reduce MLT. While this approach was published in the *Journal of Manufacturing Systems* (Johnson, 2003;22(4),283-298) for reducing manufacturing throughput time, but he did not consider how to reduce move time in practice.

1.5 Outline of Thesis

The rest of the thesis is organised as follows. Chapter 2 provides a review of the relevant literature, including a definition of manufacturing lead time, characterisation methods for lead time, an assessment of review on manufacturing lead time formulation, the role of QRM system dynamics on reducing lead time, the factors determining flow time, scope of the review and gaps for further study. Chapter 3 describes how the research methodologies of manufacturing lead time reduction will be achieved—a survey questionnaire and case studies based on this research study. How to use the various technical tools and practical, inexpensive strategies that could benefit an investigation of manufacturing lead time reduction is discussed; also the samples, measuring instruments and several statistical approaches to the acquired data, and the validity and reliability of the analysis are described. Chapter 4 describes the survey questionnaire as a conceptual framework in this research study, describes several statistical data analyses, and how this approach will provide a preliminary analysis of a firm's strengths, defects and weaknesses. Also identified are those areas of plant operation that may need some attention, and the non-technical parts of an operation may be impede growth and competitiveness are described. Chapter 5 presents a case study of the ZX plastic pipe factory, describes the effectiveness of designing the capacity planning for accurate capacity planning and how lead time will be improved, describes different tools for smoothing the load—thus reducing the impact of a changed lead time, and improving delivery date adherence—as well as how to utilise capacity more efficiently to meet the order requirements, also describe the role of overall equipment effectiveness (OEE) for monitoring the system and investigating on down time, defects, reliability factor, utilisation factors, the number of stoppages and identifying the root cause of production losses , also describe the role of hypothetical transactions on reducing move time . Chapter 6 presents conclusions, including a summary of research findings, that show the main contributions, and discusses possible directions of future work.

Chapter 2- Literature Review

This chapter provides a review of the current literature relating to lead time. This literature review is a survey of everything that has been written about lead time and throughput time. The purpose of the review is to develop a framework that will enable the identification of the factors that affect manufacturing lead time and throughput time and the various tools and techniques that can be used to optimise quick-response manufacturing.

2.1 Introduction

Why are most companies concerned with reducing lead time? Primarily, because it is the major measure of the effectiveness of systems; short lead times have value to certain customers and are a major source of potential competitive advantage.

According to Gaither and Norman (1994), “The main focus of companies in the 20th century was the customers. It has become more and more competitive to satisfy customers).” More recent research by Kuhlang et al. (2011) suggests that the redesign of assembly workplaces or workstations and the redesign of production logistic processes will have an impact on reducing inventory/lead time. Johnson (2003) summarises the problem: “the process for manufacturing throughput time reduction can be a daunting task due to the many factors that influence it and their complex interactions”. Shorter lead times mean improved customer service, a smaller inventory and higher efficiency. Setup, process, waiting (non-operation) and move time reduction in the manufacturing process are areas that can be focused on to identify efficient ways of reducing lead time, enabling a quick response to customers or an efficient approach to reducing throughput time. Reductions in manufacturing throughput time can generate numerous benefits, including lower work-in-process and finished-goods inventory levels, improved quality, lower costs, and reduced forecasting errors.

In the last two decades, a spate of programs has been developed by industry; all aimed at reducing inventory levels and lead time and increasing efficiency on the shop floor. These suggest some of the key factors that should be considered in MLT and using proper basic principles for reducing time in the manufacturing process, as well as reducing work in process (WIP) and throughput. If applied correctly, these programs can be used to reduce MLT by identifying the action that can be taken to alter the relevant factors and their interactions. This will lead to the definition of specific problems and the identification of the sources and causes of delays; the central research question(s) can be derived from these. Johnson (2003) has stated that the basic factors that determine MLT or throughput time must be clearly understood.

This research has provided a broad and specific review of the issues related to MLT reduction and/or throughput time reduction for manufacturing systems. The main objectives of this research paper are reducing time and identifying simple strategies for reducing lead time. This research is detailed enough to provide guidance to the industry practitioner on how to reduce manufacturing throughput time, while being general enough to be applicable to most manufacturing situations. In addition, new possible methodologies are discussed in later sections.

2.2 Lead-Time Reduction Review

A frequent complaint of customers among all business lines is failure to complete the product or service by the date provided. Without a clear understanding of the lead time required to produce a product or service, you can’t run your business. The problem of most organisations is that the time taken to procure, make and deliver a product is longer than the customer will wait. Also, manufacturing practices and processes have come under increased pressure from global competition. Demands for improved customer service, increased breadth of product line, improved quality, quicker response time, and shorter time to market for new product introductions cannot be ignored by firms. So, this is the key to thinking about how to reduce lead time.

Lead time is the time between customers placing an order and the time when they receive the finished product (Gaither, 1994). Silver et al. (1998) state that lead time is the time that elapses between the placement of an order and the receipt of the order into the inventory.

The area of lead-time reduction is made up of several components (process, moving, waiting, setup, lot size, and rework time), most of which should be treated as controllable variables in our study. It is necessary to use game theory to analyse lead-time reduction. For example, in an early paper, Gerchak and Parlar (1991) assumed that lead time is random and analysed the problem of investing in reducing lead-time randomness (for similar models, see Gerchak (2000) and Ray et al. (2004)). New research shows the relation between customer order lead time-based decisions and potential sources of competitive advantage, which can, according to Petri (2012), be described as “the impact of customer order Lead Time-based decisions on the firm’s ability to make money”.

Lead time has a strong relationship with WIP, utilisation and process time. The relationship between key logistical figures, like WIP, lead time, utilisation, finished goods inventory and service level, is addressed by many authors. A good understanding of the relationship between the logistical figures and understanding their influence on the deviation of processing times, lead times and inventories on the performance measurements is crucial to finding the right mix of logistical objectives. Ketokivi and Heikkila (2003) propose that strategic objectives derived from the market should be the basis for the necessary trade-off between conflicting logistical goals, such as high utilisation versus low WIP, while Hopp and Spearman (1996) have shown that lead time is an increasing function of the WIP.

In addition, they have developed bounds describing the best and worst cases for the actual lead time. Likewise, Spearman et al. (1990) defined the service level as the fraction of jobs whose actual lead time is not greater than the planned lead time. Hopp and Spearman (1996) present a good overview and summary of the relationships between the logistical figures in inventory, utilisation, lead time and service level. Furthermore, responsiveness has a conceptual relationship with lead time. Fengqi and Grossmann (2008) described their model for design-responsive supply chains under demand uncertainty and defined the probabilistic model, which suggested that reducing lead time will increase the responsiveness of supply-chain systems (see Figure 2.1).

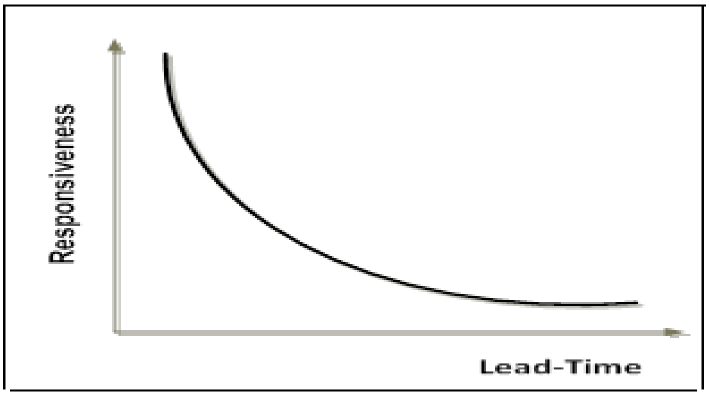

Figure 2.1 Conceptual relationship between lead time and responsiveness

(Fengqi & Grossmann, 2008)

The outline shows that customer orders have a major impact on lead time, determining lot-size decisions. With their complex interactions throughout the manufacturing process, these can be considered an important factor that can be used to find the quickest guidance on reducing time in WIP. The research procedure should be applied to more studies to identify simple strategies for reducing lead time, because lead-time reduction can be a daunting task due to the many factors that influence it and their complex interactions. Therefore, very little research has been done that relates to MLT, especially in terms of the quickest guidance for reducing time.

2.3 Lead Time and Time Based (QRM)

QRM focuses on reducing lead time in manufacturing operations. Other researchers defined the time-based competition (TBC) advantage in this concept, which was documented by several US authors (Stalk, 1988; Schmenner, 1988; Blackburn, 1991; Charney, 1991; Stalk & Hout, 1990). They studied TBC at the end of the 1980s (Suri, 2003; Richard J. et al., 1995). Suri combined academic research on TBC and his own observations from various lead-time reduction projects.

QRM dates back to the 1980s. Its roots, as well as the roots of lean production and TBC, can be found in total quality management (TQM). The main difference between TBC and QRM is that whereas TBC strategy can be applied to any businesses, QRM is most effective in manufacturing operations that make a large number of product specifications with low-volume and highly variable demand, and/or highly engineered products produced in small batches, or even one-of-a-kind products. QRM thus sharpens the focus of TBC (Suri, 1998). “QRM is a companywide strategy that pursues the reduction of lead time in all aspects of a company’s operations” (Suri, 2004). Richard J. et al. (1995) have stated that lead-time reduction strategies are responses to numerous logistical chain problems, such as procurement, manufacturing and distribution problems. According to Hopp and Spearman (2000), global competition comprises three main competitive dimensions: cost, quality and speed. “These three competitive dimensions are broadly applicable to most manufacturing industries but their relative importance obviously varies from one firm to another.” Historically, manufacturers and distributors have been plagued by procurement problems that prohibit efficient capital employment. Perry (1990) and Wieters (1979) report that procurement lead times are a significant source of excessive lead times. In fact, Wieters found backlogged suppliers to be the major market factor contributing to lead-time problems. This procurement bottleneck limits the ability of firms to decrease MLTs. O’Neal and Bertrand (1991) noted that a significant factor hindering the effective employment of just-in-time strategies is the inability of suppliers to operate in a just-in-time environment. Petri (2012) and Kuhlang et al. (2011) stated that the most significant development to come out of QRM is the use of applied statistics to gain an understanding of how particular characteristics—such as process variability, arrival time variability, and queuing theory—impact upon a given system or process. They refer to Suri (2004), who focused more on QRM.

QRM Principle 1: Suri tried to find entirely new ways of completing a job, with a focus on lead-time minimisation. Figure2.2 shows the typical progress of an order through a company, identifying the 'touch time' (when someone is actually working on the job) as compared with the elapsed time. Figure2.2 shows that touch time accounts for just 2.5 hours out of 34 days. The rest of the time is the 'white space' in the diagram, where nothing is happening to the job. Traditional approaches focus on reducing the touch time (grey space), while the QRM approach focuses on reducing the total elapsed time. Suri mentioned, however, that our organisations are not designed to manage this total elapsed time. "Organizational structures, accounting systems, and reward systems are based on managing large scale operations and minimizing local cost" (Suri, 2003). The main objective of this research study review should be to explore more specific studies on those component areas, such as the fabrication and assembly process at the work station, with the goal of reducing throughput time in the manufacturing industry.

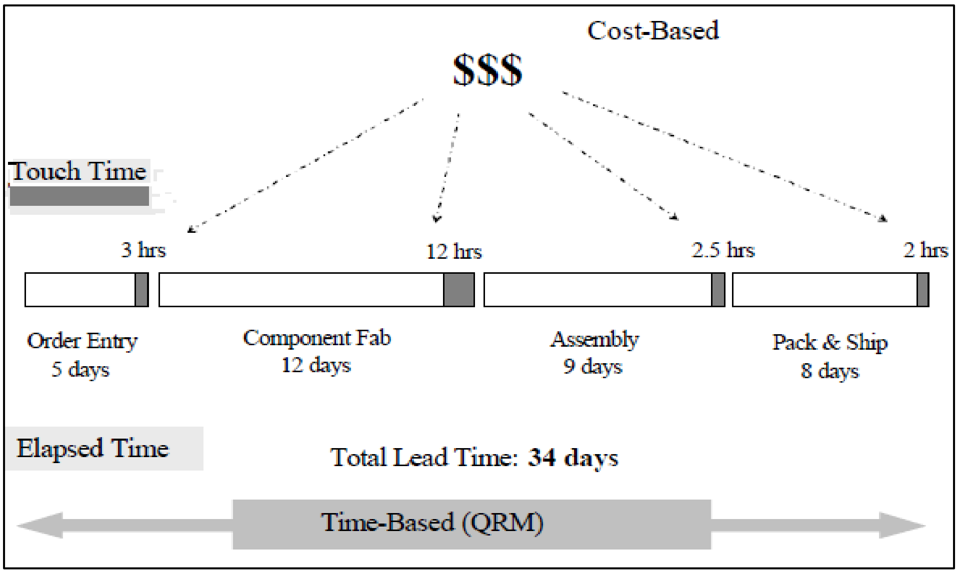

Figure2.2 Comparison of cost-based and time-based (QRM) approaches

(Suri, 2003)

2.3.1 Manufacturing Lead Time and the Principles of QRM System Dynamics

Manufacturing companies are trying to reduce their lead times, also the role of Lean Manufacturing is very important because Lean Manufacturing is a systematic approach for achieving the shortest cycle time and lead time as well as Lean manufacturing is a process management philosophy, also called Lean Production ((Heizer & Render, 2008). “Lean production system aims to produce products or services through using the minimum levels of everything such as minimum capital investment, minimum human efforts, and minimum wastes. The key element of the lean strategy is to develop learning system that has the ability to identify and distinguish between the value-added activities and wastes. Lean philosophy aims at enhancing the flow- rate of materials by eliminating or minimising the non-value added activities” (Groover, 2001) and (Heizer & Render, 2008).
Suri, Director of the Centre for QRM at the University of Wisconsin–Madison. In the last technical report from the Centre, dating to May 2003 (Suri, 2003), he gave an overview of the QRM principles and explained the POLCA system. Suri has shown that while manufacturing companies are trying to reduce their lead times, most managers still support policies that increase their companies’ lead times.

Suri investigated why, for 21st-century markets, lean manufacturing principles do not work well. He explained that those characteristics are used by QRM to develop a concept called ‘system dynamics’ to describe the underlying principles that govern how a particular system works. Particularly significant is that QRM uses this technique to understand how multiple factors interact; for example, the impact of lot sizes on lead time (Suri, 2003).

QRM can be predicted by the material requirement planning (MRP) system because QRM integrates well with other process improvement techniques. Many other organisations can also benefit from these concepts. Therefore, this research will focus on factors such as how lot sizes impact on lead-time reduction. Most researchers in the last decade studied how QRM builds upon and extends the techniques developed in numerous other process improvement methodologies that have come before it, such as TQM, lean manufacturing, re-engineering, constraint management, and Six Sigma. It will most likely be the foundation for the body of knowledge that will ultimately form the agile or flexible manufacturing methodology.

Key QRM characteristics were explained by Petri (2012) and Kuhlang et al. (2011), and were referred to at the annual meeting of the General Electric Company, as reported by Chet Kagel (1999). These characteristics focus on aspects of lead-time reduction, and include:

(a) A singular focus on lead-time reduction.
(b) Utilises a continuous improvement cycle.
(c) Utilises applied statistics to analyse variability in process, arrival and departure times.

Many of the quantitative models focus on the effects of lead-time reduction on operational decisions, such as batch size and quality. Karmarkar (1993) states that demand is typically assumed to be an exogenous parameter. So, it is very important to study the factors in that field in order to find quick guidance on how to reduce flow time in a manufacturing process.

Figure 2.3 and Suri (2003) showed that the traditional performance measures of utilisation and efficiency encourage managers to maximise resource utilisation, and only think about their capacity limit as a boundary between feasible and infeasible production targets, as shown in (a), and to run large lot sizes, as in (b). With QRM's focus on reducing lead time, it is important to understand the impact of utilisation on lead time (c), as well as the effect of lot size on lead time (d). QRM theory includes the fundamental principles of manufacturing system dynamics that provide insights such as these about the impact of management policies on the enterprise's lead time. So, managers need to have basic knowledge of manufacturing system dynamics to understand the impact of their policies on lead times. Figure 2.3 shows that one of the principles of QRM was to measure the reduction of lead times and performance measures and to eliminate traditional measures of utilisation and efficiency.

QRM achieves these lead-time reductions and other results through detailed management principles, manufacturing methods, analysis techniques and tools that use basic concepts of system dynamics, and a step-by-step methodology. In addition, QRM puts a great deal of emphasis on creating the mind-set of pursuing lead-time reduction (Suri, 2004).

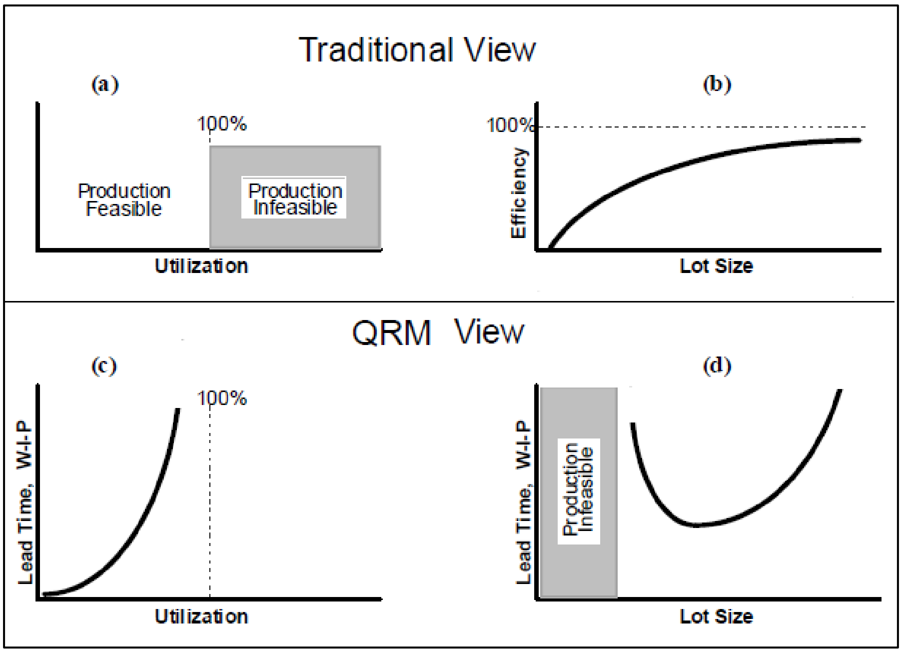

Figure 2.3 Traditional versus QRM views of capacity and lot sizing

(Suri, 2003)

Porteus (1986) and Rosenblatt and Lee (1986) were among the first who explicitly elaborated on a significant relationship between quality imperfection and lot size. Keller and Noori (1988) extended Porteus's (1986) research to a situation where the demand during lead time is probabilistic and shortages are allowed. Hwang et al. (1993) studied multiproduct economic lot size models in which setup reduction and quality improvement can be achieved with a one-time initial investment. Before 1980, customers tolerated long lead times, which enabled producers to minimise product costs by using economical batch sizes. Later, when customers began to demand shorter lead times, they were able to get them from competitors. This is when problems arose and companies started to seek changes to become more competitive (Hwang et al., 1993). In an attempt to reduce lead time, businesses and organisations found that in reality 90% of existing activities were non-essential and could be eliminated. Kuhlang et al. (2011) and Jodlbauer (2008) described how the fluctuations and disturbances of real systems in that article may be used for research, teaching, and private study purposes; for example, a time-continuous analytic production model for service level, WIP, lead time and utilisation. Vaughan (2006), in his most recent research, stated that lot size has a substantial impact on manufacturing process time reduction as follows: lot size affects process lead time, lead-time demand, and safety stock.

Therefore, factors including lot size, utilisation, setup and transfer batch size are important and will provide quick guidance to the industry practitioner on how to reduce manufacturing throughput time. Consequently, these factors need to be studied further because, if applied as a quick solution and correctly, they can be used to reduce MLT in order to identify the action that can be taken to alter the relevant factors and their interactions. This will lead to a specific problem definition and the identification of the sources and causes of delays.

2.4 Manufacturing Lead-Time Formulation

Production consists of different processing and assembly operations. Between the operations there are tasks related to material handling, inspections, and other non-productive activities. MLT is the sum of setup time, processing time, and non-operational time (Groover, 2001). Therefore, production activities are divided into two main categories. In addition, the operational and non-operational elements in those categories were explained further by Fahimnia (2007).

$$MLT = \sum_{i=1}^{n} (\boldsymbol{Tsui + Q\,.Toi + T\,noi}) \ldots\ldots\ldots \textit{(1) (Source: Groover, 2001)}$$

Where:

T_{su} = setup time for each process

T_{o} = operation (processing) time per item per process

Q = batch size

T_{no} *= non-operational time (waiting time) for each process*

n = number of processes needed to manufacture the product

Groover (2001) explained that the summation process in the previous equation (1) can be transformed into the following multiplication process:

$MLT = n \cdot (T_{sui} + Q \cdot T_{oi} + T_{noi})$………….. (2) *(Source: Groover, 2001)*

Looking for (T_{no}) non-operational time means there is a waiting time with two components: wait-for-parts time and wait-to-move time (Hopp & Spearman, 1990). Waiting time is the main factor that can be reduced in order to reduce manufacturing throughput time. This indicates that the "Waiting time is the sum of the queue, wait-in-batch, wait-to batch, times at all workstations in the production routing for the part" (Johnson, 2003). In addition, Groover (2001) and Fahimnia (2007) have defined product lead time (PLT) as the total time that is required to design, plan, control and process a given product through the plant. This is the sum of design time, manufacturing planning time, manufacturing control time, and MLT (Groover, 2001; Fahimnia, 2007). This can be expressed as:

$PLT = T_{PD} + T_{MP} + T_{MC} + MLT$………….. (3) *(Source: Fahimnia, 2007)*

Where:

PLT = product lead time

T_{PD} *= product design time*

T_{MP} *= manufacturing planning time*

T_{MC} *= manufacturing control time*

MLT = manufacturing lead time

Fahimnia (2007) explained that the total time of each phase is the amount of time that each function takes to complete its part of the job for a given product.

MLT is one of the major components of PLT and it has an important relationship with PLT, because a short PLT reduces the manufacturing plant's dependence on forecasts and allows the plant to operate using short-term planning. This consequently creates a more accurate master schedule (Fahimnia, 2007; Salomone, 1995). The operation is no longer separate from process design, as reducing PLT will also improve QRM (Fahimnia, 2007; Groover, 2001). Also, $T_{\mathbf{PD}}$, $T_{\mathbf{MP}}$ and $T_{\mathbf{MC}}$ should be controlled by an accurate process for each step of processing (Groover, 2001; Charny, 1997). For example, in his research for analysing and formulating PLT, Fahimnia assumed that the following data is available from a manufacturing company's current operations and calculated the PLT for a company producing three similar products throughout the year (Fahimnia, 2007).

Table 2.1 Calculations for MLT and PLT *(Fahimnia, 2007)*

Time Per Item	Value	System (Lead Time) h	Value
Processed through an average of six machines (n)	6	Manufacturing lead time (MLT) (hours/item)	4.2
Average setup time is by h (T_{sui})	5	Product design time (T_{PD}) (hours/item)	0.036
Average batch size is by parts	25	Manufacturing control time (T_{MC}) (hours/item)	0.2
The average operational time is min per item (T_{oi})	6	Manufacturing planning time (T_{MP}) (hours/item)	0.014
Average non-operational time is by h (T_{noi})	10	Product lead time (PLT) (hours/item)	
MLT = (5 + 25 *(6/60) +10) *6 = 105 hours/(25) batch by hours/item	4.2	PLT = T_{PD} + T_{MP} + T_{MC} + *MLT* (PLT = 0.036 + 0.014 + 0.2 + 4.2)	4.45

Therefore, we must try to find out why MLT is one of the main components of PLT that should be reduced in the manufacturing process. Is MLT an indicator for PLT? In order to understand these questions, consider (Figure2.4). The company produces three similar products throughout the year, and the assumption is that all the operational times, setup times, and non-operational times are equal for each manufacturing process. This research deals with the key methods for reducing lead time for those components of MLT that can lead to reduced lead time in the manufacturing industry, assuming that the values of PL and MLT are available from Table 2.1. For instance, if you put PLT and MLT into a single pie chart, MLT will comprise 49% of the whole pie chart (for more details, see (Figure2.4). Table 2.1 also shows that MLT will take up 94% of the duration time of PLT (refer to Equation 3), such as: 4.2/4.45*100. This has been supported by several authors, as a major portion of the time is non-operational time because it depends on an average batch size, which is determined by parts. Thus, previous researchers have stated that this is particularly important, since 90–95% of the time spent in a factory is spent waiting (wait time) (Hopp & Spearman, 1990). Also, in reality 90% of the existing activities are non-essential; for example, queue time and waiting time could be eliminated (Kuhlang et al., 2011). Therefore, the MLT is an indicator of production time, and a high MLT implies a higher PLT.

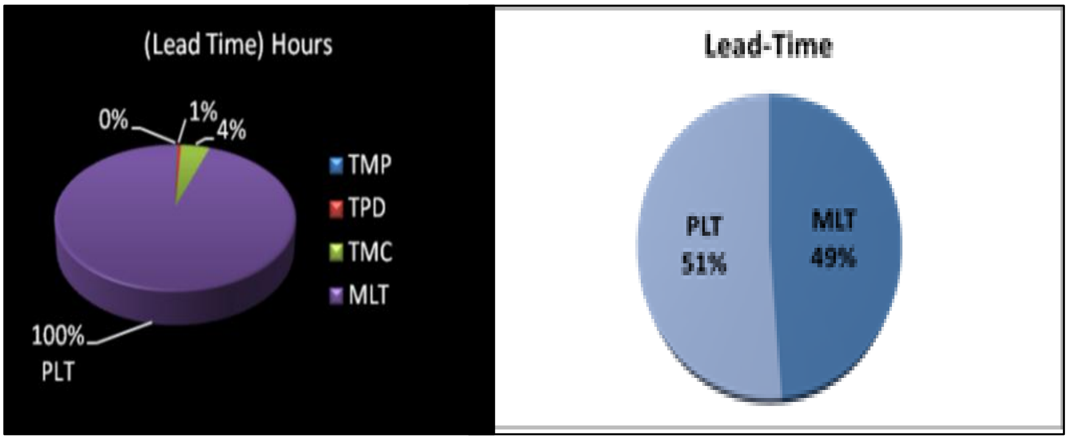

Figure2.4 Approximate contribution of MLT through the PLT elements

Today, more companies are using software that could be applied to lead-time calculation to support manufacturing systems. “Reducing manufacturing lead times and minimizing (WIP) are the cornerstones of popular manufacturing strategies” (Yang & Benjaafar, 2001). Calculating lead time in Oracle e-business R11 will yield more details about how to use that software. For example:

Fixed lead time = completion date (of one item) - system date.

Variable lead time = [(completion date - system date) (rate) - fixed lead time] / lead-time lot size. More details are shown in Figure 2.5:

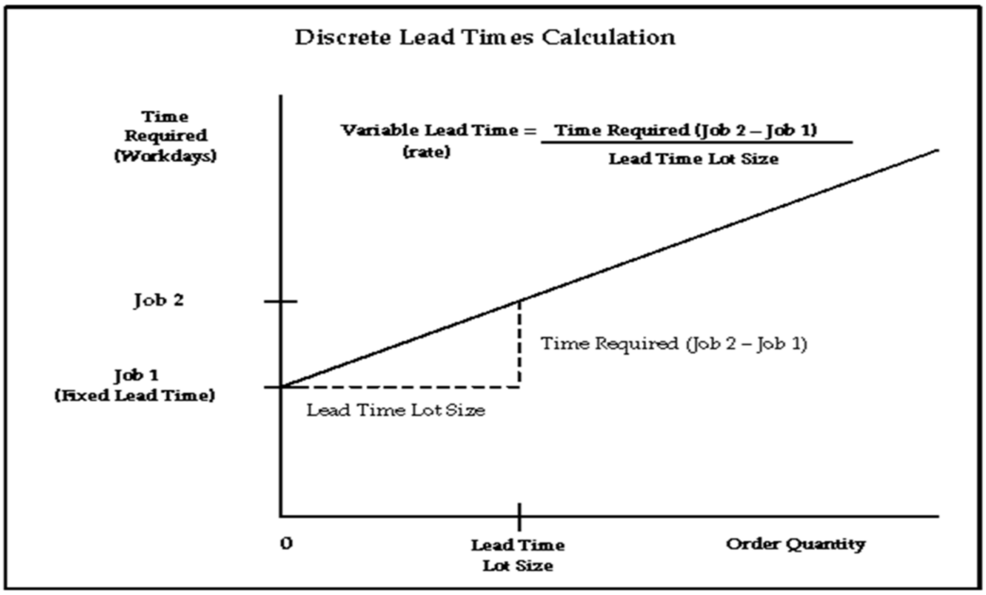

Figure 2.5 Lead-time calculation.

(Oracle, 2012)

The most important factors that can contribute to MLT reduction and should be reduced are process time, setup time and waiting time, for these factors influence manufacturing throughput time. Therefore, this research review will try to assemble a quick guide for reducing flow time or reducing WIP as a function of time, describing the actions that can be taken to alter each factor and their interactions. As customers are concerned with the response time to their order, more specific studies are needed to investigate this. In addition, that research first uses a simple hypothetical manufacturing system to illustrate the basic factors that determine MLT and explain why each factor occurs. The aim is to make a tutorial that could be used to train workers in these basic concepts. The new potential methodologies are discussed in later sections.

2.5 The Factors Determining Flow Time

This research review aims to identify simple strategies for reducing lead time, as well as acknowledging throughput time reduction, in order to find those factors that have a relationship and can reduce lead time. Many companies, specifically those in the service and make-to-order manufacturing sectors, are adopting the strategy of advertising a uniform delivery time for all customers. During the past decade, practitioners have focused on speed as the basis of competitive advantage (Saibal & Jewkes, 2004). The main strategies fall into categories such as process time per part, variability, setup and move time, waiting time, production and transfer batch sizes, and resource utilisation or resource availability. More researchers have described using a shorter flow time for lead-time reduction (Kwan et al., 2013; Petri, 2012; Kuhlang et al., 2011; Suri, 2004). A shorter flow time, especially on the production side, has been described by Hopp and Spearman (1990) and Fahimnia (2007), who have mentioned that the shorter MLT presents an opportunity for a shorter flow time via the following procedures:

- Improve quality management by reducing the opportunity for work to be damaged and shortening the time between manufacturing and defect detection.
- Reduce in-process inventories.
- Decrease disruption of the production process due to changes to engineering orders.
- Enable shorter frozen zones in the master production schedule, thereby reducing dependence on distant forecasts.
- Allow easier overall management of the facility because there will be fewer jobs to keep track of and fewer special cases (e.g. expedited jobs) to oversee.

In terms of flow time, Hopp and Spearman (1990) state that flow time has several components:

Flow time = *run time* + *setup time* + *move time* + *queue time* + *wait-for-parts time* + *wait-to-move time*

Several authors have tried to reduce flow time in the manufacturing process (Kwan et al., 2013; Yang & Benjaafar, 2001; Johnson, 2003; Fahimnia, 2007), but the best examples capable of identifying those components that have the greatest role in flow-time reduction have been mentioned by several of the authors above. They are as follows:

Run time is the total processing time at work centres required to complete the job. Setup time is the sum total of all of the internal setups involved in processing the job.

Move time is the time required to move the job between work centres.

Queue time is the time spent waiting in line for work centres to become available.

Wait time has two components: *wait-for-parts time*, which is the time spent waiting for other subassemblies so that an assembly operation can begin, and *wait-to-move time,* which is the time spent waiting for the other parts in a batch to be completed so that the batch can be moved to the next work centre. Note that a job waiting for a resource to be used to accomplish the move, such as a forklift, does not incur wait-to-move time in our terminology (Johnson, 2003; Karmarkar, 1987; Hopp & Spearman, 1990).

These authors described that situation as being exactly analogous to waiting for a machine for processing and hence are appropriately included in queue time. But the variability and the level of utilisation of those two factors will contribute to flow time and will occur during the manufacturing process. Johnson (2003) has defined them and shown that reducing manufacturing throughput time can be a daunting task due to the many factors that influence it and their complex interactions. Table2.2 outlines the previous research on MLT or throughput-time reduction factors.

Table2.2 Previous researches on lead-time and throughput-time reduction factors

Factors	References
Setup time	Kwan et al. (2013), Rahul & Naik (2012), Kohn & Rose (2011), Lixia & Meng (2010), Bernardo Villarreal (2010), Allahverdi & Soroush (2008), Mehmet & Mahmut (2007), Johnson (2003), Villarreal et al. (2002), Hopp & Spearman (2001), Suresh & Meredith (1994), Yang & Jacobs (1992)
Processing time & Lead time	Kohn & Rose (2011), Kuhlang et al. (2011), Fahimnia et al. (2007), Mehmet & Mahmut (2007), Vaughan & Timothy (2006), Johnson (2003), Cakanyildirim et al. (2000), Koppa & Doegeb (1996), Erik et al. (1996), Spearman et al. (1990)
Move time	Heizer, J. and Render, B. (2008) , Hopp & Spearman (2004), Johnson (2003), Yang & Benjaafar (2001), Hopp & Spearman (2001), Shafer & Charnes (1995), Suresh & Meredith (1994), Karmarkar (1987)
Production batch size and transfer batch size	Kwan et al. (2013), Simons et al. (2012), Kohn & Rose (2011), Kuhlang et al. (2011), Vaughan & Timothy (2006), Bo Chenet et al. (2006), Cakanyildirim et al. (2000), Hariga (2000), Askin & Madhavanur (1998), Erik et al. (1996), Eleni et al. (1994), Suresh & Meredith (1994), Chand (1989), Keller & Noori (1988), Karmarkar (1987), Porteus (1986), Rosenblatt et al. (1986)
Arrival variability and process variability	TDO solutions (2014),Kohn & Rose (2011), Stephen et al. (2008), Hopp & Spearman (2004), Johnson (2003), Hopp & Spearman (2001), Gaither & Norman (1994), Suresh & Meredith (1994)
Resource utilisation and/or resource availability	TDO solutions (2014) , Altendorfer & Jodlbauer (2011), Jodlbauer (2008), Fahimnia et al. (2009), Yang & Beibei (2008), Jodlbauer (2005), Hopp & Spearman (2004, 2001, 2000), Johnson (2003), Yang & Benjaafar (2001)

According to Petri (2012), Johnson (2003), and Hopp and Spearman (1990), total run, setup and move times typically make up only a fraction of the total flow time, while a large percentage is made up of waiting in queues, waiting for parts and waiting to move. Thus, it makes sense to focus our research in this review on reducing flow time via techniques associated with these components and their complex interactions.

2.5.1 Process Time (Run Time)

Process time (run time) is the sum of the net lapses during which the single unit is actually processed (Bartezzaghi et al., 1994). Spearman et al. (1990) defined run time as the total processing time at a work centre required to complete the job. It depends on the capacity of the resources and their specialisation degree. Run time is computed to the single unit rather than to the batch to which the object is possibly assigned; in this way, run time concentrates on resource efficiency as a source of time (Spearman et al., 1990; 2000).

Process time is related to many different factors such as capacity, lot size, utilisation, resource availability, setup time, batch transfer and product design. Cakanyildirim et al. (2000) address the issue of lot size, using a model that recognises only a portion of the overall lead time (processing time) as being dependant on lot size. The process time is a major part of MLT, as defined by Bartezzaghi et al. (1994) in their lead-time models of business processes, which described the relationships between lead time and business process performances (see Figure 2.6), also showing time as an indicator of the utilisation of the resources that operate the process. For example, it is computed as the effective use of equipment (machine hours) or labour (man hours). It relates to the resource saturation when compared with the overall resource availability (Bartezzaghi et al., 1994). This time concept is connected with minimising the idle times and in this way improving the productivity of the resources. However, Hopp and Spearman (1990) and Johnson (2003) have different explanations for idle times in the process time; in some cases, idle time will support process time. Because the machine was not busy, the machine will start up immediately and the unit will be processed when the parts arrive at the work station (if variability is increased through the workstation).

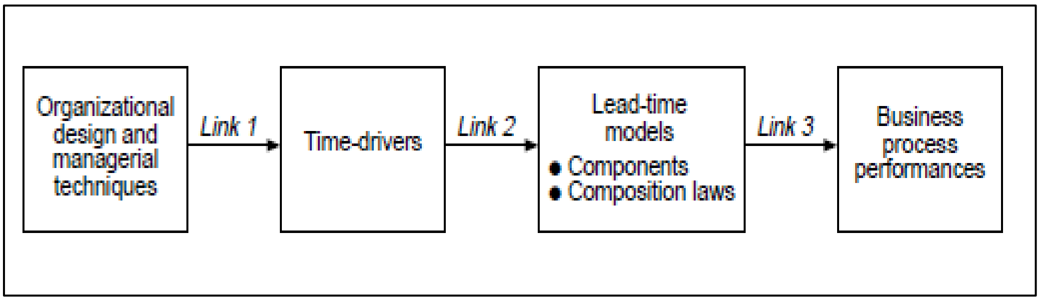

Figure 2.6 The links between organisational design and process performances through lead-time management

(Bartezzaghi et al., 1994)

The relationship between key logistical figures like WIP, which depends on the duration of process time, lead time, utilisation, finished goods inventory (FGI) and service levels, is addressed by many authors. Karmarkar (1993) states that actual lead time are highly dependent on actual workloads (speed) and lot sizes. Hopp and Spearman (1996) have shown that lead time is an increasing function of WIP when process time is increased. In addition, they have developed bounds describing the best and worst cases for actual lead time. Hopp and Spearman (1990) and Jodlbauer (2008) defined service level as the fraction of jobs whose actual lead time is not greater than their planned lead time. Hopp and Spearman (2004), Karmarkar (1993), Kohn and Rose (2011) and Altendorfer and Jodlbauer (2011) have presented good overviews and summaries of the relationships between the logistical figures of inventory, utilisation, process time, lead time and service level.

More authors have tried to reduce or control process time as related to lot size and design; most of them have tried to build a model to investigate the slowdown effect that occurs when lot size or batch size was processed. Therefore, Kohn and Rose (2011) proposed an analytical cluster tool model suitable for predicting process times and considered the effects of small lot size and the slowdown effect that occurs when simultaneously processed lots interfere with each other. Johnson (2003) described how we can reduce manufacturing throughput time using two work stations and two products (X will be processed first and Y second). They are processed consecutively for each station. The manufacturing throughput time per part (MTTP) for each part type is the sum of the processing times at each station for a total of 20 minutes.

Given the current state of the technology used in production, 20 minutes is the minimum MTTP possible, and it is a perfect system. Any increase in the processing time per part would increase the MTTP by the same amount. (Figure 2.7), which reveals an opportunity to reduce process time indicates that reductions in processing time per part can be accomplished by reducing the number of operations required, reducing the processing time per operation, and/or reducing scrap and rework. The number of operations per part may be reduced through the adoption of new technology that allows a single operation to do what was previously done by several operations, or by redesigning the part so that fewer operations are required. Processing time per operation can be reduced by redesigning the part to require less processing, incorporating faster technology to process the part (if available),

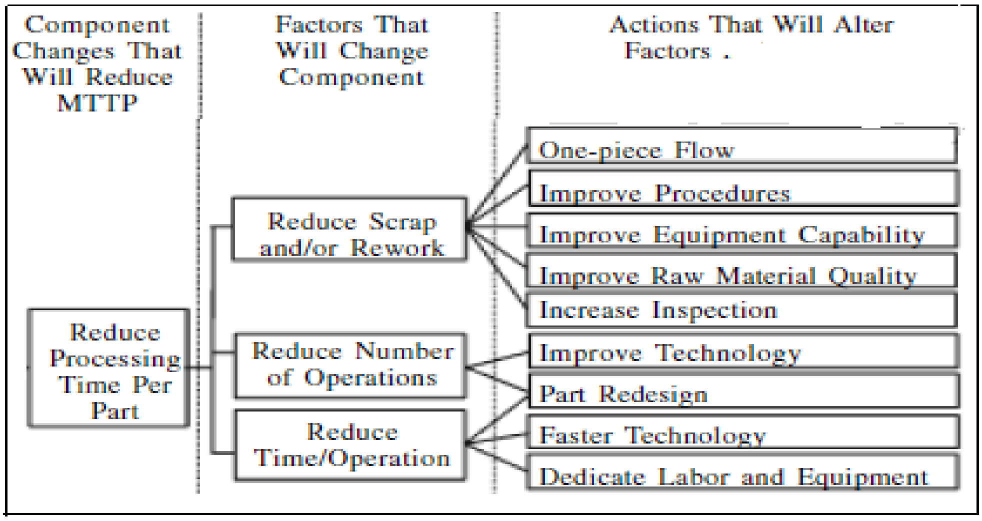

Figure 2.7 Reducing process time per part in MTTP

(Johnson, 2003)

2.5.2 Production and Transfer Batch Sizes

Transfer batch sizes are the number of parts moved at the same time to the next workstation. Production batch sizes are the number of parts of the same type processed before the workstation is set up to process a different part (Johnson, 2003; Spearman et al., 2001). The large batch size may be required at some work centres to achieve the required capacity. However, it is not always necessary to use large batch sizes on non-bottleneck operations to reduce or control flow time: at the bottleneck, where capacity is conical, reducing the lot size (process batch) may not be practical. However, the lot size processed by the bottleneck does not have to equal the lot size that is transferred (transfer batch). Forcing the entire lot to wait until the last piece is finished can be a significant source of waiting time. Therefore, large lots should only be used in most bottlenecks. Elsewhere, the process lot should be split into transfer lots that are as small as can be practically handled (Spearman et al., 1990; Jacobs, 1984). The most fundamental challenge in cutting MLT is to reduce setup times and decrease production batch sizes. By producing goods in small lots, the factory can eliminate the waste associated with overproduction and excess inventory (Kiyoshi, 1987; Spearman et al., 2000).

Now, many researchers are beginning to make the distinction between production batch sizes and a transfer batch. Askin and Madhavanur (1998) examined a flow shop where workers are responsible for both machine operation and material handling. An efficient algorithm computes the cycle time for a single part type, and this algorithm is used to help determine the optimal number of equal-sized transfer batches. Finally, these results are extended and tested for a flow shop producing multiple part types. Also, Potts and Baker (1989) and Trietsch and Baker (1993) solve a similar problem by splitting an order into different transfer batch sizes to minimise the maximum completion time. These authors consider optimising the transfer batch sizes with or without intermittent idling of machines. Whenever the transfer batch size is smaller than the process batch size, processing on the succeeding machine does not have to await the completion of all products on the preceding machine and production activities may overlap (Spearman et al., 2001).

A good example of production and transfer batch sizes that have different characteristics is explained by Johnson (2003), who says that to process part X we have 10 units. Each part incurs only 20 minutes of actual processing time, which means that the total MTTP is equal to 200 minutes to complete 10 units of part X. The remaining 180 minutes is either the time a part spends waiting for its turn to be processed at a workstation, or the time a part spends waiting for the remaining parts in the batch to be processed so the batch can be moved. The wait-for-lot time incurred by each part in this case is linearly related to the size of the production and transfer batches used. These wait times are sometimes referred to as wait in-batch and wait-to-batch times, respectively (Hopp & Spearman, 2001), or collectively as the wait-for-lot time (MPX, 1996). This also causes MLT to increase in a linear fashion as production and transfer batch sizes increase (Johnson, 2003; MPX, 1996; Spearman et al., 2000). The above literature provides us with a foundation for quick guidance and analysis of MLT reduction.

2.5.3 Setup Time and Lot Sizing

Setup time reduction is a process through which the total time required to change over or set up equipment or a work centre is dramatically reduced. Through a systematic, problem-solving, waste-eliminating approach to support the movement towards small lot size runs, the main goal of setup reduction is to reduce the downtime of equipment during changeover and reduce MLT (Heizer & Render, 2008; Vaughan, 2006).

Setup reduction can deal with frequent changes in diverse environments by improving equipment availability and eliminating various aspects of wastage in setup change. According to the principles of lean production, we should only carry out value-added activities that customers are willing to pay for; others are wastes that consume time and other resources that customers are not willing to pay for. It has been proven that setup reduction can reduce setup change time by 50% compared with traditional setup methods (Lixia & Meng, 2010; Allahverdi & Soroush, 2008). Lixia and Meng (2010) also evaluated the impact of setup reduction using some indices such as percentage reduction in setup time, increased equipment availability, labour cost savings from setup reduction, batch size reduction (without economic penalty), and overall equipment effectiveness. Along with the reduction of setup time, the effective cycle time per part becomes shorter and shorter, which greatly decreases the cost of small-batch products and makes smaller batch sizes possible, as shown in Figure 2.8. However, according to Allahverdi and Soroush (2008), treating setup times separately from processing times would allow operations to be performed simultaneously and hence improve resource utilisation. Setup time reduction programs have been one of the main components of manufacturing performance improvement strategies. Prioritising setup investment projects in a multi-product, multi-machine, resource-constrained environment is a major concern, especially if our objective is to become faster and more flexible in response to customers' requirements. The most frequently suggested approach to deal with this situation is the use of Pareto analysis of total setup time in a period (Shingo, 1985). Even though this ensures that investment efforts are assigned to the machine with the largest setup time, it does not make sure that the system's performance as a whole is improved. Decreasing setup time yields important benefits in productivity, response time and flexibility (Villarreal et al., 2002). Theory of constraints (TOC)-based procedure is used to prioritise setup reduction efforts. It was applied to machines in a department of a Mexican company, having been developed for the purpose of improving productivity and capacity utilisation. Joshi and Naik (2012) deal with the basic overview of a reduction in setup time via Single-Minute Exchange of Die (SMED).

Setup reduction requires good design, lot-sizing prediction, well-maintained machines and tools, thoughtful efficiency planning, and timely material handling (Lixia & Meng, 2010) (for more detail, see Figure 2.8). Most of the literature dealing with estimating or reducing MLT is based upon the use of queuing models. Karmarkar et al. (1992), Yang et al. (1993), Dobson et al. (1992) and Kekre (1987) focus on the impact of lot sizing on lead time. Kekre (1987) and Yang et al. (1993) consider the impact of product mix and Karmarkar et al. (1992) discuss the relevance of order-release mechanisms. Yang et al. (1993) provide guidelines to prioritise setup-reduction efforts, according to product setups, for a closed manufacturing cell using the MIGI queuing model. No one discusses in detail how a reduction of setup time will affect the level of MLT. The purpose of batch size in JIT is to minimise inventory investment, shorten production lead times, react faster to demand changes and uncover any quality problems (Heizer & Render, 2008). Hariga (2000) also addresses the 'queuing factor' such that lead time is linearly related to lot size and recognises a critical nonlinear relationship, implying a queue-minimising lot-size vector. Moreover, steady-state average queue times grow unbounded as decreasing lot sizes and increased setup frequency drive the utilisation of the available process time to 100%. By reflecting this relationship, the model to be developed implicitly recognises a constraint on the total process time available. Vaughan (2006) explains that process utilisation is partly determined by the collective lot-sizing decisions applied to the process. The single-item lot-sizing analysis is structurally inadequate for addressing the true lot-sizing problem.

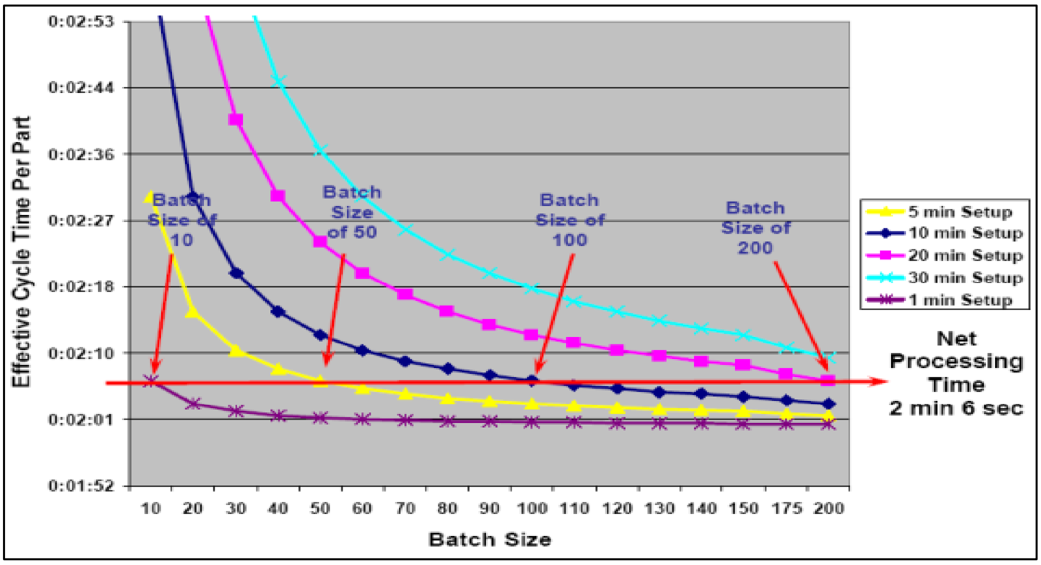

Figure 2.8. Impact of setup time on effective cycle time per part

(Lixia & Meng, 2010)

Only a select group of authors have formally addressed the relationship between lot size and job-queuing characteristics. Karmarkar et al. (1985) appear to be the first to explicitly address the relationship. Karmarkar (1987) presents the average queue time under the M/G/1 model, in response to (n) items having been given demand rates, setup times, processing rates, and batch sizes. The most fundamental challenge in cutting MLT is to reduce setup times and decrease production batch sizes. By producing goods in small lots, the factory can eliminate the waste associated with overproduction and excess inventory, so lot-sizing techniques—such as lot-for-lot techniques—order only what is required for the production based on net requirements (Orlicky, 1975; Kiyoshi, 1987). Heizer and Render (2008) also state that material requirement planning (MRP) demands fixed lead times that might actually vary with batch size. MRP also has a big role for manufacturing processes, which are described as a dynamic system (a common technique), as well as a better response to customer orders. Therefore, lot sizing depends on MRP because lot-sizing techniques, such as lot-for-lot techniques, only order what is required for production based on net requirements. The logic of net requirements related with lot-for-lot calculation as well as all lot sizing decision Heizer and Render (2008) stated that “net requirements plan depend on the logic of net requirements such as below:

Net Requirements = [Gross requirements + allocations] – [On hand + Scheduled receipts]”. Furthermore, MRP plans are executed using JIT techniques based on ‘pull’ principles. General guidelines exist for specifying unit load sizes and quantitative techniques for use in determining what unit load sizes would be suitable for a particular application on the shop floor (see Figure 2.9).

Lot Size	Lead Time	On Hand	Safety Stock	Allocated	Low-Level Code	Item ID			Period							
									1	2	3	4	5	6	7	8
Lot FoR Lot	1	0	0	10	0	Z	Gross Requirements									~~80~~ 90
							Scheduled Receipts									0
							Projected On Hand	0	0	0	0	0	0	0	0	0
							Net Requirements									90
							Planned Order Receipts									90
							Planned Order Releases								90	

Figure 2.9. MRP planning sheet

(Heizer & Render, 2008)

MRP is widely used to determine production schedules in manufacturing systems. Orlicky (1975) states that the basic idea of MRP is to “translate customer requirements into quantities and due dates for components, based on bill-of-material and lead-time information. However, the procedure assumes a component’s lead time is a function of the component alone and is not affected by congestion in the production facility.”

Also, estimating capacity and lot sizing are important. Spearman et al. (1990; 2000) found that while specific environmental improvements are certainly influential (e.g. setup reduction, production smoothing), there are three primary logistical reasons for the improved performance of pull systems: throughput depends on lot sizing and is controlled by specifying an input rate. If the input rate is lower than the capacity of the line, then throughput is equal to input. If not, throughput is equal to capacity and WIP builds without bounds. By incorrectly estimating capacity, input can easily exceed the true capacity. The effect of learning on process quality is very important to reduce setup and process times. Many authors have studied and explained the effects of the rate of learning on lot sizes, and have analysed the setup frequency to investigate the effects of setup time and cost reduction, as achieved through learning, on optimal schedules in the capacitated lot-sizing problem (Partsini et al., 1994). They focus on two issues. The first is to investigate how the reduction of setup time through learning affects the optimal production schedule in the capacity. Chand (1989) also studied setup learning in the economic lot-size model with constant demand and constant capacity, and developed an efficient algorithm that finds the optimal lot sizes. This is also mentioned by Kohn and Rose (2011) and Lixia and Meng (2010).

This review will try to understand how multiple factors interact, considering, for example, the impact of lot sizes on lead times; therefore, setup time and lot sizing are important factors. Thus, it makes sense to focus our research in this review on our efforts to reduce the flow time associated with these components and their complex interactions. This review identifies the factors in delays and sources of waste, which contribute to the long MLT. Also, this literature review has provided a broad and specific review of the issues related to MLT reduction and throughput time reduction in manufacturing systems.

2.5.4 Variability

MLT is the total time required to process a given product through a plant. Long MLT is the main cause of inefficient manufacturing. One of the factors that are increasing MLT is variability (Suresh & Meredith, 1994; Fahimnia et al., 2009; Spearman et al., 2001).

Variability can occur as a result of either controllable or random variation in the time between arrivals (Hopp and Spearman, 2001). In addition, Hopp and Spearman (1990) and Johnson (2003) stated that "Controllable variation is a result of decisions made and includes such things as differences in the processing time of different parts due to design differences, differences in wait-for-batch time due to production and transfer batch size decisions, and so on." By contrast, Johnson (2003) states that random variation is a result of events beyond our immediate control. This includes such things as natural variation in process time for the same type of part due to unplanned machine downtime or differences in machines, operators, or materials. Another factor can be variation in the time between arrivals at each workstation. Fahimnia et al. (2009) mentioned the issue of unplanned machine downtime. Therefore, Spearman et al. (1990) and Johnson (2003) felt that, regardless of the type, variability generates the possibility that a batch of parts arriving at the workstation will find that the workstation is still busy processing a previous batch. When this happens, the new batch must join the queue and wait its turn for processing. Therefore, in order to reduce MLT, variability should be eliminated.

More authors have discussed and classified internal and external variability. The causes of variability can be classified into various internal factors, such as setup time, downtime (scheduled and unscheduled), operator-induced fluctuations in production rates, yield loss, rework, engineers changing orders, and many others (Spearman et al., 2001). External factors include irregular demand, product variety to meet market needs, customers changing orders, etc. External variability is often the consequence of a firm's business strategy, such as offering high levels of product variety to achieve a competitive advantage (Erik et al., 1996; Altendorfer & Jodlbauer, 2011). In addition, Spearman et al. (2004) developed and implemented the idea that, "one of the strategies is reducing variability in subassembly and final assembly. This was done by streamlining the flow and establishing a CONWIP system. Lead time came down from 23 days to 6 days, while service went from less than 50% to over 95% and continual improvement as variability is reduced, we can reduce the capacity buffer and keep the inventory buffer low" (Spearman et al., 2004, pp…). Furthermore, Buzacott and Shanthikumar (1993) and Spearman et al. (2004) have suggested that variability reduction is close to the core of lean. Indeed, with its emphasis on production smoothing, quality improvement, setup time reduction, total preventative maintenance, and many other practices, it is clear that Toyota appreciated the key role of variability reduction in JIT right from the start.

Variability causes MLT to increase. Likewise, increases in variability cause queue size and the associated queue time to increase. Variability generates the possibility that a batch of parts arriving at the workstation will find the workstation still busy processing a previous batch. When this happens, the new batch must join the queue and wait its turn for processing (Spearman et al., 1990). Furthermore, the impact of variability on MTTP (see Figure 2.10) shows that variability is one of the factors that has a great impact on MLT in the manufacturing process (Johnson, 2003). That research has provided a broad and specific review of the issues related to MLT reduction and throughput time reduction for manufacturing systems. Also, this literature review is sufficiently detailed to provide guidance to the industry practitioner on how to reduce variability in order to reduce manufacturing throughput time.

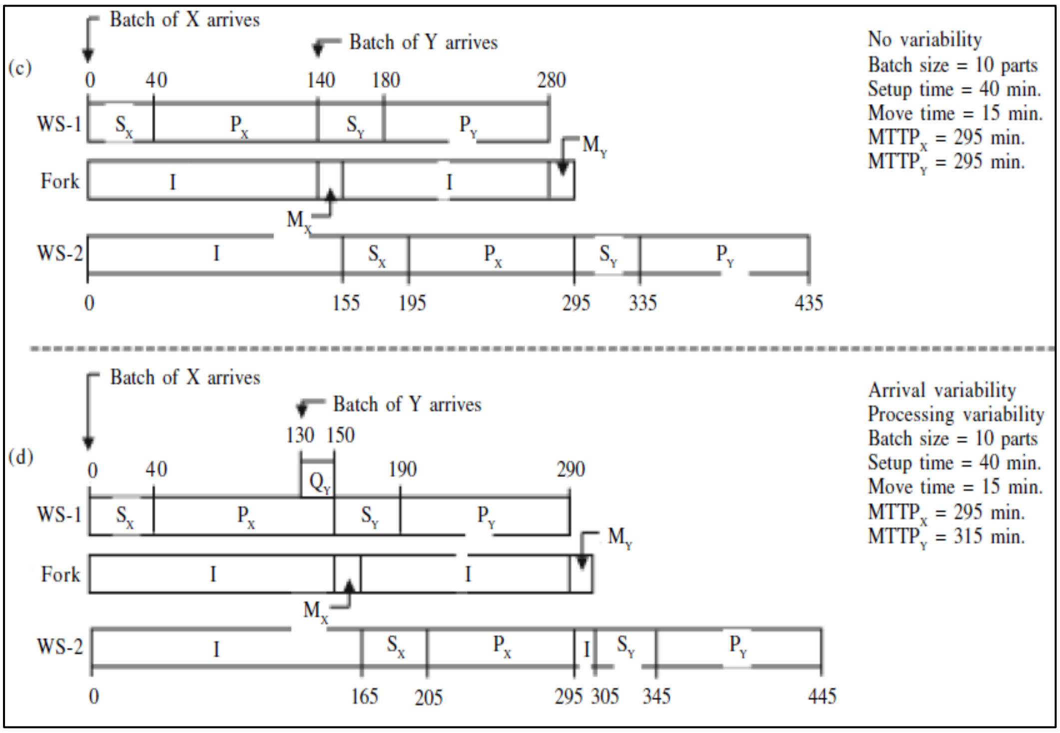

Figure 2.10. Impact of variability on MTTP

(Johnson, 2003)

2.5.5 Utilisation of Available Time

Utilisation is the proportion of the available time (usually expressed as a percentage) that a piece of equipment or a system is operating for. The formula is: operating hours x 100 ÷ available hours (Groover, 1987). Johanson (1968) defined capacity utilisation as the (weighted) average of the ratios between the actual output of firms to the maximum that could be produced per unit of time, with an existing plant and equipment. Berndt and Morrison (1981) defined capacity utilisation as a concept in economics and managerial accounting that refers to the extent to which an enterprise or a nation actually uses its installed productive capacity. Thus, it refers to the relationship between actual output that 'is' produced using installed equipment and the potential output that 'could' be produced with it, if capacity were fully used. Ragan (1976) also states that capacity is an elusive concept; capacity refers to the quantity of output that can be produced in a fixed period of time, given the existing stock of capital, while Heizer and Render (2008) defined capacity as the throughput or the number of units a facility can hold, receive, store, or produce in a period of time. Capacity decisions impact all of the 10 decisions of operations management, as well as the other functional areas of the organisation. Also, utilisation and efficiency have a relationship, as previously mentioned: utilisation is the per cent of design capacity achieved, while efficiency is the per cent of effective capacity achieved. However, a number of interpretations for the expression can be produced (for more details, see Krajewski & Ritzanan, 2007 and Heizer & Render, 2008).

Utilisation = {average output rate ÷ maximum capacity} × 100 % ... (1)

$C = 100\% - \text{Utilization rate } (\%)$ ..(2)… (1 & 2) (Krajewski & Ritzan, 2007)

The average output rate and the average time that each part spends in the system are explained by Little's Law (Little, 1961; Conway et al., 1967), which is based on the queuing theory. Little's Law states that the average number of items in storage is the product of the average output rate and the average time that each one spends in the system. Karmarkar (1987) stated that the actual lead times are highly dependent on actual workloads and lot sizes. The role of WIP is very important to control lead time because the CONWIP (CONstant Work In Process) control system strives to maintain a constant work in process. It was first introduced by Spearman et al. in 1990 and can thus be classified as a very new control concept. In terms of lead time, inventory and WIP for controlling those, Jodlbauer (2005) states that one of the most interesting results is that the variability of the inventory or the production load causes a waste of capacity and therefore a reduced utilisation and an increased lead time. If the production system works with an average inventory greater than the critical WIP, the lead-time bound rises. If the average inventory is less than the critical one, the utilisation bound falls. However, Altendorfer and Jodlbauer (2011) explained that the direction of the influences of logistical key figures on economic value added (EVA) can be stated as follows: higher utilisation leads to lower capital being employed in machinery, which therefore leads to a higher EVA. One further insight is that an increase in the maximum possible personnel capacity in relation to the average available machine capacity implies that higher average machine utilisation becomes optimal for maximising EVA. For example, Spearman et al. (1990) discuss how to reach a specified throughput with minimum WIP and introduce the constant WIP (CONWIP) methodology as a solution to this problem. In the relationship between utilisation and WIP, a linear increase in utilisation leads to a strictly convex increase in WIP (Hopp & Spearman, 1996; Jodlbauer, 2008). The most significant results are that the joint lead-time and order-acceptance rate policies developed reduce the quoted MLTs and increase system utilisation rates and the expected profit (Weng, 1996). Yang and Beibei (2008) set out to tackle this problem. In particular, they developed an automated approach to optimising standard lead time and resource utilisation.

Comprehensive mathematical descriptions of the links between the factors involved (e.g. utilisation, variability, etc.) can be found in Hopp and Spearman (2000) (see also Figure 2.11). However, despite the importance of queuing theory in manufacturing processes, very little empirical research investigates the nature of the relationship between lead time and utilisation (Pahl et al., 2005). Therefore, that research review identifies the factors of delays and sources of waste that contribute to long MLT.

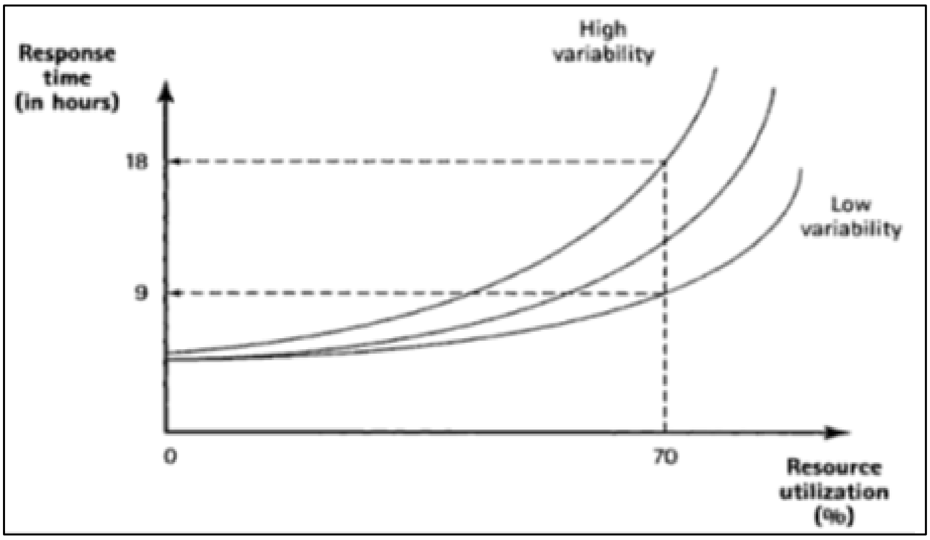

Figure 2.11 Dependencies between utilisation, lead time and variability

(Suri, 1998)

Variability has less of an impact on queue time when workstation utilisation is low than when workstation utilisation is high. When utilisation is low and significant slack workstation capacity exists, it is fairly easy for a batch to arrive when the workstation is idle and be processed immediately (Hopp & Spearman, 1996). Johnson (2003) states that "as utilization increases and less slack capacity is available, it becomes more difficult for a batch to arrive when the workstation is idle. It increases the probability that the batch must join the queue, resulting in longer queue times and MLT for per part." The magnitude of the impact that utilisation and variability have on MLT will vary from system to system. However, queuing theory indicates that the general pattern of results (shown in Figure 2.12) holds for all systems; in particular, queue time and its associated MTTP increase as utilisation increases (Johnson, 2003).

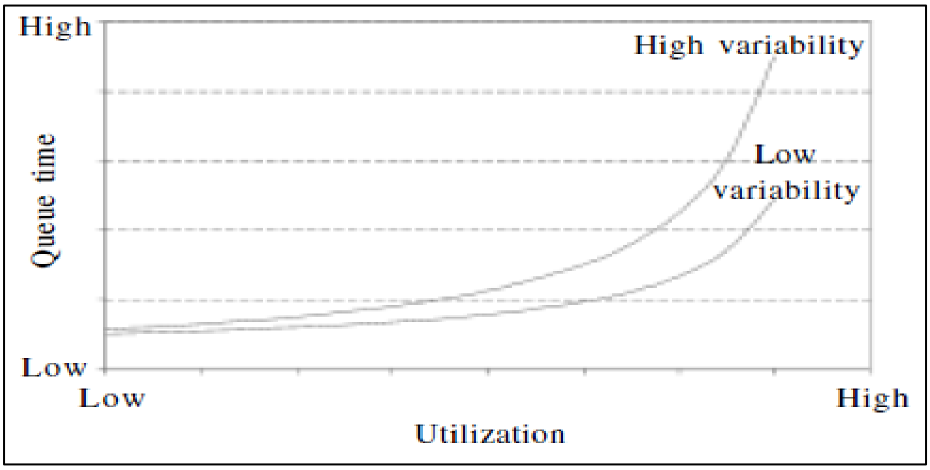

Figure 2.12 Queue time vs utilisation. Note: Graph constructed using the GI/G/M queuing formula found in *Whitt (1983)*

2.5.6 Factor Interactions and Move Time

MLT reduction or throughput time reduction in manufacturing processes can be defined as a difficult task due to the many factors that influence it and their complex interactions. Any further increases in setup and move time would directly increase MLT by the same amount (Hopp & Spearman, 2001; Karmarkar, 1987). The time required per move can be reduced by increasing the speed of the material handling equipment (which may not be possible due to the safety implications), or by reducing the move distance required (Heizer & Render, 2008). Altendorfer and Jodlbauer (2011) stated that "if the speed of the material handling system is increased through the installation of conveyors or other automated handling equipment, it is questionable how realistic this option would be when a job shop/functional layout is used". While move distance can sometimes be reduced by reorganising the equipment to optimise the material handling between departments in a job shop/functional layout, the level of reduction is greater if the equipment performing sequential operations on a part is grouped to form manufacturing cells. Shafer and Charnes (1995) and Krajewski and Ritzanan (2007) deemed the role of manufacturing cells to improve and increase the speed of the material handling equipment. For example, "If a job shop or functional layout is currently being used, the number of moves requiring material handling equipment can often be reduced by grouping workstations performing sequential operations into manufacturing cells."

Johnson (2003) argued that, in some cases, technological improvements that allow more sequential operations to be done by a single machine can achieve the same result. For example, a CNC milling machine can be used to perform the operations previously done by several machines. Johnson (2003) also determined the situation for reducing time in manufacturing processes by taking actions that will alter factors such as moving time (see Figure 2.13). In addition, Fahimnia et al. (2009) demonstrate this in their models and state that: Analysing the hindrances to the reduction of MLT and their associated environmental pollution to find the alternative action for those factors.

The previous discussion indicates that MLT is equal to the sum of the processing, setup, move, queue, wait-in-batch, wait-to-batch, and wait-to-match times. Because queue, wait-in-batch, wait-to-batch, and wait-to-match times all involve waiting, and because the actions taken to reduce one type of waiting may also reduce other forms of waiting, they are collectively referred to as waiting time in the MLT or flow-time reduction. Reductions in MLT per part thus require reductions in one or more of these components. While setup time, processing time per part, and move time are independent of each other (i.e. a reduction in move time does not affect setup time or processing time per part, and so on), changes to any of these three components can affect waiting time (Hopp & Spearman, 1996; Johnson, 2003; Kwan et al., 2013). Similarly, one way to reduce waiting time is to manipulate the other three components of MLT (Hyer & Wemmerlöv, 2002). Another example that shows most of the factors that influence waiting time and the complex interactions contributing to and associated with MLT, and used for calculating lead-time and processing performance ratios, can be found in Gardner (2004). He states that "process efficiency, which is the percentage of lead time that is value-adding process time, Time utilization, which is the percentage of lead time that is consumed by work and Work utilization, which is the percentage of process time that it value-adding work" (page reference). Consequently, one way to reduce waiting time is to manipulate the three other components of MLT. Johnson (2003) provides a good example to support our factor interactions. He stated that if the average processing time is reduced to five minutes for each part type at each workstation and the batch processing time is reduced by 100 minutes for each part (i.e. to 50 minutes) at station one and by 50 minutes at station two, there would be a 150-minute reduction in MTTP results for part (Y) due to the additional impact on waiting time at WS-1. Therefore, Y would only wait 100 minutes at WS-1 and the $MTTP_Y$ would be 295 minutes from the last process, so 445 minutes in total. Waiting time is usually the largest of the four components, accounting for as much as 90% of MLT in some systems (Houtzeel, 1982). This section on factor interactions and move time provides a brief literature review related to the research concerning these factors and their interactions. Column 3 of Figure 2.13 indicates that reductions in move time can be accomplished by reducing either the time required per move or the number of moves required.

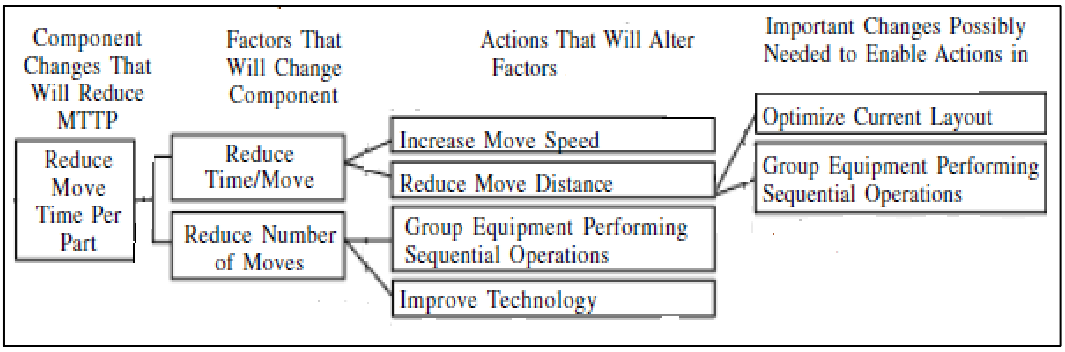

Figure 2.13 Reducing move time per part in MTTP

(Johnson, 2003)

2.6 Scope of the Review

This literature review contains more than a simple list of sources: it aims to determine how far existing research has come and move science forward. If systematic reviews had been updated, the researcher only considered the most recently published review. The researcher reviewed various different articles, social media and books in order to find an alternative simple strategy for reducing lead time in the manufacturing sector. In order to ensure that the project has a stable scientific basis, a literature review had to be conducted; this also helps the researcher to avoid mistakes that others have encountered in previous research. The literature study presented different conceptual frameworks of the causes of excessive lead time: some took a theoretical approach, while others adopted a practical approach. These frameworks also describe the relationships between the factors, such as setup time, operational time, and non-operational time. This literature review has illustrated the actions that can be taken to reduce each factor in order to reduce lead time.

Therefore, this literature review will support the researcher to find further potential methodologies that should be considered in order to reduce lead time in the manufacturing process. There have been extensive studies on throughput time reduction, and these methods and factors are highlighted in the literature review, but very little research has been done that relates to MLT reduction, even though throughput time is a major component part of MLT.

There is an opportunity in this literature review to point out the major methodological gaps in some prior research. (Stalk & Hout, (1990) stated that the negative impact of time-based competition (TBC) is inevitable when it is applied blindly without knowledge of how to make time a competitive advantage; the main strategy of TBC is to use speed for competitive advantage. QRM is rooted in the same principles as Stalk's TBC. QRM focuses on manufacturing operations, whereas TBC can be applied to any business, including banking, insurance, hospitals and food services; therefore, QRM sharpens the focus of TBC and 10 principles of QRM (Suri, 2003). The researcher focuses on the implementation of the 10 principles for QRM, which is one of the contributions to knowledge used in order to find a research approach for this study. This is important in terms of assessment tools and TQM, which are important factors when it comes to reducing lead time. It is also an interesting research area for further research on reducing MLT; therefore, this is an opportunity to identify more research in that direction. Suri (2003) provides a summary of the 10 QRM principles that must replace the 10 traditional beliefs presented in the quiz to answer; therefore, Suri gave an overview of the QRM strategy, where he focuses on lead-time reduction throughout the enterprise. That research study was used to present the QRM quiz, which was only given to managers, not practitioners, in order to find defects or delays in manufacturing processes and reduce lead time under TQM thus QRM was focused on lead time reduction and not on tools and methods. Suri also demonstrates that the combination of QRM and POLCA will provide companies with a significant competitive advantage through their ability to deliver customised products with short lead times but in order to develop and use performance measures of lead time reduction is critical within the TBC/QRM.

If you are in industry, complete the quiz as follows. Suri (2003) stated that the mangers should have considered the assertions in the quiz. For instance, ask yourself: “Do the key managers in my company consider this statement to be true or false?” Suri gives an overview of the reasoning behind the correct answers to the QRM quiz.

Traditional belief #1: Everyone will have to work faster, harder and longer hours, in order to get jobs done in less time. True or false?

QRM principle #1: Find whole new ways of completing a job, with a focus on lead-time minimisation.

Therefore, traditional belief #1 must be replaced by QRM principle #1. In that case, when management clearly understands the basis for each QRM principle, it can lead the organisation along the QRM journey; therefore, the researcher determines the gap. in the literature could be identified as follows: the first is the lack of quantitative studies showing more the benefits of TBC and QRM in the term of using of survey for manufacturing assessment questionnaire (action research for designing the survey as face to face) and the second there are some principles and assessment tools of TBC/QRM paradigms are rarely studied and the third is the application of principle and traditional beliefs of TBC/ QRM in practice may be scared without manufacturing assessment tool which provides a preliminary analysis of your firm’s strengths and weaknesses benchmarked against comparable manufacturing firms. Also, the researcher thought about and asked questions concerning how a manufacturer can find the best alternative method to the QRM quiz, as well as to traditional beliefs, before reducing lead time. Therefore, this research felt that it would be best to start by looking up a manufacturing assessment and considering how to convert a manufacturing assessment into survey questionnaires. What are the simple strategies used before reducing lead time? And what kind of steps should be taken into account before reducing MLT? Should all traditional beliefs be replaced by the 10 principles of QRM? Therefore, the research proposed that the quick-view manufacturing assessment is an effective assessment tool that can help manufacturers to reduce lead time instead of the 10 principles of QRM; therefore, quick view will help manufacturers to better understand the problems and opportunities confronting their operations.

Because of this reasonable idea, this research will focus on converting manufacturing assessments to survey questionnaires so that the manager or manufacturer could evaluate the system before reducing MLT. Survey questionnaires will help to identify areas for capital, defects, problems, delays and time in the system. This research has decided to design the survey questionnaire based on nine areas of management: management practices, human resources, market management, operations management, manufacturing technology, maintenance, quality management, engineering/design, and information management. These nine areas are important because quick view aims to achieve the following objectives: to stimulate policy dialogue on the business environment, to help shape the agenda for reform, to assess the constraints to manufacturing sector growth and enterprise performance, and to highlight some of the non-technical parts of operations that may be impeding growth. These can all lead to an increase in MLT. Suri (2003) and previous researchers have not investigated manufacturing assessment tools that relate to MLT; therefore, manufacturing assessment will evaluate the system to detect defects and delays and also support the manufacturers to reduce lead time.

Therefore, this research will seek or decide to convert and create a modification on manufacturing assessment to survey questionnaire. This is because the survey questionnaire is an effective assessment tool used to help practitioners better understands the problems, defects, delays and opportunities confronting their operations. This also enables companies to dramatically shorten their lead times to deliver products for most area more for delivery time in order to find opportunity for reducing lead time. Therefore, survey questionnaires will support and identify simple strategies for reducing lead time that can help move towards achievement. The assessment questionnaire will lead to the achievement of the following objectives: to provide statistically significant business environment indicators that are comparable across all of the world’s factories; to assess the constraints to private-sector growth and enterprise performance; to build a panel of establishment-level data that will make it possible to track changes in the manufacturing sectors over time (thus allowing, for example, impact assessments of MLT, reforms and policy changes); and to identify opportunities for more research. This also raises additional important and relevant research topics; therefore, this will lead to the research question being answered.

The research focuses on interesting published papers for operation research (OR) notes; these are a series of introductory notes on topics that fall under the broad remit of the field of OR. They feature different solution cases and are presented by Beasley (2012). Fixing lead time is important for production planning because there are two important procedures: reschedule capacity planning and material requirements planning (MRP). These are used to provide feedback to the capacity plan and the production plan so that planning can be kept valid at all times.

MRP is a production planning system used to ensure that the parts and materials required are available at the right time in the correct amounts. Beasley (2012) demonstrated that MRP should estimate and fix the lead time between releasing an order to the shop floor and producing a finished product. MRP is a technique that assists a company in the detailed planning of its production. Beasley (2012) and Heizer and Render (2008) stated that “the master production schedule sets out an aggregate plan for production thus MRP translates that aggregate plan into an extremely detailed plan”. Beasley (2012) mentioned that the production planner should avoid a stock-out; therefore, Beasley asked the question “in each and every period, should I order in this period and if so how much?” However, he did not mention that determining the system’s available capacity involves only two related decisions about ordering; in his example solutions, Beasley used lot-for-lot and fixed-period requirement (FPR) techniques for the quantity decision. Both are termed lot-sizing decisions. Beasley compared both techniques against cost only, and did not mention how to reduce lead time or suggest techniques for smoothing the load and minimising the impact of the changed lead time. Thus, by focusing on rescheduling for capacity planning, both WIP and lead times could be decreased, as well as capacity requirements (detailed), which are very important factors for controlling or reducing MLT. Therefore, this research finds the gaps related to reschedule capacity planning and could be identified for finding simple strategy to cope when production time is greater than demand time. Also, in his second introductory series of OR notes, he created a queue theory model for the management line: this is the priority rule for determining the order service for customers. Beasley, in his model, needed to balance the cost of increased capacity against the gains of increased productivity and service. Beasley also compared both models in terms of cost alone, but did not mention how to control lead time. Also, Beasley did not mention how to manage capacity and synchronise this with demand, or how to synchronise this with available capacity times. However, publishing papers for OR notes is important and interesting for more researchers because all the sections present an analytical method of problem solving and decision making that is useful in the management of organisations. This allows industries or practitioners to improve their performance in order to retain business in a competitive world.

In order to reduce lead time or minimise the impact of changed lead time, this research focuses on the reschedule capacity planning phase and lot splitting or order splitting; this is because these technical approaches are important for creating a proper planning, such as a closed-loop MRP system, that can then reschedule capacity planning in the net requirements plan for lot sizing and lead time. This is done in order to trade-off between lot size and the available capacity for the system. Nieuwenhuysea and Vandaeleb (2006) proved analytically that lot splitting improves the delivery reliability of the supplier, and hence the production schedule stability of the buyer. Vandaeleb (2006) also proposes an approximation to estimate the delivery reliability in terms of the lot-splitting policy and the system characteristics. Neither previous researcher created a closed-loop MRP system and rescheduled capacity planning phase in order to provide information for the capacity plan and ultimately the production plan. Doing so would have enabled the production planner to control or minimise the impact of both changed lead time and lot sizing. One of the strategies that should be used in this respect is order or lot splitting, which involves breaking up the order and running part of it off schedule. Lot splitting is known to offer numerous advantages over a lot-for-lot policy, such as decreasing flow times and leading to lower congestion levels. Therefore, future research will be focused on lot splitting policy and the system characteristics to estimate the delivery reliability.

All companies strive to reduce the gap between receipt of an order and shipment. Thus, many companies have come to develop, realise and implement systems that the old, traditional methods couldn’t accomplish. Hoppe and Spearman (2001) stated that MRP has, for many years, been utilised by businesses to improve production efficiency and product delivery. On the other hand, one of the limitations of MRP has been its deterministic, fixed view of lead time—it does not take into account, for example, the capacity of each factory’s machinery.

Also, according to Hoppe and Spearman (2001), “the materials order placement, a fundamental feature of MRP, is most of the time, performed much earlier than necessary resulting in an exorbitant increase in inventory”. In production management terms, this is called infinite capacity scheduling. These shortcomings of MRP have been successfully corrected by finite capacity scheduling, but Hoppe and Spearman (2001) did not mention how to apply this or which technical tools should be used. Therefore, future research will be focused on reschedule capacity planning, MRP and optimising the current layout strategy. It will contribute to reschedule capacity planning, MRP and optimising the current layout strategy, which is potentially needed to enable actions that will reduce lead time and move time. This will allow the number of moving units between departments and, consequently, MLT to be reduced.

Johnson (2003) stated that “move time is one of the components of manufacturing throughput time”. Also, move time is important because it is directly associated with MLT in terms of loading and unloading time for lot-sizing procedures during manufacturing processes. Johnson (2003) stated that “move distance can sometimes be reduced by reorganizing the equipment to optimize the material handling between departments in a job shop/functional layout, the amount of reduction is greater if the equipment performing sequential operations on a part is grouped to form manufacturing cells”.

MRP is a production planning system for ensuring the parts and materials required are available. It presents three decisions, which are: in each and every period, should I order? If so, how much? What is the current capacity available for the system?

Additionally, this research proposes that the concept of the simulation technique is important for reschedule capacity planning in terms of the use of two technical tools: the first technical tool is overall equipment effectiveness (OEE), which is an effective assessment tool. According to Vorne Industries Inc. (2008), “OEE truly reduces complex production problems into simple, intuitive presentation of information.” OEE helps manufacturers to systematically improve their process with easy-to-obtain measurements, such as lead time. It is also a ‘best practice’ way to monitor and improve the effectiveness of your manufacturing processes, which can also reduce time. The second technical tool is a quantitative tool, such as queuing analysis using queuing theory, which is used to manage lines to identify the amount of waiting required for products. This will be a function of various factors, including: the rate at which inputs arrive, how fast the servers serve, and how the service system is configured. Therefore, both technical tools are helpful when it comes to adjusting manufacturing processes in manufacturing. They also lead to evaluating the system to take into account a machine's availability, performance and quality.

The research now turns to the main purpose of this literature review, which is to identify simple strategies for reducing lead time. An interesting article by Hopp and Spearman (1996) explored the causes of excessive lead time and suggested practical, inexpensive strategies for reducing lead time. Their recommendations and systematically reviewed potential methods for reducing lead time are reducing mean flow time and/or flow-time variance. The strategies presented by Hopp and Spearman (1996) to reduce flow time fall into five general categories: (1) look for the WIP; (2) keep things moving; (3) synchronise production; (4) smooth the work flow; and (5) eliminate variability. there is the question; which kind of technical tool could be used to identify the variable controllable and random variation for process time to failure or time to repair in order to analyse defects to get their root causes which is not mentioned by (Hopp and Spearman, 1996, p.79), this is the "gap in the knowledge." and very little research has been done on monitoring the system in terms of the variability,

However, this research has to ask how this is done. Which technical approach could yield lead time reduction strategies? Therefore, this research focused on two general areas: keeping things moving faster and eliminating variability. These are important factors used to create the best practical case study on how to reduce lead time by eliminating variability. Hopp and Spearman (1996) and various other researchers have demonstrated that the variability in process times caused by rework, downtime and lack of consistency in production methods increase both mean and the variance of flow time. But which technical tool could lead to reduced variability? Very little research has been done on monitoring the system in terms of the reliability of machines and/or processes and their maintainability, yet these play a crucial role in ensuring that there is no downtime and guaranteeing the successful operation of production processes. These could be used to determine production availability and to increase speed and quality, also monitoring reliability. This will help with the design of a preventative maintenance schedule to keep operational time and production rate on schedule. It is not easy to predict the outage of the scheduling without a reliable reason or evidence.

The question is how to monitor manufacturing processes regularly for a period of time in order to check and record the reliability of machinery. This is because measuring reliability is very important to discovering the probability that a machine part or product will function properly for the specified time under the stated conditions. Thus, a high reliability being recorded means no delay or stoppages and less non-operational time. Groover (2001) and Heizer, J. and Render, B. (2008) has stated that MLT is the sum of setup time, processing time, and non-operational time; also, less variability will occur to reduce throughput time, so consequently MLT will be reduced. Therefore, the research will focus on key performance indicators (KPIs). This is the best technical tool because KPIs can be used to discover: equipment reliability, number of incidents (stoppage), mean time between (MTBF), mean time to repair (MTTR) and maintenance cost index. KPIs must have a method to measure progress in improving reliability and to set future targets. As a minimum, the plant should be targeting the utilisation factor and the reliability factor. Also, KPIs take into account both the number of running hours and the number of stops; therefore, they can prioritise both eliminating stoppages and increasing the number of hours that the plant runs for. This is because reducing the causes of short stoppages not only increases efficiency but also eases the burden on operators, resulting in an improved man–machine ratio (because some companies didn’t take short stoppages into account).

KPIs can monitor the system in order to ensure manufacturing processes and machines are available. This is because availability is an important factor that is also associated with WIP. Little’s Law defines WIP as throughput multiplied by lead time (Lowe, 2014); however, Hopp and Spearman (1996) and Heizer, J. and Render, B. (2008) have stated that: “Although the most of companies track machine availability, some do not track the mean between failures (MTBF) and mean time to repair (MTTR).” The research considered how to track MTBF and MTTR, and how they should be identified via a simple strategy prior to the reduction of lead time, which is the best area to research in more depth. Therefore, the research assumes that processing times are deterministic while machines are subject to exponential failures and repairs. Therefore, downtime, reliability, utilisation, MTBF and MTTR are important factors that should be considered in order to reduce lead time in terms of non-operational time, which is one of the main components of MLT. The researcher finds that one of the contributions to knowledge in terms of eliminating variability is defined by Hopp and Spearman (1996). This is because Hopp and Spearman (1990, p. 82) don't consider the KPI tool for monitoring the system because this is one of the simplest strategies for reducing MLT. This research suggested that this new conceptual framework will contribute to KPI tools, which are the best technical tools for monitoring a system, also identifying opportunities for reducing lead time as well as supporting the production planner to utilise capacity more effectively. This makes it possible to meet the order requirements, leading to production orders being delivered according to the right time schedule. Therefore, a more important related research topic will lead to the answers to our research questions.

This research review aims to provide an easy-to-use tool that manager or practitioners can use to determine a course of action to reduce MLT in their own plants. The ultimate goal of a comprehensive lead-time reduction strategy is not merely to cut the total lead time, but to increase the speed of throughput because lead-time reduction is one of the investment strategies that can be considered a future research topic. One of the gaps in research is how to reduce MLT and manufacturing throughput time rapidly and directly in order to provide guidance to the industry practitioner. Thus, MLT needs to be studied further, specifically in manufacturing systems.

The literature in each category is reviewed according to the key factors mentioned. Several researchers have studied the factors that have a significant impact on lead time and throughput time (see Table2.2). We will focus on a simple hypothetical manufacturing system to illustrate the basic factors, which are process time, setup time, move time and work station utilisation. These lead to the determination of MLT and manufacturing throughput time (the literature review explains why each factor has a significant impact on the duration of MLT).

According to Johnson (2003), Hopp and Spearman (1996) and Fahimnia (2007), “production and transfer batch size reductions offer the largest potential for reducing MTTP in most plants”. If the plant has a job shop/functional layout in place, significant reductions in batch size may require conversion to manufacturing cells (Johnson, 2003). High workstation utilisation is a major contributor to long MLT, especially in cases where variability is high. If variability cannot be reduced, workstation utilisation must be reduced to lower throughput times (Johnson, 2003). In general, workstation utilisation levels in the 75–80% range may be required on critical resources to keep MLT low (Suri, 1998). A long MLT is often the result of policies and procedures implemented in the past that are used to control production batch sizes, transfer batch sizes, workstation utilisation, resource access, and so on (Suri, 2003). MLT reduction can be a daunting task due to the many factors that influence it and their complex interactions. While Johnson (2003) indicates that reductions in move time can be accomplished by reducing either the time required per move or the number of moves, it is questionable how realistic this option is when a job shop/functional layout is used. Therefore, Johnson (2003) only gives guidance on reducing move time, which is one of the components of MLT and manufacturing throughput time. He does not mention how to achieve this via a practical procedure, or which kinds of technical tools or research methods could be used to reduce move time, lead time or flow time in the system. Some research has been done on how to reduce move time (Hopp & Spearman, 2004; Johnson, 2003; Yang & Benjaafar, 2001; TDO solutions (2014). but this research has identified a gap that future research studies on move time should focus on. Also, this should be evaluated in MLT. Therefore, one of the contributions to knowledge will be applied in this research because a big advantage of a process-oriented layout is its flexibility in equipment and labour assignments. It is also most efficient when making products with different requirements or when handling customers as needed in order to minimise move distance, move time, and cost. These lead to a reduction of non-operational time and, consequently, MLT will be reduced. Therefore, move time needs more specific attention in this research study.

2.6.1 Summary

A wide range of characterisation and techniques have been discussed in this literature review, this review is a survey of everything that has been written about lead time. Findings', what opportunities do manufacturers have to reduce lead times? What major procedures should be considered before reducing lead times? as well as more research and testing are required to gain a better understanding or finding simple strategies for reducing lead-time. Finding the gap in past literature is bridged through complete analysis of issues pertaining to the manufacturing processes Finding that first procedure in this research study will focus on a survey questionnaire as one of the most important ways to improve competitive edge and reduce lead time; therefore, this research will modify the quick-view manufacturing assessment by converting the assessment questionnaire into a survey questionnaire to identify improvement opportunities for reducing lead time. Second, this research will focus on rescheduling capacity of planning phase and order splitting. This is because these technical approaches are important for creating a model such as a closed-loop of MRP system, which can then reschedule capacity planning in the net requirements plan for lot sizing and lead time. This makes it possible to trade-off between lot sizes and available capacity for the system. The requirements are for creating a proper planning by using the following technical tools: MRP, lot-sizing decision (lot-of-lot), splitting order, queuing model as a constant service time, and overall equipment effectiveness (OEE). Reducing lead time is important for every business because short lead times have value to certain customers; additionally, shortening delivery time is a major potential source of competitive advantage. An effective literature review analyses and synthesises information about MLT as considered in this research study; thus, it surveys all the relevant literature to determine what is known and what is not known about a particular lead time. Therefore, MLT needs more specific study in this research. While most companies seek to reduce MLT, short lead times are a major source of potential competitive advantage. Also, most factories have difficulty reducing lead time because they have overlooked it. Additionally, reducing MLT can be a daunting task due to the many factors that influence it and their complex interactions.

In order to create a proper conceptual framework as well as a research hypothesis and questions related to the research topic, this research decided to identify simple strategies for reducing MLT. Also, a range of research methods should be considered to review the various tools and techniques available for reducing the causes, defects and delays that lead to excessive lead times. This should make it possible to suggest practical and inexpensive strategies for reducing MLT, consequently leading to the creation of new modifications and information that can improve the effectiveness of the manufacturing sector and reduce excessive lead times. This could also support quicker responses to customers, as well as research and development. This is particularly important since it can be used to provide guidance to industry practitioners on how to reduce MLT and throughput time to create research aims and objectives. These can be used in order to establish the research hypothesis for this research study. Thus, this research has asked the following questions:

- What opportunities do manufacturers have to reduce lead times? How can they systematically review the potential methods for reducing lead times?
- What major procedures should be considered before reducing lead times?
- How can we improve lead-time performance?
- What major procedures should be considered to implement changes in processes that help prevent defects and ensure their early detection? How does a defect prevention mechanism work?
- How should the production planner make a decision to find or identify simple strategies for the manufacturing sector before reducing lead times?
- What problems exist? How can the relationships that caused the problem initially, consequently leading to a long MLT, be defined? Why do they exist in the production process?
- Which kind of factors and their interactions have a great impact on MLT or throughput time?
- How can the causes of excessive lead time be explored or quickly detected? What practical, inexpensive strategies for reducing MLT can we suggest?

In particular, the thesis will focus on a survey questionnaire as one of the most important ways to improve competitive edge and reduce lead time. This will be focused on instead of the 10 principles for QRM, because that survey should be considered and contributed to the implementation of the 10 principles for QRM that were recommended by Suri (2003). He also provides a summary of the 10 QRM principles that must replace the 10 traditional beliefs for delivering products and services to customers faster; thus, QRM sharpens the focus of both TQM and TBC. Therefore, this research will modify the quick-view manufacturing assessment by converting the assessment questionnaire into a survey questionnaire, which is the best way to balance both the 10 principles of QRM and the 10 traditional beliefs of time-based competition (TBC). Also, one of the main steps of creating a survey knows how best to balance both qualitative and quantitative research in the survey process. This is because they both play critical roles in ensuring that our data provides actionable insights that will allow manufacturers to make better decisions before reducing MLT. That assessment questionnaire (quick view) will evaluate the system in terms of TQM for any procedures, because the sources of the qualitative questions in that survey depended on the manufacturing assessment review; they included topics such as management practices, human resources, market management, manufacturing technology, operation management, quality management and maintenance. Therefore, the survey employs effective assessment tools to help industry practitioners and manufacturers better understand the problems and opportunities confronting their operations.

Why is the survey procedure needed?

The survey questionnaire will be an expert system-based assessment tool that will provide a preliminary analysis of a firm's strengths and weaknesses once it is benchmarked against comparable manufacturing firms. Thus, the survey is one of the future conceptual frameworks in this research study. The principles of survey questionnaires as face-to-face procedure are determined by solving the problems in project production. Moreover, the practical method involves visiting the factory, watching the production line, talking with people, knowing the current situation in the factory, and then analysing a practical project in order to take a proper decision about the guidelines for solving the problem and reducing MLT. The survey questionnaire's aims and objectives are to: identify those areas of manufacturer operations that may require some attention; identify areas of capital, defects, wasting time, delays and excessive lead time; highlight some of the non-technical parts of the manufacturer's operations that may be impeding their growth and competitiveness;

and replicate to evaluate MLT outcomes. This can be done when other data collection systems (e.g. surveillance) are not feasible. It can also be used to determine assessment tools that can be used to find defects, delays, and other factors that have a great impact on MLT. This makes it possible to resolve problems and recommend strategies for MLT reduction.

The main purpose of this literature review is how to determine or identify simple strategies before reducing lead time. In particular, the thesis will focus on reschedule capacity planning, materials requirements planning (MRP), and optimising the current layout strategy, which is possibly necessary to enable actions to reduce move time. Consequently, MLT will be reduced. This contributes to knowledge in this research framework, because MRP is a production planning system used to ensure that the parts and materials required are available. It poses three decisions: in each and every period, should I order? If so, how much? How much capacity is available? Therefore, this research will focus on interesting published papers for OR notes, which are a series of introductory notes on topics that fall under the broad field of OR. Different solutions are presented by Beasley (2012) in term of MRP and lot-sizing decisions; there has also been a focus on Johnson (2003), who published a paper on reducing MTTP in terms of optimising the current layout strategy to enable action to reduce the number of moves or the move distance necessary in order to reduce move time. Therefore, those published articles contribute to knowledge in this research framework. This research study has asked the following questions:

- How can the production planner trade-off between lot sizes and available capacity times for the system?
- How can the production planner engage in rough-cut capacity planning (RCCP) to evaluate a tentative master production schedule (MPS) with respect to available capacity time in the work centre each day?
- How can the production planner provide feedback to the capacity plan and production plan? Is planning being kept valid at all times?
- How can the production planner manage demand to synchronise with the available capacity for sum capacity requirements for each resource by time period? Also, how can they determine the appropriate planning factors using historical data?

- How can manufacturing companies make use of different bundles of manufacturing practices or different technical tools to develop certain sets of capabilities, with the ultimate goal of supporting the delivery of customer orders on time?
- How can tactics for smoothing the load and minimising the impact of changed lead time be identified?

In order to reduce lead time or minimise the impact of lead time changes, therefore, this research will focus on the reschedule capacity planning phase and order splitting. This is because these technical approaches are important for creating a model such as a closed-loop MRP system, which can then reschedule capacity planning in the net requirements plan for lot sizing and lead time. This makes it possible to trade-off between lot sizes and available capacity for the system. The requirements are for creating a proper planning by using the following technical tools: MRP, lot-sizing decision (lot-of-lot), splitting order, queuing model as a constant service time, and overall equipment effectiveness (OEE).

In terms of the purposes of creating the reschedule capacity planning, this research has the following aims and objectives:

- To reduce MRP 'buckets' from weekly to daily to perhaps hourly. Buckets are time units in an MRP and lead to the convergence of finite capacity scheduling (FCS) and MRP. This is because sophisticated FCS systems modify the output from the MRP system to provide a finite schedule. This approach can integrate MRP with just in time (JIT). Making MRP more responsive to moving material rapidly in small batches with JIT procedure will reduce the WIP inventory. Consequently, lead time will be reduced because Little's Law mentioned that WIP is throughput multiplied by cycle time (Hopp & Spearman, 2001). Little's Law for a Kanban team WIP equal throughput by multiply to lead time (Lowe, 2014).
- To enable the production planner to utilise the capacity system more effectively and still meet the order requirements or customer demands, at least moving the work between time periods to bring it within capacity.
- To smooth the load and minimise the impact of changed lead time, consequently reducing the delivery time for products.

- To enable reschedule capacity planning in order to:
    1- Reduce WIP and lower inventory level, which releases capital for other uses and leads to faster product throughput (that is, shorter lead times).
    2- Reduce floor space and reduce move time.
- To control the waiting line (queuing model) lead to determine the flow through a production process, to design systems that optimise some criteria, to evaluate alternatives in an attempt to control/improve the situation, to analyse models of waiting lines that can help managers evaluate the cost and effectiveness of service systems.
- To monitor and improve the effectiveness of manufacturing processes (i.e. machines, manufacturing cells, assembly lines) and OEE in order to:
    1- Analyse the plant operating time; the amount of time a facility is open and available for equipment operation.
    2- Determine availability (downtime loss).
    3- Identify performance (speed loss).
    4- Identify quality loss (defects that require rework).

In particular, the thesis will focus on the reliability of machines and equipment. It is very important to determine the probability that a machine part or product will function properly for a specified time under the stated conditions; thus, if a high reliability is recorded that means no delays or stoppages and less non-operational time (Heizer & Render, 2008). This is because MLT is the sum of setup time, processing time, and non-operational time (Groover, 2001). Also, less variability will occur, leading to a reduction in throughput time; consequently, MLT will be reduced (Hopp & Spearman, 2001). For example, machines subject to exponential failures and repairs lead to increased non-operational time; consequently, MLT will be increased. (Vorne Industries Inc (2008) and Hopp and Spearman, 1996, pp.78-84) stated that "to identify simple strategies for reducing lead time and their simple strategies fall into five general categories" but there is the question; which kind of technical tools could be used to identify the variable controllable and random variation for process time to failure or time to repair in order to analyse defects to get their root causes which is not mentioned by (Hopp and Spearman, 1990, p.79) , this is the "gap in the knowledge." and very little research has been done on monitoring the system in terms of the variability . However, two of them are particularly important: keeping things moving and eliminating variability. This is because random variation is the result of events like process time to failure due to unplanned machine downtime or broken machinery. This leads to increased time to repair; consequently, both non-operational time and MLT will be increased. Also, the source of the delay is one of the elements of non-operational time raised by Johnson (2003, pp. 283-297) and Groover (2001, p.46). Therefore, this research has asked the following questions:

- What is the best technical tool that should be available to perform the task of monitoring the system in order to reduce lead time and variability?
- What is the best applicable technical tool to collect evidence of problems, such as: what are the failures and delays? What are the number of defects and their severity? How does a defect prevention mechanism work?
- How can practitioners eliminate variability to support their plant to achieve better performance?
- Can Root Cause Analysis (RCA) processes help prevent defects, reworks and long MLT?
- How should we define the causal relationships that caused the problem initially? What should be considered to ensure their early detection?

KPIs are the best technical tool for monitoring the system in terms of the reliability of a machine or process and maintainability, because KPIs will play a crucial role in ensuring there is no downtime or success operation in production processes. This is because KPIs could be used to determine production availability, which leads to increased speed and quality. Also, KPIs lead to systems being monitored to measure the reliability of machines and manufacturing processes; therefore, KPIs will help to design a preventative maintenance schedule to keep operational time and production rate on schedule. It is not easy to predict the outage of the scheduling without good reason or reliable evidence, because machines are subject to exponential failures and repairs; therefore, downtime (for number of stoppages), the reliability factor, the utilisation factor, MTBF and MTTR are important factors that should be measured and considered in order to reduce lead time in terms of non-operational time, which is a major component of MLT (Groover, 2001). Therefore, the research finds that one of the contributions to knowledge in terms of eliminating variability and keeping things moving, as defined by (Hopp and Spearman , 1990, pp.78-84) in this research study because reliability is the probability that a machine will function properly for a specified time(Heizer & Render, 2008). ‘A problem clearly stated is a problem half solved’ This future framework has the following aims and objectives:

- To identify the cause of breakdowns, the source of flow-time variance can be machine downtime. This can be used to determine the capacity of a machine.
- To minimise machine downtimes in order to improve machine reliability.
- To define the causal relationships that caused long MLT initially.
- To measure the number of stoppages, MTTR, MTBF, reliability factor and utilisation factor in order to design ways to extend MTBF.
- To support the plant to achieve better performance, mainly under the RCA process.
- To identify defect tracking, this begins with a systematic process.

A wide range of characterisation techniques have been discussed, and this research has reviewed different articles based on those assessments in this chapter. However, MLT reduction can be a daunting task due to the many factors that influence it and their complex relationships (Johnson, 2003). Furthermore, this review identifies the causes of delay and the factors that contribute to the increased MLT (see Table2.2) for previous research on lead time and throughput time, and also see section 2.6 for a conceptual future framework in this research study and a further discussion of the gaps in the research). Therefore, reducing lead time is important for every business because short lead times have value to certain customers; additionally, shortening delivery time is a major potential source of competitive advantage, thus customers are increasingly sensitive to time. The main challenge is waiting time in the factory, and this should be considered because “90–95% of the time spent in a factory is spent waiting” (Hopp & Spearman, 1990), (Lowe, 2014) and (Groover, 2001). This research intends to propose a study on reducing MLT in factories in the Kurdistan region of Iraq, where lead time has become a major issue in the manufacturing industry. The aim is to provide guidance to industry practitioners/technicians on how to reduce MLT. The main objectives in order to achieve the research aims are:

- Survey-based research will be Face-to-face and it will be carried out to identify the factors that have had the greatest impact on reducing lead time, to identify the defects in the manufacturing industry (caused by increased lead time), and to identify improvement opportunities for reducing lead time.

- Case study will be done by creating a reschedule capacity planning in the net requirements plan, using different technical tools for smoothing the load and minimising the impact of changed lead time. This includes carrying out order splitting so as to reduce MLT, to utilise capacity more effectively to meet order requirements, to monitor and improve the effectiveness of manufacturing processes (i.e. machines, manufacturing cells, assembly lines), and to reduce move times. This will be done using technical tools such as KPIs to identify defects. This begins with a systematic process to identify the probability that a machine part or product will function properly for a specified time, to identify machine downtimes in order to improve machine reliability, and to measure the number of stoppages, MTTR, MTBF, reliability factors and utilisation factors.

This literature review aims to find out further alternative techniques to reduce MLT. This literature review also analyses the applicability of different techniques for MLT and throughput time reduction. The purpose of the review is the development of a framework that enables the discovery of factors that affect MLT, throughput time and various tools and techniques to optimise QRM in order to conduct an analytical investigation into lead-time reduction in the manufacturing industry because this is particularly important, as it can be used to provide guidance to industry practitioners on how to reduce manufacturing lead time.

Chapter 3- Research Methodology

3.1 Overview of available research methodology

This chapter discusses the theory behind the various tools and techniques for lead-time reduction that were used. These tools and techniques were chosen to step-by-step identify and solve problem areas to support the research study. It also presents a detailed description of the study's research methodology. The research design will be outlined with a particular emphasis on the data collection and data generation processes used to achieve the research aims and objectives.

Research methods can be classified into three distinguished methods: quantitative, qualitative, and triangulation strategies (Yin, 2003, p. 12–4). This combination method enhances validation and verification of the collected data and hypotheses, where weaknesses of one approach can be compensated by strengths of another (Yin, 2003). This research used qualitative and quantitative approaches, applying more than one method as triangulation research.

The qualitative method permits a flexible and iterative approach, while the quantitative research method permits specification of dependent and independent variables, and allows for longitudinal measures of subsequent performance of the research subject.

Quantitative research focuses on the objective rather than the subjective. In this research study, quantitative research aims at:

- Studying and examining the collected data to identify the problems based on given hypotheses or theory.
- Using a statistical technique to measure and analyse the relationships among the collected data.
- Displaying the findings and results in tables and charts.

The value of qualitative research can best be understood by examining its characteristics. One of the primary advantages of qualitative research is that it is more open to the adjusting and refining of research ideas as an inquiry proceeds. Also, that research does not attempt to manipulate the research setting, as in an experimental study, but rather seeks to understand naturally occurring phenomena in their naturally occurring states. Inductive reasoning, as opposed to deductive reasoning, is common in qualitative research, along with content or holistic analysis in place of statistical analysis (Meyer et al, 1995). A written literature review is very significant, providing research background as well as evidence and support for a point of view, argument and thesis. The literature produced to date was obtained through electronic databases and through articles, newspapers, journals and books. Other literature was written as a background for different reports, including articles convincing readers to accept changes in the manufacturing practice of reducing lead time, while other articles state a concept or strategy for readers or researchers to fully understand the topic of manufacturing lead-time reduction.

3.1.1 The research approach

In this study, a combination of survey-based research and case study was used to provide the means for an in-depth investigation of selected factories. This approach made it possible to handle each selected factory as unique and to analyse it as a single-case study (Yin, 2003, p. 12–4; Mangan et al., 2004). A large amount of statistical operations data were analysed to establish the needed evidence to test hypotheses and answer the research questions.

The aim of this research was to identify simple strategies for reducing manufacturing lead-time (MLT) in factories in the Kurdistan region of Iraq. The framework was designed to provide guidance to industry practitioners/technicians on reducing MLT or throughput time and to be used to train workers in these basic concepts. In particular, this study was conducted to assess the manufacturing sector and the strategy of factories in the Kurdistan region in terms of quick response to customers.

Following is a description of how, when and from whom data were collected in order to make such recommendations. This section also includes a discussion of the use of the inductive approach, which relies on interpretive methods such as surveys and case study-experiment strategy and on identifying common characteristics of the case studies as well as the behaviour of the investigation process from specific case findings.

The first stage of the procedure involved survey-based research. This research needed to be traced over a period of time to reflect manufacturing processes and lead time, and to find the greatest number of factors which had a significant impact on reducing lead-time. The objective of the questionnaire was to gain insight

into the MLT being studied, to identify the defects which cause an increase in lead-time and to identify improvement opportunities for reducing lead-time.
The hypotheses formulated to address the research problem were tested by using the Mann-Whitney U test, Kruskal-Wallis test, and Spearman's chi-square test. Correlation analysis was used to examine whether a particular proposition concerning the population was likely to be true or false.

The second stage of the procedure was to consider experiential case study. According to Yin (2003, p. 12–4), a case study enables researchers to use multiple methods for data collection (e.g. interviews, questionnaires, observations, analyses of documents) and for data interpretation. The case study in this research implemented various tools, techniques and practical strategies to reduce lead-time and to speed up the improvement in the quality of manufacturing processes and MLT without delays.
The case study was designed and located in the ZX Plastic Pipe factory. A face-to-face interview and workshop procedure were carried out to examine the procedure that enables the production planner to move the work between time periods to smooth the load or at least to bring the manufacturing system within capacity, consequently leading to MLT reduction. The case study used an interpersonal interaction to elicit answers pertinent to the research hypothesis by creating capacity plan. The determination of an accurate capacity plan and lead time estimates were achieved by using lot splitting as a tactic for smoothing the load, reducing the impact of changed lead time, reducing MLT, improving delivery date adherence as well as utilising capacity more efficiently to meet the order requirements. The case study used an interpersonal interaction to elicit answers pertinent to the research hypothesis by creating a new method. The case design of this research involved a hybrid exploration-explanatory approach to investigate the cause of the longer MLT. Also, this case study could be to identify the opportunities to reduce MLT and to provide a consistent approach to reducing lead-time in the manufacturing sector.

3.1.2 Summary

This section presented the means by which the research was conducted and the methods used to give it purpose and strength as a reliable and analytical study. The methods were chosen to help in the processing of the data and the formulation of conclusions. For these reasons, the study followed a descriptive research methodology that included a questionnaire survey instrument to assess the perceptions of staff members of selected factories. (See the appendix for the survey questionnaire form.)

Assessment questionnaires can have a great impact on manufacturing lead-time directly and indirectly. Designing the experiential case studies depended on several tools, techniques and practical strategies in order to give factories strategic direction and help to determine which solution should be implemented to reduce lead-time (Figure3.1).

The case study in this research has been used in many different areas of engineering management, information systems, innovation and organizational change. This reflects the versatility of the design and ability to investigate cases in depth and to employ multiple sources of evidence which makes them a useful tool for descriptive research studies where the focus is on a specific situation.

Research Theories & Literature Review	**Survey & Case-Study Methods**	**Reporting & Analysis**	**Target: Instructions & Solution**

Figure3.1: Overview of research process

According to (Mangan et al. 2004), the combination of the quantitative and qualitative techniques produces a third type of research method known as the triangulation research method. This combination method enhances the validation and verification of the collected data and hypothesis, where the weaknesses of one approach can be compensated for by the strengths of another.

Table 3.1 presents how different research strategies are designed to answer different types of research questions. This research methodology section shows that all case studies are based on the questionnaire survey results and depend on a simple hypothetical manufacturing system used to illustrate the basic factors that determine MLT and throughput time. These case studies offer valid survey results.

Table 3.1: Using different research strategies (Yin, 2003, p. 5).

Strategy	**Form of research question**	**Requires control of behavioral events**	**Focuses on contemporary events**
Experiment	How, what?	Yes	Yes
Survey	Who, what, where, how many	No	Yes
Archival analysis	Who, what, where, how many, how much	No	Yes/No
History	How, why	No	No
Case study	How, why	No	Yes

The aim of this research was to identify simple strategies for reducing lead-time in the manufacturing sector as well as to increase the understanding of the role of operations management and its immediate impact on manufacturing lead time. Reducing MLT in factories in the Kurdistan region of Iraq is important because lead-time has become a major issue in the manufacturing industry. The aim of the study also was to provide guidance to industry practitioners and technicians on how to reduce MLT or throughput time; this could be used to train workers in these basic concepts. The study also was designed to investigate how manufacturing companies make use of different practices and technical tools to develop certain sets of capabilities, with the ultimate goal of supporting the market requirements towards reducing MLT.

The primary data, from a survey and multi-case study, were gathered from a number of organisations that are applying assessment questionnaires and the principles of quick-response manufacturing to analyse the critical success factors for reducing lead time. The treatment of evidence is difficult and demanding in case studies as compared to other enquiry forms. The research coped with these challenges by employing a wide array of data collection and analysis techniques.

3.2 Overview of statistical methods and techniques

Statistical procedures are divided into descriptive and inferential statistics (Howell, 2008). Descriptive statistics are used to represent and report the measures of central tendency (mean, median and mode), measures of dispersion (range and standard deviation) and measures of position (quartiles, deciles and percentiles). Graphical representations of the data such as bar charts also are pictorial representations or descriptions of the distribution of data used. Inferential statistics are used to generalize the sample findings to the broader target population from which the sample data was collected. Statistical inference can be performed through parameter estimation or hypothesis testing (Antonius, 2003). This research used the latter, which aims to examine whether a particular proposition concerning the population is likely to be true or false. It is essential to select the most appropriate statistical technique for every hypothesis to be tested. Following is a description of the statistical techniques used in this research as well as a discussion of how to interpret survey responses for the five techniques that were implemented to make the raw responses more interpretable.

Sauro (2011) stated that there are five techniques to interpret survey responses:

- Per cent Agree (78%): An old marketing trick is to summarize the per cent of respondents who agreed to the item.
- Top-Box (56%) or Top Two box (78%) scoring: For 5-point scales, the top box is strongly agree, which generates a score of 56%. The top-two box score is the same as the agree score
- Net Top Box (50%): Count the number of respondents that select the top choice (strongly agree) and subtract the number that selects the bottom choice (strongly disagrees choice).
- Z-Score to Percentile Rank (56%): This is a Six Sigma technique that converts the raw score into a normal score because rating scale means often follow a normal or close-to-normal distribution.
- Coefficient of Variation (29%): The standard deviation is the most common way to express variability but it is hard to interpret, especially when you use a mix of scale points (e.g. 5 and 7).

The hypotheses formulated to address the research problem were tested by using Mann-Whitney U test, Kruskal-Wallis test, Spearman's chi-square test, and correlation analysis. This research used the Statistical Package for the Social Sciences Software (SPSS) software to conduct statistical analysis.

The Mann-Whitney test is a non-parametric alternative to the independent sample *t*-test. It is used to compare two independent groups when the independent variable is not normally distributed (Miller et al., 2002) or if the means of two unrelated groups of data are significantly different from one another (Miller et al., 2002). The Kruskal-Wallis test was used to determine if the means of three or more unrelated groups of data were significantly different.

The Spearman's correlation coefficient (Spearman's rho) is a measure of association between rank orders, or a measure of linear association between the variables. Spearman's rho is used for categorical or ordinal data where both rows and columns contain ordered values (Miller et al., 2002).

Reliability is an assessment of the degree of consistency between multiple measurements of a variable (Miller et al., 2002). Cronbach's alpha has been used to assess the consistency of the entire scale.

Statistical Process Control (SPC), a standard methodology for measuring defects or variability and controlling quality and lead time during the manufacturing process, also was applied. The main areas of waste, defects and inefficiency at the plant facility are identified in order to take control of quality. SPC presents problems in a format that is very easy to interpret such as a Pareto chart and a cause-and-effect (fishbone) diagram as you determine what causes equipment downtime, what causes of defects in manufacturing plants and it MLT takes so long. Therefore, with real-time SPC, you can dramatically reduce variability, cost and scrap as well as scientifically improve productivity and uncover hidden process personalities in order to make real-time decisions on the shop floor.

In research methodology, the strategic importance of forecasting was carried out. One of the forecasting methods in this research methodology was average methods (moving-average) for equally weighted observations. This is a basic assumption behind averaging and smoothing models, and it is a time series which is locally stationary with a slowly varying mean (Heizer and Render, 2008). The study also used an exponential moving average (EMA), which uses an exponentially weighted multiplier to give more weight to recent lot sizing to determine the trend of order demand when compared with a weighted moving average. **For more details** see survey measurement procedure and questionnaire design on section 4.3.3

3.3 Overview of various tools and techniques for lead-time reduction

Various tools and techniques were used to determine how to reduce manufacturing lead-time. These techniques examined the current way of working and developing an effective method based on elimination, defect tracking, and a monitoring system, as well as combining, changing and simplifying activities to reduce MLT. This research applied lean tools such as just-in-time (JIT) manufacturing, cellular manufacturing, Quick View manufacturing assessment and overall equipment effectiveness (OEE). These lean tools help reduce complex production problems into a simple, intuitive presentation of information that supports analysis of how non-value-added activities increase MLT and drive costs. The tools and techniques were used to help manufacturers systematically improve their processes with easy-to-obtain measurements, which consequently lead to reductions in MLT. In this research, material requirements planning (MRP), (MRP II) and finite capacity scheduling (FCS) plans were executed using JIT techniques based on 'pull' principles.

By merging MRP and FCS, a finite schedule can be created with feasible capacities. This facilitates rapid material movement, which leads to increased quick response manufacturing (QRM) and the creation of closed-loop MRP (Heizer and Render, 2008). This, in turn, provides feedback to the capacity plan, master production schedule and production plan, keeping planning valid at all times. Real-time planning leads to a good control system and MLT, and the implementation of a closed-loop MRP can be used to reduce work-in-process (WIP) and flow time (Heizer & Render, 2008).

Lot-sizing techniques used in this research were lot-for-lot and fixed period requirements (FRP); these require two related decisions to be made concerning timing (i.e. when to order) and quantity (i.e. what to order and how much to order).

Lot-for-lot techniques involve ordering just what is required for production based on net requirements (Heizer & Render, 2008). This research used queuing theory to analyse waiting-line production problems to ensure that average capacity is adequate for executing the plan as well as to determine the characteristics of a waiting-line system and evaluate of MLT for any causes of delays in the system. A lot-splitting, or order-splitting, technique was used to reduce lead time or minimise the impact of changed lead time because it improves the supplier's delivery reliability and hence the buyer's production schedule stability (Vandaeleb, (2006). It also enables the production planner to utilise the capacity system more effectively and still meet the order requirements or customer demands as well as to move the work between time periods to bring it within capacity (Heizer & Render, 2008). This makes it possible to trade-off between lot sizes and available capacity (minutes). To ensure manufacturing processes and machines are available; the key performance indicators (KPIs) method was used such as Overall Equipment Effectiveness (OEE). This is the best technical tool because OEE as a key performance indicator in the pursuit of maximum efficiency. OEE must have a method to measure progress in improving reliability and to set future targets. OEE tracking, reporting and analysis become fast and simple, highlighting where to focus resources. The result is dramatic improvements in productivity, which gives a rapid return on investment. OEE helps to determine system downtime and three categories of machine related losses - Availability, performance and quality which they are the source of delays. Downtime is one of components of lead time (Warren et al., 2004).

3.4 Limitations and ethical considerations

The resources from previous research and studies are very limited. The main concern in conducting this survey research was the sampling. Due to limited resources, cost and time, only a small portion of the sufficiently sophisticated staff members in the Kurdistan region were asked to participate in this survey. It is only through the researcher's personal and work relationships with these staff members that participation and completion of the survey were ensured. Sampling sometimes can be complex and often is not done well as it is difficult to define a population of interest. Most of the sample are engineers, supervisors, technicians and managers of companies who have extremely hectic schedules but are more likely to have in-depth knowledge of the subject to provide accurate reflections.

There is very little information available on the subject of factors influencing manufacturing management choices. The main limitations were, and will be, the differentiation of firms in this kind of research. Of course, all case firms will be different. Even in this survey and case-study research different firms were serving different customers with different needs and in different and changing competitive environments. Also no analysis or modifications will be made to physical material handling in the eight factories due to the firms' policy situation.

This study utilized human participants and investigated company practices. Certain issues had to be considered to ensure the participants' privacy and security. These issues were identified in advance so as to prevent problems that could have arisen during the research process. Among the significant issues that were considered were consent, confidentiality and data protection.

The main difficulty in this survey was obtaining permission to enter most of the factories. Although the research had two cover letters, some of the managers would not allow researchers to conduct both the survey and the workshop for different reasons (e.g. they were anxious about missing work time). This issue caused this project to spend more time and money because sometimes researchers had to cross more kilometres to enter the factory to do the survey and workshop.

Limitations of a study are potential weaknesses and sometimes are those things over which the researcher has no control. The main challenges and limitations in this survey resulted from the decision to undertake a survey dependent not only the on the type of information that research study required but also upon a number of human, political and financial factors because of the interview procedure.

The research was affected by limitations such as asking for the specific new techniques required to interpret the survey responses (e.g., Top-2-Box, Top-Box, Net Top Box, Z-Score to %, Percent Agree) and to resolve rating issues given the scale was a 4-point scale rather than a 5-point scale. In addition, the limitations related to the questionnaire designed previously. The challenge with a case-based approach is that there are no comprehensive templates for the case design as may be the situation with other enquiry forms. The treatment of evidence is difficult and demanding in case studies as compared to other enquiry forms. In addition, most of the eight factors do not have previous clear documents to support the purpose of lead-time analysis. The purpose of setting delimits for the survey and the case research were to establish a research environment that was constructed with firms that were experiencing similar issues in similar environments:

- Survey-based research and the case study participant had to be located in factories in the Kurdistan region

- The case firms could not have implemented any major changes in the production principles or product structures during the studied period.

The policy at several factories in Kurdistan region posed a great challenge, making it difficult to take research further. Most of manufacturing companies in the region do not have a Quick View database for manufacturing assessment and Standard Industrial Classification (SIC) codes. The database contains the responses from thousands of manufacturing companies and is indexed by the SIC codes. The firms do not have procedures on a one-to-one correspondence with SIC to enable a comparison and to better help understanding of the problems and opportunities confronting operations.

3.5 Reliability

This research used primary data from a survey and case study which was gathered from a number of organisations to analyse the critical success factors for reducing lead time and to obtain reliable, quality data for decision making. The reliability of gathering data and analyses is of great significance when performing research and the way of ensuring that reliable data is being used is to involve and obtain co-workers opinions. Results or observations from interviews can also be discussed in order to ensure that all participants have not been misinterpreted. A face-to-face interview and workshop procedure were carried out to enable the investigator to explain the questions, relate them to the processes and adjust them to the current manufacturing strategies used in the case firms. This required previous knowledge of the case firms, but since the investigator had been acquainted with the case firms during his formal working experience, this opportunity was grasped. The reliability of the quantitative data was ensured by using different approaches. The data collection principles and guidelines for the needed data were defined. In practice, this meant that sources for the quantitative data were defined, and both obligatory and supporting performance indicators were defined for the study in order to ensure the testing of the research questions. The suitability of this research methodology designed to obtain reliable, quality data to enable the right decisions to be taken also designed to simulate real world conditions. Where appropriate, consideration was given to step procedures also for measuring and data analysing in this research methodology based on ISO 9001:2000 for quality management systems requirements.

3.6 Validity

A method called triangulation has been used in this research methodology to get a clearer perception of the phenomenon. According to (Mangan et al. 2004), triangulation means that data should by gathering by using different methods and thus seeing the phenomenon from different angles. A common method of validating a measure is to test if it correlates with some objective measures or already-validated other measures therefore validating a measure refers to the extent which the measure really measures what it was intended to measure . This study could not rely purely on the correlation analysis, due to the nature of the data and their distributions as well as the graphical analyses of the data were conducted in order to build evidence for the research questions. The validity perspective was also the decision to make analysis only of sample sizes that had enough cases to be considered statistically relevant. Therefore it is important that the correct phenomenon is being measured to ensure validity. There need to be a connection between what is supposed to be measured and what actually is being measured. Also the suitability of this research methodology provides usable data and knowledge sharing in the manufacturing sector.

3.7 Summary

This chapter presented an overview of the various tools, statistical methods and techniques that were used to build a theoretical framework for analysing and integrating existing literature on MLT and quick response manufacturing. This research used primary data from a survey and multi-case study which was gathered from a number of organisations to analyse the critical success factors for reducing lead time and to obtain reliable, quality data for decision making.

The chapter also presented the hypotheses on the use of different effective assessment tools and provided an understanding of the context of the research and opportunities for use of the results. Where appropriate, consideration was given to step procedures in this research methodology based on ISO 9001:2000 for quality management systems requirements.

Building a theoretical framework led to the following research questions:

- What opportunities do manufacturers have to reduce lead times?
- How can we systematically review the potential methods for reducing lead time?
- What major procedures should be considered before reducing lead time?
- How can manufacturing companies make use of different bundles of manufacturing practices or different technical tools to develop sets of capabilities with the ultimate goal of delivering orders to the customer?
- What is the proper tactic for smoothing the load and minimising the impact of a changed lead time?
- What is the best technical tool that should be available for the task of monitoring the system in order to reduce lead time and variability?
- How can practitioners eliminate variability to support their plant in achieving better performance towards MLT reduction?

The main objectives to achieve the research aims were:

- Survey Face-to-face will be carried out to identify the factors that had the greatest impact on reducing lead time, to identify the defects in the manufacturing industry (caused by increased lead time), and to identify improvement opportunities for reducing lead time. Survey questionnaires reduce complex production problems into simple, intuitive presentation of information. They help systematically improve processes with easy-to-obtain measurements that provide an excellent gauge for measuring where a firm is and how it can improve productivity towards MLT reduction and how to incrementally revise the operations itself.
- Case study-based research: This was done by creating reschedule capacity planning in the net requirements plan, using different technical tools for smoothing the load and minimising the impact of changed lead time. Therefore only slight increases in production capacities can lead to significant reduction of manufacturing lead times. This includes carrying out order splitting so as to reduce MLT, to utilise capacity more effectively to

meet order requirements, to monitor and improve the effectiveness of manufacturing processes (i.e. machines, manufacturing cells, assembly lines), and to reduce move times.

This will be done using technical tools such as OEE to identify defects. This effort begins with a systematic process to identify the probability that a machine part or product will function properly for a specified time, to identify machine downtimes in order to improve machine reliability, and to measure the number of stoppages, downtime and the Six Big Losses are divided into three categories of machine related losses - Availability, Performance and Quality. This technique also identifies equipment with excess capacity which could be easily and inexpensively tapped.

In this research, the choice was to use survey-based research and case study to validate this research. Due to limited resources, cost and time, only a small portion of the sufficiently sophisticated staff members in the Kurdistan region were requested to participate in this research also they were hesitant to commit to the case study and they were cautious about making sources available to conduct the case study. The aims of the survey and case study were to provide insightful information about how to evaluate manufacturing processes and lead-times in the manufacturing sector, particularly concerning factories in the Kurdistan region. The purpose of this chapter was to describe the research methodology of this study, explain the sample selection, describe the procedure used in designing the instrument and collecting the data, and provide an explanation of the statistical procedures used to analyse the data. This approach enabled viable conclusions to be drawn which eventually might help organisations on the road to reduce lead time. No longer is it good enough for firms to be high-quality and low-cost producers to succeed today. Manufacturers also must be first in getting products and services to the customer fast.

Chapter 4-Survey Questionnaire

4. Survey-based research

4.1 Introduction

This chapter discusses the approach of the research, environment of the conducted research, sources of the acquired data, methodology of the data collection, methods of data analysis and data interpretation. In this research study, quantitative research aims are studying and examining the collected data to identify the problems based on given hypotheses or theory and also using a statistical technique to measure and analyse the relationships between the collected data and displaying the findings and results in tables and charts. The first stage of the procedure involved survey-based research because of the lack of quantitative studies showing the benefits of TBC and QRM, but using a manufacturing assessment questionnaire is the best research method for designing the survey as face-to-face for success in reaching the intended target. This research needed to find the greatest number of factors that had a significant impact on reducing lead time. The objective of the questionnaire was to gain insight into the MLT being studied, to identify the defects that cause an increase in lead time and to identify improvement opportunities for reducing lead time. The study followed a descriptive research methodology that included a questionnaire survey instrument to assess the perceptions of staff members of the selected eight factories in order to find the major procedures that should be considered before reducing lead time and the potential methods for reducing MLT. The application of principal and traditional beliefs of TBC/QRM in practice may be risks and also QRM was focused on lead time reduction and not on tools and methods; therefore, developing and using performance measures of lead time reduction is critical within TBC/QRM, thus this research thought that the proper and effective assessment tool is a manufacturing assessment tool that provides a preliminary analysis of a firm's strengths and weaknesses benchmarked against comparable manufacturing firms. The primary data, from a survey gathered from a number of organizations for which the survey questionnaire has been designed and based on both manufacturing assessment and the principles of quick-response manufacturing in order to analyse the critical success factors that have had the greatest impact on reducing lead time (see the appendix for the survey questionnaire form). Based on my first hypothesis the research developed the following general research questions:

1- What opportunities do manufacturers have to reduce lead times?
2- How can we systematically review the potential methods for reducing lead time?

What major procedures should be considered before reducing lead time?

The above questions are designed to illustrate these problems more clearly through a comparison between the literature and the survey questionnaire. The effects of the application of principles and traditional beliefs of time based on competitive (TBC) and quick response manufacturing (QRM) in this survey questionnaire are considered. Therefore, this research will decide to convert and create a modification on manufacturing assessment to survey questionnaire. This is because the survey questionnaire is an effective assessment tool used to help practitioners better understands the problems, defects, delays and opportunities confronting their operations see *sample of survey MLT and summary of percentage of results in Appendix.* This also enables companies to dramatically shorten their lead times to deliver products for most area more for delivery time in order to find an opportunity for reducing lead time.

4.2.1 Primary Quantitative Research

What is a Quick View (manufacturing assessment)?

Quick View (such as assessment questionnaires) will help manufacturers to better understand the problems and opportunities confronting their operations. It is an assessment tool to identify a company's competitive strengths and discover opportunities for enhancement and improvement. According to Quick View (2001), 'Quick View is a simple, but effective, assessment tool helping small and medium-sized manufacturing companies better understand the problems and opportunities confronting their operations. Responses to the questionnaire are plugged into a database comparing them to more than 3600 other manufacturing companies' standards'. According to Quick View (2001, p. 1), 'TDO is the New York state designated Regional Technology Development Centre which is a not-for-profit consulting and training organization helping manufacturing and technology companies also developed Quick View ^{TM} 3.0 also TDO committed to assisting local companies with business growth, innovation and industrial effectiveness strategies'. This Quick View approach was developed in 2001 by TDO Solution for manufacturing and technology in USA then published on Quickview@tdo.org. The assessment questionnaire leads to creating the report; it helps identify operational areas that may be impeding a company's growth and competitiveness and the advantages are: a powerful benchmarking tool for evaluating technical and business operations, continuous improvement efforts and comprehensive self-assessment also the responses to the questionnaire are plugged into a database comparing them to more than 3600 other manufacturing companies' standards (Quick View 2001).

4.2.2 Overview of Quick View

Why is Quick View important?

Quick View is a primary assessment and business planning tool that was designed in the USA in the 1990s (Quick View 2001). Also, Quick View methodology serves as a reference of management practices. The assessment questionnaire for Quick View^{TM} 3.0 includes 12 areas of management according to Quick View (2001, p. 1), which are: 'Management Practices, Human Resources, Market Management, Bidding/Quoting, Purchasing, Engineering/Design, Operations Management, Manufacturing Technology, Maintenance, Quality Management, Information Management, Pollution Prevention and Waste Minimization' (Quick View, 2001, p. 1). This is a reasonable idea, therefore this research will focus on converting manufacturing assessments to survey questionnaires so that the manager or manufacturer can evaluate the system before reducing MLT. According to Quick View (2001, p. 1), 'the assessment questionnaire and their answers will help to:

• Identify those areas of your operation which may need some attention.

• Identify areas for capital and time investment.

• Highlight some of the non-technical parts of your operation that may be impeding your growth and competitiveness'.

This research study has decided to design the survey questionnaire based on nine areas of management: management practices, human resources, market management, operations management, manufacturing technology, maintenance, quality management, engineering/design, and information management. The survey questionnaire aims to achieve the following objectives: to stimulate policy dialogue on the business environment, to help shape the agenda for reform, to assess the constraints to manufacturing sector growth and enterprise performance, and to highlight some of the non-technical parts of operations that may be impeding growth. These can all lead to an increase in MLT. Therefore, this research will seek to convert and create a modification on manufacturing assessment to survey questionnaire. The survey questionnaire should be conducted through face-to-face interpersonal interactions, as this is the major technique for collecting information, opinions and data. This survey questionnaire has great motivation for this research methodology. Therefore, survey questionnaires will support and identify simple strategies for reducing lead time. The assessment questionnaire will lead to the achievement of the following objectives: to provide statistically significant business environment indicators that are comparable across all of the world's factories; to assess the constraints to private-sector growth and enterprise performance; to build a panel of establishment-level data that will make it possible to track changes in the manufacturing sectors over time (thus allowing, for example, impact assessments of MLT, reforms and policy changes); and to identify opportunities for more research. The measurement instrument also included multiple performance factors, namely, operational performance, inventory management performance, employee performance, innovation performance, social responsibility and market performance, to cover all aspects of firm performance. This also raises additional important and relevant research topics; therefore, this will lead to the research question being answered.

4.3 Methodology

4.3.1 Survey procedure

(Why is the survey approach is needed in this research study?)

All variables can be described as more categorical (qualitative data) and there is less quantitative data in this research survey. The analytical survey aims to establish relationships and association between the attributes /objects of your questionnaire (Naoum 2013), as well as to aid planning. To move forward and achieve measurable results, a survey requires the following qualities:

- Can give a reasonably accurate estimate of the prevalence of manufacturing lead time conditions in a manufacturing process
- Can be replicated to evaluate manufacturing lead time outcomes.
- Can be achieved when other data collection systems (e.g. surveillance) are not feasible.

The survey-questionnaire instruments were used to achieve the main objective of the study. This survey consists of a standardized list of 17 questions that eliminates the chance elements of general opinion and interviewer bias, because this survey is a structured interview; it is a face-to-face interpersonal role situation in which an interviewer asks respondents questions designed to elicit answers pertinent to the research hypothesis. See *Appendix Survey MLT and the modification were done on the final questionnaire*. This stage of research methodology shows that the survey research method has been chosen to determine the factors that have been a great influence on manufacturing lead time and to identify defects and delays during the manufacturing process. The survey is used to gather data from a relatively large number of respondents within a limited time frame. In addition, a survey is concerned with a generalized result when data is abstracted from a particular sample, so the major research technique for data collection is the personal interview. In total, 160 respondents were selected from different staff depending on their job functions. Samples were gathered from eight factories. The source of qualitative questions in this survey depended on core manufacturing assessment reviews, such as: Management Practices, Human Resources, Market Management, Manufacturing

Technology, Operation Management, Quality Management and Maintenance. This survey is designed to answer specific questions that will have the greatest direct and indirect impact on manufacturing lead times. *For more details see section 3.1.1 and 3.2.1*. In this research study it was decided to undertake a survey that depends not only the type of information that you want, but also upon a number of human, political and financial factors. The data collection and data analysis are also included in that stage. Finally, the limitations of the survey procedure are discussed.

Notes: Multi-dimension constructs of the factors influencing lead time and manufacturing assessment choices. For more information regarding the research instrument, please refer to Appendix1, 2 &2.1 Survey MLT and the modification were done on the final questionnaire.

4.3.2 Sampling

Which type of sampling should be selected in this study and why?

The samples are selected on the basis of the knowledge, connection and judgment of the researcher in the field of factories. The sampling technique has been described, followed by techniques for data collection. This survey deals with selected sampling because this type of sampling is usually chosen with the interview approach such as the personal interview. Therefore, this is the major research technique available to elicit data and information from respondents

This sampling method is conducted where each member of a population has an equal opportunity to become part of the sample. As all members of staff have an equal chance of becoming a research participant, this is said to be the most efficient sampling procedure. Then, members of staff are selected on the basis of their functions in the factories in respect of the manufacturing process. For more details see Table 4.1. For this purpose eight factories were chosen as the location for this survey, which was conducted as a structured interview, i.e. it is face-to-face. In a structured interview, questions are presented in the same order and with the same wording to all interviewers. The main advantages of the structured interview are:

1-The answers will be more accurate.

2-The answers can be explored by finding out ‘why’ the particular answers are given.

For those reasons the structured interview is the preferred method, and in addition, Nachmias (1996) stated that a structured interview has more advantages. While it incurs a higher cost, it is a quicker way to find a respondent to interview.

The process will continue until the research study has at least 160 respondents willing to participate in this research. The questions have been carefully worded and documented and given to each respondent with two covering letters that explain the purpose of this research. The survey was completed between 28 August 2013 and 7 October 2013. *.For more details on this section and Table 4.1 & 4.2 see section 3.2.1, 3.2 and 3.7 and also see Appendix1, 2 &2.1 Survey MLT and the modification were done on the final questionnaire*

Table 4.1. Definition of the sampling

Definition	Description
Sampling	Engineer, technician, supervisor etc. in Kurdistan region of Iraq
Sampling unit	Eight factories (manufacturing industry) were identified
Type of sampling	Selected sampling
Extent	N/A
Time	Between 23 August 2013 and 7 October 2013

4.3.3 Design survey – questionnaire

What is the role of survey-questionnaire methodology in this research? What questions will the evaluation seek to answer?

A survey-questionnaire methodology is one of the ways to achieve answers to any of the manufacturing industry questions. The method employed by this research is totally dependent upon the nature of the question and the objectives of the manufacture research. The main role of the survey-questionnaire is to justify the means by which the study was obtained and will help in giving it purpose and strength as it will then be reliable and analytical. Also, this survey questionnaire will be an expert system-based assessment tool that will provide a preliminary analysis of a firm’s strengths and weaknesses once it is benchmarked against comparable manufacturing firms. In addition, it will help to investigate, track (defects and delays), evaluate and measure nine key areas of management for the manufacturing sector to be a focal point for strategic discussion towards reducing MLT. All these will help in the processing of the data and the formulation of conclusions. This particular survey questionnaire instrument has been chosen due to the unique characteristics of the study in the manufacturing assessment and the efficiency of data collection. This research study has designed a self-administered questionnaire for the data-gathering process to gather qualitative and quantitative data. More steps to designing a successful questionnaire were applied in this survey approach. *See Appendix1, 2 &2.1 Survey MLT and the modification were done on the final questionnaire*

Table 4.2. Specification of survey-questionnaire

Specification	Description
Techniques for data collection	Personal interview (structured interview) Face-to-face processing.
Questionnaire construction	Question format: Open and close-ended
Subjective measurements	Check list, grid, Likert scale and ranking
Statistical methods and techniques	Descriptive statistics, per cent agree %, top box %, net top box %, z-score to percentile rank %, coefficient of variation %, hypotheses formulated, Mann-Whitney U test, Kruskal-Wallis test, Spearman's chi-square test and statistical process control (SPC)
Number of questions	17 questions
Number of responses	160 responses
Design of questionnaire	Google Docs for (Form) Publishing
No. of covering letters	2 covering letters
Process of testing	Pre-test and pilot (validity) processing

The measurement procedure and questionnaire design in terms of the aims and objectives in this questionnaire-survey are summarized as follows:

1-The type of questionnaire is well designed for interpersonal contact, such as a written paper, because in every case this research has considered the respondent's ability and willingness to answer a question. In addition, the questions are presented in the same order and with the same wording to all interviewees.

2-The questions are formulated based on the objectives, research questions and hypothesis of this research study.

3-The questions are designed for personal interviews because it is the major technique for collecting factual information as well as opinions. The design of the survey-questionnaire is a face-to-face interpersonal role situation in which an interviewer asks respondents questions designed to elicit answers pertinent to the research hypothesis. See (Table 4.2)

4-The questions will follow a logical progression starting with simple themes and progressing to complex issues to sustain the interest of respondents and gradually stimulate question answering.

5-The survey will consist of close-ended and open-ended questions formulated to ensure more in-depth information is provided.

6-The survey uses a structured interview because the interviewer will have full control of the questionnaire throughout the entire process of the interview, while the respondents have plenty of opportunity to answer and understand the questions, supported by the interviewer.

7-The interviewer has a standardized list of 17 questions that are designed by Google Doc software, each respondent being asked the same questions in the same order. The closed questions also have a range of pre-coded responses available.

8-The characteristics of the questionnaire-survey will be used to investigate respondents' attitudes towards the factors influencing manufacturing lead time decisions. The Likert categorical scale will be used to measure the respondents' multi-dimensional constructs measurement, in order to score the most likely Likert categorical means, such as scale response, and also determine the question response format for three types of survey question:
Open ended ('how do you feel about...'); Closed ended (Yes/No);
Scale response ('on a scale of 1 to 5, please rate the following').

Each of these types of questions has their strengths and their weaknesses. According to David and Lori (2009) "A likert scale is great for allowing respondents to rate a specific item also it is scale from strongly disagree to strongly agree as 5 scale or 3 scale, 4 scales , 7 scales. The likert scale is a great choice for both it's visual aesthetic quality, and for it's ease of use. And the Weights: Statistics a factor associated with one of a set of numerical quantities, used to represent its importance relative to the other members of the set" for more details are shown on (Table 4.3)

9-The option questions (subjective measurement) such as checklist, grid, and ranking for constructing measurement are used.

10- A self-administered interview procedure has been applied for all kinds of personnel in the selected sample and contact information of the researcher has been provided in case a respondent has any questions. The aims to evaluate the efficiency of the strategies of manufacturing assessment review related to the manufacturing lead time, in order to determine whether its strategy is effective or not, as well as to find the opportunities for reducing manufacturing lead time.

11-The process of analysing responses is done by assigning weighting to the responses. Therefore, the process was a dichotomous approach. Firstly, for a positive impact statement the response indicating the most favourable measurement is given the highest score from the five-category scale coding. The number 5 is assigned to the most favourable measurement 'great impact' and 1 is assigned to the least favourable measurement 'less impact'. The second shows the rating scale that requires the subject to indicate staff degree of agreement or disagreement to a statement. To this type of question, the respondents were given five response choices. These options served as the quantification of the participants' agreement or disagreement on each question item. More details see (Table 4.3)

12-Process of pre-test: The last step in a questionnaire design is to test a questionnaire with a small number of interviewees before conducting the main interviews. This kind of test run can reveal unanticipated problems with question wording; instructions to skip questions, in order to see if the interviewee understands all the questions and gives useful answers. The process of amending is done by correcting some types of question.

13-Process of pilot survey (**validity**) after pre-test: In order to test the validity of the evaluation tool that is used for this study, this research tested the questionnaire with five respondents. These respondents, as well as their answers, were not part of the actual study process and were only used for testing purposes. After the questions had been answered, the researcher asked the respondents for any suggestions or any necessary corrections to improve the instrument further. This research modified the content of the questionnaire based on the assessment and the suggestions of the sample respondents. This process is completed before the final survey commences.

14- Ethical considerations: As this study utilized human participants and investigated company practices, certain issues were addressed. The consideration of these issues is necessary for the purpose of ensuring the privacy as well as the security of the participants. Two cover letters have been written by University and Union of Engineering in ' Sulaimaniyah ' city to support this survey in terms of ethical.

15- The title of the survey in the questionnaire-survey needed to show the aim and objectives of this survey, as well as to explain the purpose of this research, its relevance and two covering letters from two institutions, such as Engineering Union and Slemani Polytechnic University in the Kurdistan region, were documented and addressed to each factory to explain the purpose of this research. Both were general letters to seek their agreement to participate in this research. This process completed as the final survey commenced.

Different kinds of designated quantifications have been used in the questionnaire-survey ***as shown below*** *and also see how survey has done and where and when research study has been done it, refer to sections (3.1, 3.1.2, 3.2 and 3.7). To see the factory names that participated in this research survey and the signatures of managers refer to Appendix2 Survey MLT.*

Table 4.3. Different kinds of designated quantifications

<table>
<tr><td colspan="5">Ranking</td></tr>
<tr><td>1 Less impact</td><td>2</td><td>3</td><td>4</td><td>5 Great impact</td></tr>
<tr><td colspan="5">Grid</td></tr>
<tr><td colspan="5">Extremely, Moderately, Slightly, Not at all</td></tr>
<tr><td colspan="5">Likert</td></tr>
<tr><td colspan="5">Strongly-Agree, Agree, Neutral, Disagree, Strongly- Disagree</td></tr>
<tr><td colspan="5">Level of qualitative frequency (checklist)</td></tr>
<tr><td colspan="5">Mostly Often Rarely None</td></tr>
</table>

4.3.4 Data collection method

Data for this survey were gathered from 23 August to 7 October 2013. A questionnaire survey (Design) was carried out from 18 to 23 August see (Figure 4.1) The questionnaires were distributed and a total of 160 staff were interviewed, consisting of 21 engineers, 54 technicians, 11 managers, 29 supervisors and 45 staff with varying functions. Staff representatives from different levels of function were interviewed from 9 September to 7 October 2013. The data were recorded and updated simultaneously as responses were received. The results have been organized in Google Docs and then transferred to a Microsoft Excel spread-sheet with the code sheet that has been developed to measure the attitudes from the data of the survey results. The data is organized into separate rows and columns with the assigned attitude score. The responses to each question have been assigned with numerical values for the data analysis, so the data collection method will have a strong impact on the questionnaire design. This research study refined the questionnaire based on the comments taken from the company representatives (respondents), managers and academicians also revised the questionnaire after conducting a pilot study and taking feedback from the respondents to make it simple, clear, understandable, and easy-to-follow. The Google Docs software generates a wide variety of questions that are designed by the researcher and saved as a view live paper (form) by clicking the View Lives Form option. It is also printed, in preparation for the process of recording responses by this research. Then it will give the confirmation page for a recorded response and will also give four options, such as: Show link to submit another response; Publish and show a link to the results of this form to all respondents; Allow responders to edit responses after submitting and, most importantly, to send the form. After the process of designing the survey-questionnaire and recording all responses, Google Docs records all data from the researcher or responder and this is sent to a spread sheet. From the spread sheet, Google Docs can save all data in XLS or CSV format, in order to send for further statistical analysis by SPSS software. In addition, clicking on the Responses option will show a summary of responses (results), as well as charts. The survey is used to gather data from a relatively large number of respondents. For this purpose 8 factories were chosen as locations for this survey of 17 questions and the process will continue until this research has at least 160 respondents willing to participate. Figure 4.1 shows the number of daily responses. The duration of the survey process is referred to in the daily chart below from 23/8/2013 to 7/10/2013. *For more details see Appendix1&3*

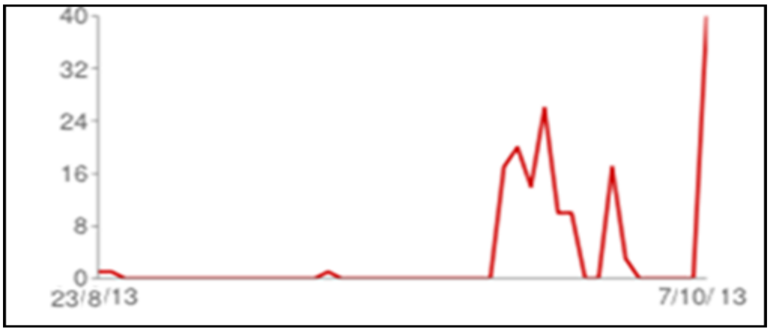

Figure 4.1. Number of daily responses

4.3.5 Data analysis procedures

What decisions or actions are likely to be influenced by the results?

Data analysis procedures for the survey questionnaire were completed on 12 February 2014 and processed using Google Docs software, which was converted to Microsoft Excel, with additional analytical software such as SPSS. The statistical analyses that have been conducted include: overall multi-dimension constructs of measurement towards each factor, descriptive statistics, regression statistics, non-parametric and parametric tests. The summary of the whole results was collected into 25 pages (refer to appendix MLT survey). The data are categorized into direct impact factor and indirect impact factor on manufacturing lead time and the same descriptive statistical analysis was performed to provide comparisons. Mann-Whitney, Kruskal-Wallis & Chi-Square tests are used for statistically significant association between the multi-dimensional construct measurement towards each factor and the actual percentage of each of the statements. The SPSS analysis showed that the factors were logical and reflected accurately what was intended to be measured. This research study also classified the reasons of and the barriers to total quality management practices of firms in Kurdistan region according to frequency distribution of the sample. The line fit plot is provided for illustration of the correlation and to predict the relationship between each factor and actual investment. Since the sample size is small, non-parametric Mann-Whitney U statistics are used to test the hypothesis and p-value is computed. The computed t-test: Two Samples Assuming Equal Sample Variances are also used for reference and comparison. Tabulations and charts are provided for ease of comparison between different categories. Five techniques to interpret survey responses have also been implemented such as: per cent agree top-box, z-score to percentile rank, and coefficient of variation (CV) %. Analyses of the survey questionnaire are also provided for ranking factors and descriptive. Survey other information related to the primary function of staff, experiences, skill, feedback, quality assurance, quality control are provided by statistical process control (SPC), which is standard methodology for measuring defects or variability and organized in pie , bar charts, Pareto chart and cause-and-effect diagram. For more details on statistical methods and techniques see *Appendix4, 5 & 6 also Chapter 3, sections 3.2, 3.4, 3.5 and 3.6* for an overview of statistical methods and techniques, limitations and ethical considerations, reliability and validity in this research study.

4.3.6 Survey questionnaire and the role of knowledge sharing

This research study used Google Forms, which is basically a way of conducting a survey, with participants' responses added automatically to a spread-sheet. Google Forms is one of the best online survey tools and is absolutely free. Online surveys originated in market research and are now widely used in academic research. This research made use of Google Forms because in comparison to Survey Monkey, Zoomerang and Survey Gizmo it is much better in three ways: researchers can customize their brand image, allow for more than 200,000 responses and export their survey questionnaires and results to PDF or a Word document (Henderson 2012).

Furthermore, the survey themes are robust; e-mail or web-embedding is easy; and there are a number of ways to visualize your data. The study also employed social media tools in order to revitalize research methodologies through setting up a YouTube channel for training and using Facebook and LinkedIn for brand promotion, joining groups and gaining insight into hundreds of companies' corporate structures. Social media was used to ask questions and share knowledge in order to solve problems faster once all questions had been designed on Google Forms. In preparing for gathering data via surveys and for sharing information, researchers should take into account these four features before sending out requests for responses:

- Showing a link to submit another response by selecting the appropriate box will allow users to submit as many form responses as they would like.
- Publishing and showing a link to the results of the form by selecting the appropriate box will give respondents access to the form's summary of responses. Allowing respondents to edit responses after submitting their answers will allow respondents to change their answers to the live form.
- Pre-populate form answers: respondents can be presented with a form with some fields already filled in; Google Forms makes this easy. Pre-populate forms answer fields by, while working on the form, clicking the 'Responses' menu, then selecting 'Get pre-filled URL'.
- Share a form with collaborators: share a form with a collaborator by clicking 'File' and then 'Share'. Choose whether to share the form for editing by managers, supervisors, practitioners or engineers

For more details see Appendix1. The procedures of using knowledge sharing is an important factor to identify improvement opportunities for reducing lead time to gain insight into different opinions between firms and customers, also to gain insight into the MLT reduction, and to investigate how manufacturing companies make use of different practices and technical tools to develop certain sets of capabilities, with the ultimate goal of supporting the market requirements towards reducing MLT. The conception of knowledge sharing and social media are contributions to the research and development (R&D), which is a diagnostic aid that matches potential solutions that can be used to shorten manufacturing lead time, improve efficiency and productivity. *See last page of Appendix1for linking to knowledge sharing.*

4.3.7 Summary

The main purpose of this chapter was to describe the research methodology of this study, explain the sample selection, describe the procedure used in designing the instrument and collecting the data, and provide an explanation of the statistical procedures used to analyse the data. The main role of the survey-questionnaire is to justify the means by which the study was obtained and will help in giving it purpose and strength as it will then be reliable and analytical. The survey tested the hypothesis with firms in the Packaging for Oil & Gas sector; Basic Materials (paper and plastic) sectors and Industrials sector (cement) using a face-to-face procedure, which ensured the answers were in-depth and accurate.

4.4 Results and Discussion

4.4.1 Survey questionnaire

4.4.1.2 Questions testing the importance of human resources factor

One hundred and sixty people were randomly selected to participate in the survey. This survey questionnaire covers the general functional requirements of MLT reduction. Survey-based research participant had to be located in eight factories in the Kurdistan region. The principles of survey questionnaires as a face-to-face procedure were applied in this research study. 160 responses to each question comprised staff members' opinions and suggestions on how to improve lead time reduction. *For more details on summary report of frequencies and percentage see appendix3 for 160 responses of survey MLT*

Table 4.4. Frequencies from participants have different primary functions

Valid	Frequency	Per cent	Valid per cent	Cumulative per cent
Engineer	21	13.1	13.1	13.1
Technical	54	33.8	33.8	46.9
Manager	11	6.9	6.9	53.8
Supervisor	29	18.1	18.1	71.9
Unspecified job	45	28.1	28.1	100.0
Total	160	100.0	100.0	

Figure 4.2. Staff experience

Every company need to measure the attitudes of their employees, through my dealings with employees all the participants have different primary functions with different experience. Referring to Table 4.4 and Figure 4.2, the responses to each question were assigned to the manufacturing assessment, which asked the respondents to answer the assessment questionnaire. The response rate was 100% and the summary of 160 responses indicates that all the participants have different primary functions. Also, among the 160 staff were 22 engineers, 54 technicians, 29 supervisors, 10 managers and 45 staff with different, unspecified jobs. Referring to Table 4.4 indicates that 28.1% of 160 staff have unspecified jobs due to lack of experience and skills, also unspecified jobs are greater than 21% of engineers and 29% of supervisors, thus the level of experience and skill have a great impact on work in process during in manufacturing processes because less opportunities method for solving problems (analysing + understanding) will be gained then defects and delays will be increased, consequently work in process and MLT will be increased . The survey shows that 76% of them have experience of between one and three years and 24% of them have more than three years' experience. Focusing on the level of experience and the participants' functions are the most important factors in their knowledge of the level of system performance. 160 responses to each question comprised staff members' opinions and suggestions on how to improve lead time reduction. In addition, these factors inform these staff members' opinions and suggestions to improve lead time reduction towards reducing MLT. Refer to Table 4.2, Table 4.4, and Table 4.5 indicating that the level of experience with skills needed to keep production at the top efficiency requires planning, also the severe shortage of manufacturing skills and years of experience today has the potential to impede the trend of steady grown in manufacturing companies. Also, an impeded manufacturing process will lead to increase working in process and consequently MLT will be increased. Therefore, years of experience, skills and different primary functions among the staff are directly linked to performance improvements in the manufacturing plant; also, they are engaged in continuous improvement and facilitate to reduce defects, delays, work in process, down time in the manufacturing process and MLT

Mann-Whitney U test: It is a non-parametric test; it's used if the means of two unrelated groups of data are significantly different from one another or to compare differences between two independent groups. The Mann-Whitney test is very useful because it indicates which group can be considered as having the higher categories of how long you have been working within your organization, overall; namely, the group with the highest mean rank. It shows the actual significance value of the test. Specifically, the test statistics table provides the test statistic, U value, as well as the asymptotic significance (2-tailed) p-value. These hypotheses are stated as follows:

H_0: p = 0 (There is no significant difference in staff level of experience existed within the shortages of quality management)

$H_{a:}$ $p \neq 0$ (There is significant different in staff level of experience existing within the shortages of quality management)

a. Which of the following shortages are likely to limit your ability to work? [Quality management]: How long have you been working within your organization?

H0: p = 0 (There is no significant difference in staff level of experience existing within the shortages of skilled labour and technical staff)

Ha: $p \neq 0$ (There is significant difference in staff levels of experience existing within the shortages of skilled labour and technical staff)

a. Which of the following shortages are likely to limit your ability to work? [Skilled labour and technical staff]: How long have you been working within your organization? Table 4.5 shows that the data on 'Quality management' – the results suggest that there is statistically a significant difference between the underlying distributions of 'Quality management' scores of between 1 and 3 years and 'Quality management' scores of more than 3 years. It can be concluded that between 1 and 3 years is statistically significantly higher than the more than 3 years (U = 1807.500, p = .014). The decision rejects the null hypothesis. This is shown in Table 4.5

Table 4.6 shows the data on 'Skilled labour and technical staff'. The results suggest that there is no statistically significant difference between the underlying distributions of 'Skilled labour and technical staff' scores of between 1 and 3 years and 'Skilled labour and technical staff' scores of more than 3 years. It can be concluded that between 1 and 3 years is not statistically significantly higher than the more than 3 years (U = 2046.500, p = .207). The decision accepts the null hypothesis. This is shown in Table 4.6. The significant difference is in quality management affecting ability to work. Newer 1–3 year employees place significantly more importance on quality management. Improving company procedures is again significant, with newer employees placing less importance on it than older ones, therefore indicating staff who have more experience than 3 years are much better than the staff who have experience between 1 and 3 years, which means that lack of quality management, skilled labour, technical staff and staff experience exist in eight factories in the Kurdistan region, also indicating that most of the eight factories have not provided enough more staff experience, staff technical, skilled labour and professional training to employees in order to improve companies procedures and their performances, which are the most important factors to support practical strategy for lead time reduction. Therefore, the role of human resources in terms of level of experience, technicians and skill have a great impact on increasing the capacity of system thus manufacturing processes will become more efficient, consequently leading to improved manufacturing lead time reduction towards sustainable manufacturing to reduce variations in manufacturing processes.

For more details on the Mann-Whitney U test for different statements see appendix5 for the Mann-Whitney U Test of survey MLT.

Table 4.5. Mann-Whitney U test results from level of experience

Ranks				
	How long you have been working within your organization?	N	Mean rank	Sum of ranks
Which of the following shortages are likely to limit your ability to work? [Quality management]	Between 1 and 3 years	120	83.44	10012.50
	More than 3 years	38	67.07	2548.50
	Total	158		
Test statistics[a]	Which of the following shortages are likely to limit your ability to work? [Quality management]			
Mann-Whitney U	1807.500			
Wilcoxon W	**2548.500**			
Z	−2.464			
Asymp. Sig. (2 tailed)	**.014**			

Table 4.6 Mann-Whitney U test results from level of experience

Ranks				
	How long you have been working within your organization?	N	Mean rank	Sum of ranks
Which of the following shortages are likely to limit your ability to work? [Skilled labour and	Between 1 and 3 years	121	82.09	9932.50
	More than 3 years	38	67.07	2787.50
	Total	159		
Test statistics [a]				
	Which of the following shortages are likely to limit your ability to work? [Skilled labour and technical staff]			
Mann-Whitney U	2046.500			
Wilcoxon W	2787.500			
Z	−1.261			
Asymp. Sig. (2 tailed)	**.207**			

Kruskal-Wallis Test

Kruskal-Wallis nonparametric tests are used to test the significance of the difference amongst the categories of primary function within your organization (independent variable). The nonparametric tests do not make assumptions about the parameters of a distribution, nor do they assume that any particular distribution is being used. ‘The Kruskal-Wallis is one way ANOVA analysis of variance test, this is a test for several independent samples and it compares two or more groups of cases on one variable when you have data that are not symmetric, such as skewed data and statistical inference can be performed through parameter estimation or hypothesis testing also the hypothesis with the Kruskal-Wallis was evaluated by testing the chi-square value’’ (Antonius, 2003). The Kruskal-Wallis tests for multiple independent samples are used in determining whether or not the dependent variables differ between two or more ranks. The Kruskal-Wallis test uses ranks of the original values and not the values themselves in its test. The hypothesis with the Kruskal-Wallis test was evaluated by testing the chi-square value.

For more results and details on the Kruskal-Wallis test for different statements see appendix4 for Kruskal-Wallis test of survey MLT.

These tests were hypothesized as follows:

H_0: p (There is significant difference in informing the customers when orders are expected to be late in all the participants that have different primary functions).

Ha: p (There is no significant difference in informing the customers when orders are expected to be late in all the participants that have different primary functions)

H0: p (There is significant difference in 'Improve Company Procedures' in all the participants that have different primary functions).

Ha: p (There is no significant difference in 'Improve Company Procedures' in all the participants that have different primary functions).

H_0: p (There is significant difference in increasing production control, scheduling in all the participants that have different primary functions).

Ha: p (There is no significant difference increasing production control, scheduling in all the participants that have different primary functions)

The sum and average rank for each rank within dependent variables are shown in the following in Table4.7, Table 4.8 and Table 4.9.

Table4.7 shows that there was no statistically significant difference in 'Customer / Contractor' in all the categories of primary function within your organization (chi-square statistic = 4.809, p-value = 0.307). There was no statistically significant difference between the 'Customer / Contractor' in all the categories of primary function within your organization therefore the decision is rejecting the null hypothesis therefore accepting (Ha = 4.809, p-value = 0.307), meaning that there is no significant difference in informing the customers when orders are expected to be late in all the participants have different primary functions, therefore the set of tests look at differences according to job type (Kruskal-Wallis). It was found that all participants are informed that the order became late on delivery time across all eight factories therefore long response manufacturing existed because their responses to questions, this is indicator for long manufacturing lead time; amongst the different job types in this survey. In addition, Table4.7 indicated that a Manufacturing Requirements Planning (MRP) system for work orders is not timely, inaccurate, and unreliable; it is an indicator that long MLT exists.

Table 4.8 shows that there was statistically significant difference in ‘Improve Company Procedures’ in all the categories of primary function within your organization (chi-square statistic = 15.921, p-value = 0.003). There was statistically significant difference between the ‘Improve Company Procedures’ in all the categories of primary function within your organization, therefore there is significant evidence to accept the null hypothesis (H_0 = 15.921, p-value = 0.003). Therefore, there are significant differences among all staff; specifically, managers and engineers seem to think improving company procedures is significantly more important than the others by looking at the mean rank for each category which is higher than the mean rank of supervisors, unspecified jobs and technical staff thus they suggest from their own experiences that the best solutions would improve the reduction of lead time by improving their company procedures in all areas of management practices, human resources and operations management. This finding that identifies those areas of operation that may need some attention especially as improving operations management and human resources in order to reduce MLT.

Table 4.9 shows that there was statistically significant different in ‘Increase production control, scheduling’ in all the categories of primary function within your organization (chi-square statistic= 11.726, p-value = 0.020). There was statistically significant difference between the ‘Increase production control, scheduling’ in all the categories of primary function within your organization, therefore there is significant evidence to accept null hypothesis (H_0 = 11.726, p-value = 0.020) because there is significant difference in increasing production control, scheduling in all the participants have different primary functions. Therefore, there are significant differences among all staff, specifically in supervisors and engineers who seem to support increasing production control and scheduling because those two factors are more important factors to reduce lead time. The mean rank for supervisors and engineers is higher than the mean rank of other categories, therefore the overall trend of engineers, supervisors and technical staff, is valued more highly by thinking that improving procedures, production control and scheduling are proper solution factors to reduce MLT.

Table4.7 Kruskal-Wallis test results from participants have different primary functions

NPar tests	Ranks		
What is your primary function within your organization?		N	Mean rank
Do you inform your customers when orders are expected to be late? [**Customer / Contractor**]	Engineer	21	87.45
	Technical	54	88.06
	Manager	11	67.50
	Supervisor	29	75.38
	Unspecified job	45	74.67
	Total	160	
Test Statistics [a,b] **a.** Kruskal-Wallis Test. **b**. Grouping variable: What is your primary function within your organization?			
	Do you inform your customers when orders are expected to be late? [**Customer / Contractor**]		
Chi-square	**4.809**		
df	4		
Asymp. Sig. (2 tailed)	**.307**		

Table 4.8 Kruskal-Wallis test results from participants have different primary functions

NPar tests Ranks			
What is your primary function within your organization?		N	Mean rank
Which of the following solutions would improve the reduction of the lead time in your company? [**Improve company procedures**]	Engineer	21	98.90
	Technical	54	79.56
	Manager	11	114.45
	Supervisor	29	78.17
	Unspecified job	45	66.24
	Total	160	
Test Statistics [a,b] **a.** Kruskal Wallis Test. **b**. Grouping variable: What is your primary function within your organization			
	Do you inform your customers when orders are expected to be late? [**Customer / Contractor**]		
Chi-square	**15.921**		
df	**4**		
Asymp. Sig. (2 tailed)	**.003**		

Table 4.9 Kruskal-Wallis test results from participants have different primary functions

<table>
<tr><td colspan="4">NPar tests Ranks</td></tr>
<tr><td colspan="2">What is your primary function within your organization?</td><td>N</td><td>Mean rank</td></tr>
<tr><td rowspan="6">Which of the following solutions would improve the reduction of the lead time in your company? [Increase production control, scheduling]</td><td>Engineer</td><td>21</td><td>92.81</td></tr>
<tr><td>Technical</td><td>54</td><td>73.80</td></tr>
<tr><td>Manager</td><td>11</td><td>72.68</td></tr>
<tr><td>Supervisor</td><td>29</td><td>94.05</td></tr>
<tr><td>Unspecified job</td><td>45</td><td>75.98</td></tr>
<tr><td>Total</td><td>160</td><td></td></tr>
<tr><td colspan="4">Test Statistics [a,b] a. Kruskal-Wallis Test. b. Grouping variable: What is your primary function within your organization?</td></tr>
<tr><td></td><td colspan="3">Do you inform your customers when orders are expected to be late? [Customer / Contractor]</td></tr>
<tr><td>Chi-square</td><td colspan="3">11.726</td></tr>
<tr><td>df</td><td colspan="3">4</td></tr>
<tr><td>Asymp. Sig. (2 tailed)</td><td colspan="3">.020</td></tr>
</table>

4.4.1.2.1 Summary

Finding the role of human resources in terms of level of experience, technicians and skill is very important and should be considered to improve the capacity of companies. It also provided a list of areas in which improvement might be possible, based on their firm's responses to the survey-questionnaire. For example, a higher level of experience with different skills could evaluate, predict and inform the system that the order will become late. Also, their suggestions and opinions on how to improve MLT are important factors because they have significant feedback to support the plants to improve company procedures and increase production control and scheduling in order to find the proper solutions to get shorter MLT. Therefore, implementing better human resource strategies will improve productivity, reduce human error consequently leading to reduce lead time because human resource leaders now challenge their function to re-engineer their own processes in order to improve quality and cycle time. Different levels of experience with skills have a great impact on reducing handoffs because removing staff that have less experience from the process eliminates handoffs because every handoff is an opportunity for a delay or an error. Increasing skill level within years of experience and functional flexibility of the workforce needs to be the top choice for operations management towards manufacturing lead time reduction. This survey provided a detailed picture of eight factories' strengths and weaknesses, as indicated by the responses to the survey-questionnaire as well as indicating that a manufacturing requirements planning (MRP) system for work orders is not timely, inaccurate, and unreliable. Also, work-in-progress isn't timely, maybe due to insufficient operations management and human resources, also indicating that management isn't aware of the current plant capacity in terms of manpower and shop hours because most of the factories informed their customers when orders are expected to be late. In terms of human resources procedures, motivation, commitment and level of experiences indicated that most of the eight factories needed improvement in human resources, thus this survey indicated that human resources in the eight factories have between average and low ranking. Therefore, all eight factories need improvement in the following areas:

1- Human resource procedures for different primary functions, staff experience, skills and to ensure the extent to which the daily management of human resource practices helps to deal with employees in a constructive way and encourage improvements.
2- Motivation, commitment and training for the set of mechanisms should be established to develop and improve employees' knowledge and/or skills in job-related areas. They should emphasize empower work cells and teams to take ownership for the entire value stream in order to reduce lead time.
3- All the eight factories should consider the skills, capabilities and resources as well as ensure the companies very often struggle to invest dedicated personnel towards continuous improvement in order to reduce lead time.

Therefore, all factories should place a greater emphasis on a better human resources policy that can improve company performance by increasing staff skills, abilities and training, which are seen as vital to sustained competitive advantage, thus it is a simple practical strategy for reducing lead times. Also, these areas of human resources and management practice have been identified as needing some attention and indeed they should be improved before starting to reduce lead time. Lack of human resources procedures and management practice may cause low flexibility, decreased resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times.

4.4.1.3 Questions testing the importance of critical management factors

This survey based assessment questionnaire provides a detailed picture of eight companies' strengths and weaknesses as well as determining the factors that have been a great influence on manufacturing performance and MLT. Focusing on the area of management practices, quality management, information management and operations management will help further validate the argument of the research and also can help achieve MLT reduction. The main functional areas of management are important factors that should be considered and improved before starting to reduce lead time.

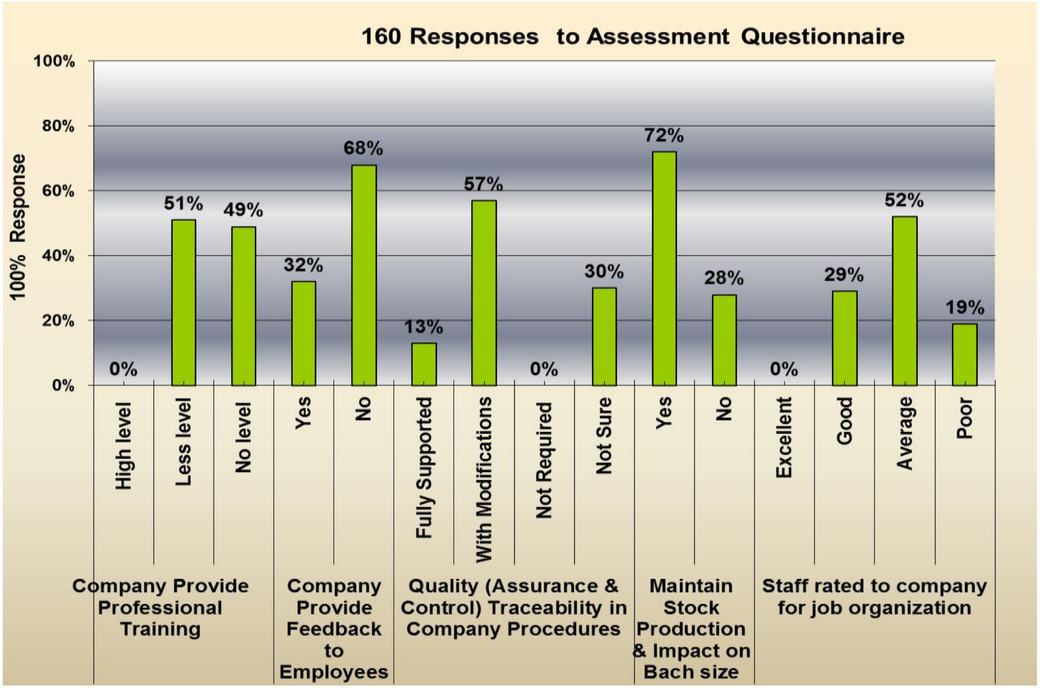

Figure 4.3. Responses to management practices and human resources assessment

Figure 4.3 shows that most of the eight factories have not provided enough professional training and feedback to employees and 51% of respondents have a lower level of professional training but 49% of others have no professional training. In total, 68% of participants suggested that their companies did not provide enough feedback to their employees in order to take pride in their work. Also, it seems that most of the factories did not provide regular, helpful feedback to their employees in a manner that encourages them to say job well done or job correction is needed. This is insufficient monitoring of the system and the responsibilities of supervisors or managers are not clearly defined, for example, the role of training, management and commitment to training as well as developing the workforce and increasing employee skills and abilities.

The assessment questionnaire noted that most of the eight factories have not enough quality assurance, quality control and traceability in place in their company procedures. This means that the quality management system has not been developed in accordance with the requirements of ISO 9001:2000; only 13% of the participants mention fully supporting company procedures. Therefore, these statements provide the major direction for reducing defects in each step, measures that should be taken before the next step. It is also noted that the responsibility is not clearly defined in a written quality plan for the investigation, evaluation, and solution of quality problems. Also, employees did not know that they are made aware of the standard of quality that is expected of them. Figure 4.3 shows that 72% of the responses mentioned that the company maintained stock production. This affects decisions about batch size for products because 90% of respondents noted in this survey that the company informs their customers when orders are expected to be late (see appendixes for 160 responses of survey MLT). Also, there are inventory build-ups (bottlenecks) at one or more particular points in the production process. This is one of the signals of improper MRP and lot-sizing decisions. This survey asked respondents to rate their companies on job organization. In total, 52% of respondents referred to an average situation and none of the 160 respondents mentioned an excellent situation; this is inappropriate work planning and there is no definition of management, and upkeep of the methods by which the jobs flow through a company's facility. Therefore, these areas of management practice, human resources, quality management and operations management have been identified as needing some attention and they should be improved before starting to reduce lead time.

Figure 4.4 shows the statements of shortages and limitations related to employees have limited ability to work at eight factories. Participants were invited to answer the following questions:

1. Which of the following shortages are likely to limit your ability to work?
2. To what extent have the following limited your current abilities?

A total of 69% of respondents indicated that lack of skilled labour and technical staff seriously limited their ability to work, this means due to an insufficient set of mechanisms established to develop and improve employees' knowledge and/or skills in job-related areas. The shortage of quality management indicated that 17% of respondents limited seriously their ability to work and 75% of respondents limited slightly their ability to work; it seems that responsibilities of supervisors and managers are not clearly defined in a written quality plan for the investigation, evaluation, and solution of quality problems and also their companies do not track and document rework and/ or scrap reasons are not investigated and resolved. The shortage of planning for lot-sizing policy indicated that 55% of respondents seriously limited their ability to work and 45% of respondents limited slightly their ability to work, which means that most of the factories have inappropriate policy planning for operations management due to manufacturing requirements planning (MRP) system for work orders being not timely, inaccurate, and unreliable. Also, batch size or lot-sizing are inappropriate decisions because of forecast errors that tend to increase with the forecast horizon. This is one of the factors that caused long lead times in manufacturing. It seems there are inventory build-ups (bottlenecks) at one or more particular points in the production process and work-in-process is not timely, consequently leading to limiting staff's ability to work. Also, it seems that one of the causes is the amount of potential work in outstanding quotes is not known and used when forecasting shop loading. Figure 4.4 shows the shortage of equipment, machine and using technology indicating that 21% of respondents limited seriously their ability to work and 67% of respondents limited slightly their ability to work. It seems that an overhaul of equipment and machine on their production floor is not defined as major refurbishing or replacement of equipment and machine during the average age or time in years and also measuring devices and machines are not periodically calibrated as a maintenance procedure. In addition, the conditions of equipment's or machines' moving parts are not checked to ensure functioning within tolerances. Appropriate measuring devices are not readily available and used to achieve the quality required. Those conditions that are discussed above have significant factors leading to inefficient manufacturing, consequently causing long MLT. The shortages layout for operations management indicated that 95% of respondents limited seriously their ability to work and 4% of respondents limited slightly. Maybe most of the factories have lower utilization of space, equipment, and people and also less employee morale and safer working conditions with interaction, less flexibility, less flow of information and less moving material, employees between various work areas. Therefore, all the eight factories need to improve their layout decision and should consider the best placement of machines (in production settings), offices and desks (in office settings) or service centres. The objectives of layout strategy are to develop an effective and efficient layout that will meet the firm's competitive requirements. This will also lead to increasing manufacturing efficiency thus manufacturing lead time will be decreased because the layout strategy will reduce move time and also improve the accuracy and speed. A better layout could change the organization from functional orientation to product orientation; this procedure is one of the principles of reducing lead time. Figure 4.4 shows that the limitations of staff abilities to work at eight factories are: Company policies, lack of communication on workshop floor and no shifts are regularly scheduled per day. 70% of respondents have slightly limited staff abilities while 12% of respondents have limited seriously staff abilities due to company policies. Furthermore, 51% of respondents have slightly limited staff abilities due to the lack of communication on the workshop floor and 82% of respondents have slightly limited staff abilities due to no shifts being regularly scheduled per day. With those conditions it seems that most of the factories have unclear policies because the set of mechanisms is insufficiently established to ensure proper flow of information from upper levels of managerial hierarchy to lower levels, especially as regards dissemination of strategic goals and associated departmental responsibilities. Also, the procedure of management practices is unclear and should ensure that the daily management of human resource practices helps to deal with employees in a constructive way and encourages improvements also to ensure the strategic goals in written form are communicated from top management to all employees. Also, the strategic goals in written form are not communicated from top management to all employees.

Figure 4.4 shows that stock supply and/or in time deliveries will limit staff abilities which are indicated that 39% of respondents indicated seriously limited staff abilities and 58% of respondents indicated slightly limited staff abilities indicated for the high level of production rate during every day. 88% of respondents indicated seriously limited staff abilities for sudden changes in transfer batch size decision.

With this high level of production rate, in those conditions it seems that the information generated by the manufacturing requirements planning system for on-hand inventory, work-in-process and lead time analysis is not timely, accurate, and reliable as well as it seems that inappropriate transfer batch sizes have been done when they moved to next workstation due to lack of capacity plan and production planner that situation. It seems that the workload consistently exceeded work-centre capacity and also that the situation leads to limited staff abilities to work properly. It is clear that small batch sizes or smooth lot-sizes can reduce work-in-process under a proper capacity plan system; consequently, MLT will be reduced as well as leading to more facilities in order to get more staff abilities for working. The shortages of different areas of management may cause limitations of staff ability to work and may cause low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, which will potentially affect critical delivery dates. All factories need improvement in those areas of management and corrective actions will be required. In this section of the survey, a preliminary analysis of staff's limited ability to work was demonstrated.

Therefore, the assessment questionnaire designed for this survey has several benefits to get early indications of potential problems or defects and lead to taking corrective action to avoid long MLT and a late delivery time.

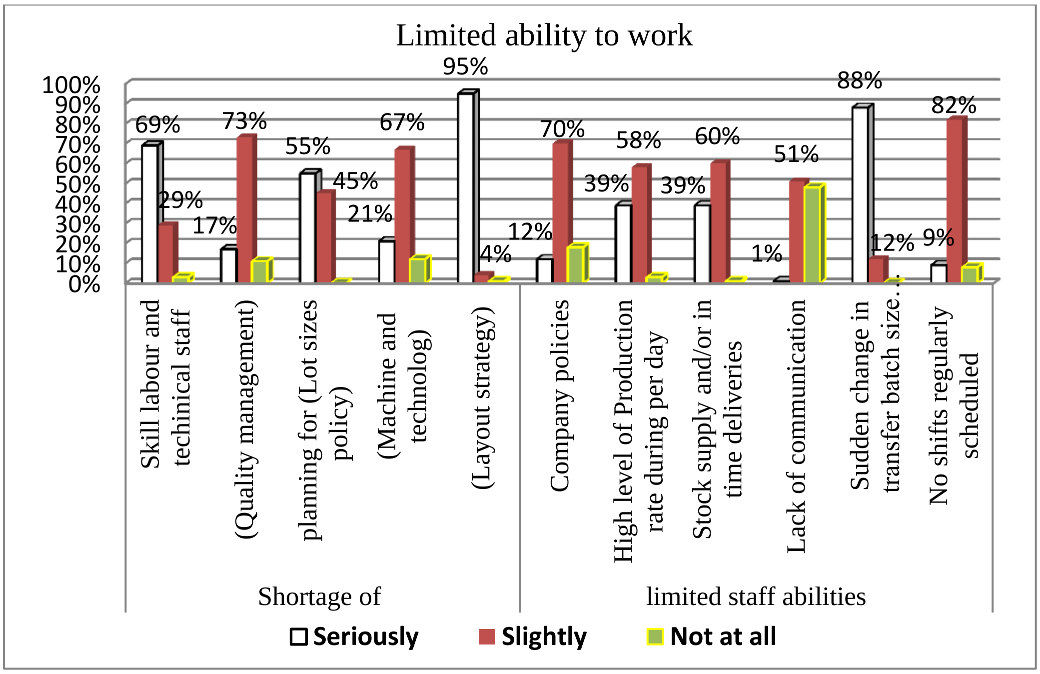

Figure 4.4. Limited ability to work

4. 4.1.4 Questions testing the importance of critical manufacturing variation and manufacturing technology factors

Manufacturing variation is critical situation for manufacturing process because it is a disparity between an actual measure of a product characteristic and its target value, Hopp and Spearman (1990, p.82) stated that 'variability can be a result of either controllable or random variation'. Controllable variation is a result of decisions made and includes such things as differences in the processing time of different parts due to design differences and transfer batch size decisions while random variation is a result of events beyond our immediate control. This includes such things as natural variation in process time for the same type of part due to unplanned machine downtime or differences in machines, operators, or material; variation in the time between arrivals to each work station. Therefore, the participants were invited to answer the following questions:

1- Do you inform your customers when orders are expected to be late? Related to the customer demand are expected to be late which is always associated with manufacturing variation.
2- What are the causes of variability of the workload? Related to the controllable variation and random variation, therefore is the variation under your control or out of your control?

In this survey data, Likert scales to collect respondents' opinions have been conducted so that the ranking question assigns default weights of (n to 1) for 3 scale points means that 'seriously' is scaled 3 and 'not at all' is scaled as 1.

The answers to question one indicated that most of the eight factories inform their customers when orders are expected to be late because 90% of participants mentioned that the orders were expected to be late, 37% of participants mentioned 'mostly' and 53% of participants mentioned 'often'. Only 10% of participants mentioned 'rarely' and 0% of participants mentioned that orders are not expected to be late, which indicated that manufacturing variation existed at most of the eight factories, therefore MLT will be increased. Consequently, a late delivery time will occur, therefore this is an insufficient monitoring of the system and responsibilities of supervisors or managers are not clearly defined the role of customer satisfaction through pre-planned and defined methods and the resulting information was not utilized during management review; for more results, see appendices for 160 responses of survey MLT.

Figure 4.5 shows that the average rated between 2.13 and 2.34 meaning that respondents indicated that most of the factories have the causes of variability of workload. 35% of the responses suggested that the causes of variability of workload are seriously out of control and 64% indicated ‘slightly’ due to manufacturing variation not being controllable while 14% of the responses suggested that the causes of variability of workload are seriously under control and 85% are ‘slightly’ due to manufacturing variation being under control, therefore both controllable variation and random variation existed in the system. Those conditions of variation were uncontrollable variation because there are differences in the processing time of different parts due to design differences and inaccurate transfer batch size decisions will be taken at different times. Also, insufficient MRP will be applied and the amount of potential work in outstanding quotes is not known and is not used when forecasting shop loading due to insufficient operations management. Random variation is a result of events beyond staff’s immediate control, which includes things such as natural variation in process time for the same type of part due to unplanned machine downtime or differences in machines, operators, or material; variation in the time between arrivals to each work station. Also, the variability generates the possibility that a batch of parts arriving to the workstation will find the workstation still busy processing a previous batch and that situation will cause long MLT (Hopp and Spearman 2001). There is always a longer lead time associated with manufacturing defects and variation; it is really a potential problem or defects and corrective action should be taken to avoid long MLT and late delivery time. All eight factories should use/or consider a formal job tracking system, therefore fewer changes to orders and production schedules mean achieving higher manufacturing efficiency levels. Insufficient areas of management may cause low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, inappropriate for capacity planning, disruptions and unreliable lead times; those factors will potentially affect critical delivery dates. Those conditions indicated that the procedures of operations management and manufacturing technology were insufficient because there were inventory build-ups (bottlenecks) at one or more particular points; also, measuring lead time analysis was not readily used to achieve the quality required in the production process at most of the eight factories. In addition, most of the factories were not aware of available shop hours and the projected work load and uses data for process planning were not documented. Increasing variability always degrades the performance of a production system (Hopp and Spearman, 2001), therefore manufacturing variation, operations management and manufacturing technology need improvement.

Note: Figure 4.5 is regarding the question number ten on appendix1:

Question 10: What are the causes of variability of the workload?

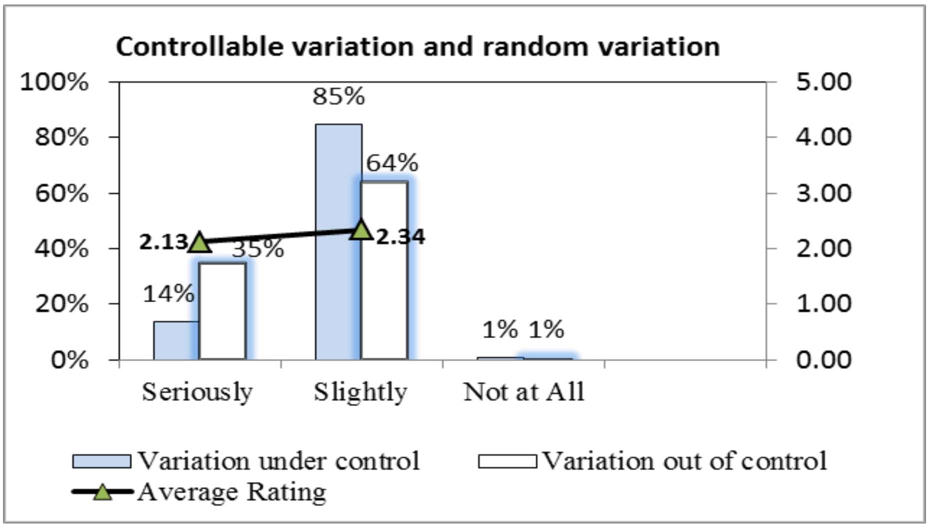

Figure 4.5 Causes of workload variation in 8 factories

In this survey questionnaire the participants were invited to answer the following question: Does your company currently use some of the following technologies? This question is related to using manufacturing technology.

If a company is currently using new manufacturing technology and quality is designed into the production process, it may be possible to eliminate inspection, defects and long lead time. Figure 4.6 shows that 99% of the respondents mentioned that most of the factories use programmable controllers (PLCs) and coordinate measuring machine (CMM), while only 74% of respondents noted that most of the factories use the production planning and inventory control system (MRP or similar). Figure 4.6 shows that from 99% to 60% of respondents noted most of the factories were not using the following technologies enough: CNC machine tools, programmable robotics, automated inspection, computer aided design (CAD), computer aided manufacturing (CAM) software and statistical process control (SPC). Those manufacturing technologies are very important to increase manufacturing efficiency and also lead to manufacturers being able to utilize capacity more effectively and control the causes of defects, order requirements and delays during the manufacturing process and quality of product. This is insufficient monitoring of the system and the responsibilities of supervisors or managers are not clearly defined in the role of manufacturing technology. Therefore, insufficient use of manufacturing technology may cause the following insufficient procedures: low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, inappropriate for quality product, disruptions and unreliable lead times, this will cause potentially affect critical delivery dates. Also, high quality of technical support is not available within most of the factories to aid with the engineering and design.

Statistical process control (SPC) is extremely important for successful quality management; it is applied in order to monitor, control a process, identify the causes of defects, delays, rework and scrap, and also it may support corrective action and continues improvement of the quality system and customer satisfaction. SPC is a powerful tool that leads to reduce work-in-process and consequently MLT will be reduced. Using manufacturing technology such as CNC machine tools and programmable robotics is extremely important for reducing move time and work-in-process – those two factors are important to reduce lead time.

It seems that most of the eight factories have not used enough manufacturing technology and also the quality of the equipment not used properly by the company, in terms of both physical condition and compatibility with current technology standards. Therefore, most of the factories need to improve manufacturing technology. It seems that manufacturing technology has been identified as needing some attention and should be improved before starting to reduce lead time.

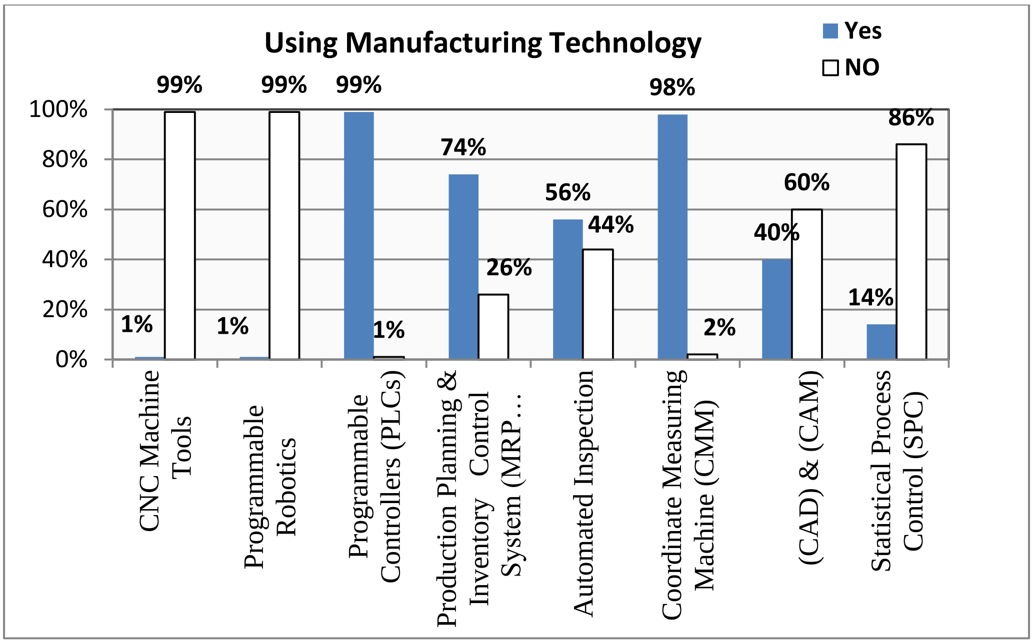

Figure 4.6 Eight factories are using manufacturing technology

The participants were invited to answer the following question:

Do you have or have you received clear explanations of the following from your supervisor? With regard to equipment and tools: Equipment idle-time and reasons, equipment down-time and reasons, use of specific equipment, use of the cutting tool inserts or other jigs and fixtures.

In this survey data, Likert scales to collect respondents' opinions have been conducted so that the ranking question assigns default weights of n to 1 for 4 scale points means 'extremely clearly' ranked 4 and 'not at all clearly' ranked 1.

Figure 4.7 indicated a range of average rating between 1.6 and 2.6, meaning respondents indicated that most of the factories' respondents have not received clear explanations from their supervisor.

Figure 4.7 shows that only 1% of respondents have received extremely clear reasons for equipment idle-time, down-time and also use of specific equipment and the cutting tool inserts or other jigs and fixtures, which indicated most of the factories have inappropriate measuring devices readily available and used to achieve the quality required to control quality product or manufacturing process. Also, their supervisors did not explain to staff the reasons, especially the reasons for down/idle time are analysed and used to improve the production process with regard to cutting tool inserts or other modern methods/devices are not used when appropriate. Those conditions indicated that tools and equipment are not properly used or ground to maintain tolerances. Also, it seems that most of the factories have a lack of management documentation related to the responsibilities of supervisors. In most of the factories the responsibilities of supervisors are not clearly defined and written down listing reasons and explanations to make matters clear to staff to increase skills, reduce human error and staff should take advantage in the future. Figure 4.7 shows that between 48% and 19% of respondents have not clearly received reasons for equipment idle-time and down-time. Also, between 46% and 43% of respondents have 'clear slightly' received the use of specific equipment, use of the cutting tool inserts or other jigs and fixtures. Those conditions, which they have significant factors to increase manufacturing variation means the variability always degraded the performance of a production system consequently lead time will be increased because when variability increased means that the task of coordination will be became more difficult due to long delays.

Manufacturing technology and manufacturing equipment, tools and documentation, which needed improvement and corrective action, should be considered. Using insufficient manufacturing technology in terms of equipment and tools that may cause low flexible manufacturing, decrease resource efficiency, disruptions and unreliable lead times, will potentially affect critical delivery dates.

The participants were invited to answer the following question:

Does your company use the following documents and procedures? The participants answered 'Yes' or 'No'.

Figure 4.8 shows that the respondents noted that most of the eight factories have not used enough documents and procedures for: lead time analysis; work in process/on-hand inventory; or master production scheduling. It seems that most of the factories have not used lead time analysis. This procedure is important to reduce lead time because the purpose of lead time analysis is: to document all steps in a process, to quantify the time and distance of each step in a process, to identify where value is being added to the process. Therefore, lead time analysis is one of the best procedures to reduce MLT. Furthermore, most of the factories have not been using enough quality control tools such as statistical process control (SPC) in their company procedures. In addition, the SPC is a powerful tool and it is also extremely important for a successful quality management. SPC is applied in order to monitor, control a process, identify the causes of defects, delays, rework and scrap. Work in process and on-hand inventory procedures are important factors to reduce lead time and also to control delivery date. It seems that most of the factories have not used proper procedures and documentation for on-hand inventory because most of the factories have not estimated the amount of inventory available each week after gross requirements have been satisfied. This is calculated by taking the on-hand inventory from the previous week therefore the production planner cannot face two related decisions about ordering: when to order?, how much to order?, to avoid stock-out. This means that information generated by the manufacturing requirements planning system for on-hand inventory and work-in-progress is not timely, accurate, documented and reliable because there are inventory build-ups (bottlenecks) at one or more particular points in the production process. Also, there is always a high inventory level causing more work-in-process, thus long MLT will be predictable. The survey asked whether respondents had received clear explanations and the reasons for equipment idle-time and down-time from their supervisors; as shown on the Pareto chart, they noted they had not received clear explanations for those defects and problems. This indicated that records are kept pinpointing the reasons for equipment idle-time and down-time so it seems that the documents and records aren’t reviewed by top management. This means no instructions or feedback had been given to employees. It seems that quality management isn’t aware of the current plant capacity in terms of using manufacturing technology and management documentation in the term of reviewed and recorded.

Figure 4.8 shows that the Pareto chart shows that 20% of all problems, those three categories will present 80% of all lack of using documents and procedures therefore identifying where the majority of lack of using documents and procedures problems in a process are originating such as: lead time analysis, SPC, on hand inventory and work-in-process should be focussed to achieve the greatest improvement because the few problems that occur most often result in the majority of problems in order to reduce lead time. These categories provide the opportunities for reducing defects and lead time at each step of the manufacturing process. The areas of manufacturing technology, management practice and operation management have been identified as needing attention, and they should be improved before starting to reduce lead time.

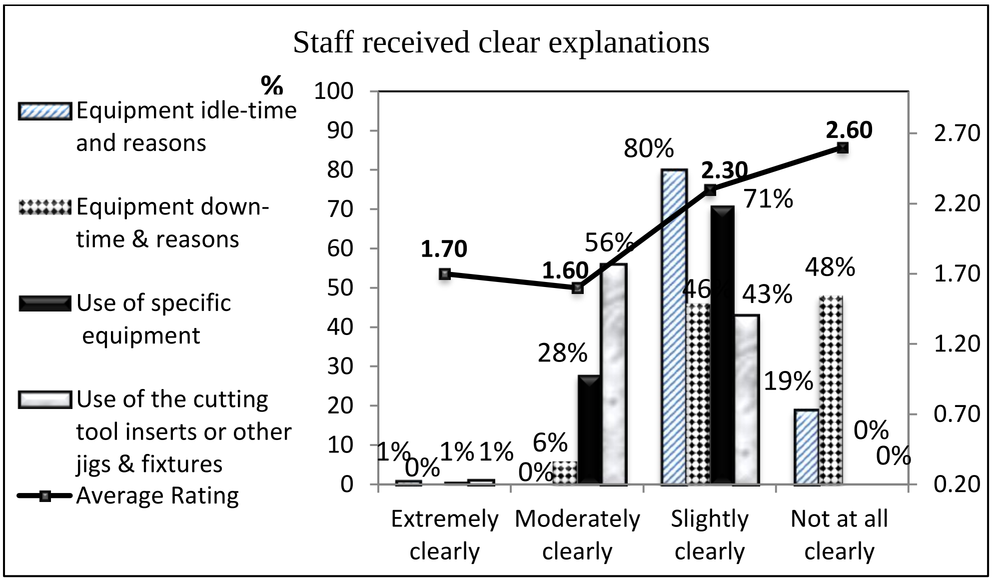

Figure 4.7 Staff received clear explanations at eight factories

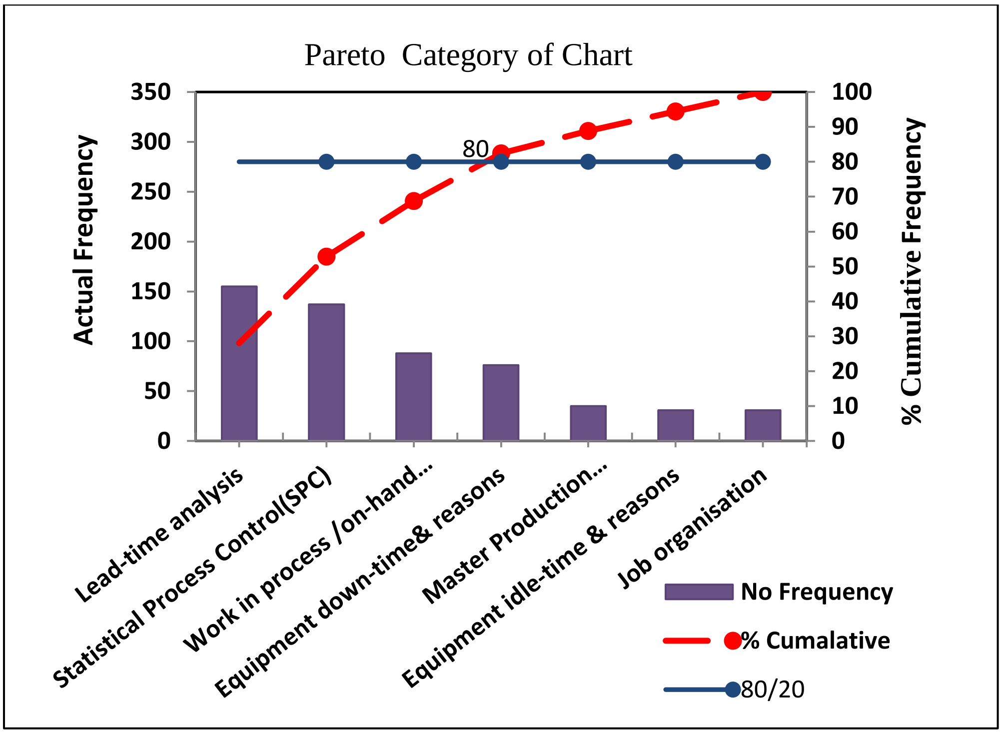

Figure 4.8 Categories for the lack of using proper documents and procedures

4.4.1.5 Questions testing the factors have a great impact on manufacturing lead time reduction

In this survey, the participants were invited to answer the following question:

Which of the following factors, in your opinion, have great impact on manufacturing lead time reduction and should be targeted in your company?

In this survey data analysis: ranking scales to collect respondents' opinions have been used that rank each of the following items in order of importance, from 1 (less impact) to 5 (great impact). In this survey ideally you can compare the responses to an industry benchmark, a competitor or even a similar survey question from a prior survey because the question was just written for this survey. There's no historical or comparative data, therefore in most cases this data doesn't exist. This research study attempts to interpret the raw responses and asked participants to compare different factors using a common scoring for 5-point scales of rating questions, therefore to interpret survey responses 5 techniques such as: Top-Box, Top Two box, Net Top Box, Z-Score and CV coefficient of variation have been used (see Table 4.11). Also, a crosstabs test has been conducted and the assumptions for chi-square includes independent observations to summarize a single categorical variable as well as if the variables are related, then the results of the statistical test will be "statistically significant", determining if two discrete variables are associated for the factors that have great impact on manufacturing lead time reduction.

These tests were hypothesized for each factor as follows:

Null hypothesis (H0): There is no association between process time (run time) and setup time.

Alternative hypothesis (H1): There is an association between process time (run time) and setup time….. (So on for other variables will be tested). Tests are being conducted to find a significant association between all other factors.

Table 4.10 shows the cross-tabulation test (chi-square tests) indicated that there is statistically significant association between setup time and process time (run time)

(Pearson chi-square with 3 degree of freedom = 24.736, p = 0.000). This result indicates that there is statistically significant association between setup time and process time (run time); that is, the setup time does not equally have the same process time (run time). We reject the null hypothesis.

This result indicates that there is a statistically significant association between setup time and process time (run time); that is, the setup time does not have the same process time (run time). We reject the null hypothesis. There is a statistically significant association between setup time and move time (Pearson chi-square with 9 degree of freedom = 21.048, p = 0.000) and so on other factors, while Table 4.10 indicated that there is no statistically significant association between process time and maintenance (Pearson chi-square with 4 degree of freedom = 7.836, p = 0.098), also between process time and reducing job overlapping (Pearson chi-square with 3 degree of freedom = 0.305, p = 0.095), therefore both null hypotheses were accepted. Table 4.10 indicated that there is no statistically significant association between setup time and reducing job overlapping (Pearson chi-square with 9 degree of freedom = 8.407, p = 0.494), therefore the null hypothesis was accepted. Also, Table 4.10 indicated that there is no statistically significant association between move time and reducing job overlapping (Pearson chi-square with 9 degree of freedom = 6.462, p = 0.693), therefore the null hypothesis was accepted.

For more details on the crosstab test for different statements see appendices for the chi-square test of survey MLT.

Figure 4.9 and Table 4.11show the participants' answers regarding the factors that have a significant impact on MLT reduction and what they consider should be targeted by their companies. Table 4.11 shows that average rating of 4.7 indicates that the general sentiment among respondents is that process time has a major impact on lead time reduction, also the CV % (coefficient of variation), standard deviation, Top Box, Top 2Box, Net Top Box are: CV 10% as less value than others factors,0.46, 69%, 100%, 69 and Z-Score, which is a six-sigma technique, indicated that the percentile rank of process time is 93%, which is more than other factors. This means that the largest average ranking indicates the top answer. Move time has an average rating of 4.04, the Z-scored 69.9% and net top box scored 38.8 % move time indicating that the improved system performance needs a strategy for process and product layout. Meanwhile, batch size, setup time, waiting time and time utilisation received average ratings (3.8, 3.4, 3.4 and 3.3, respectively). The finding was that process time, move time and batch sizes have top priority compared with other factors regarding the factors that have a significant impact on MLT reduction and should be targeted in most of the factories, therefore these factors can be viewed as having a major strategic role in reducing lead time. Since no organization can excel in all these factors simultaneously, the decision to focus on one or more of these factors provides a unifying directional force for competitive advantage. If a firm competes on quality without defects and lead time, then it should be evaluated in terms of its ability to deliver high-quality products in a timely.

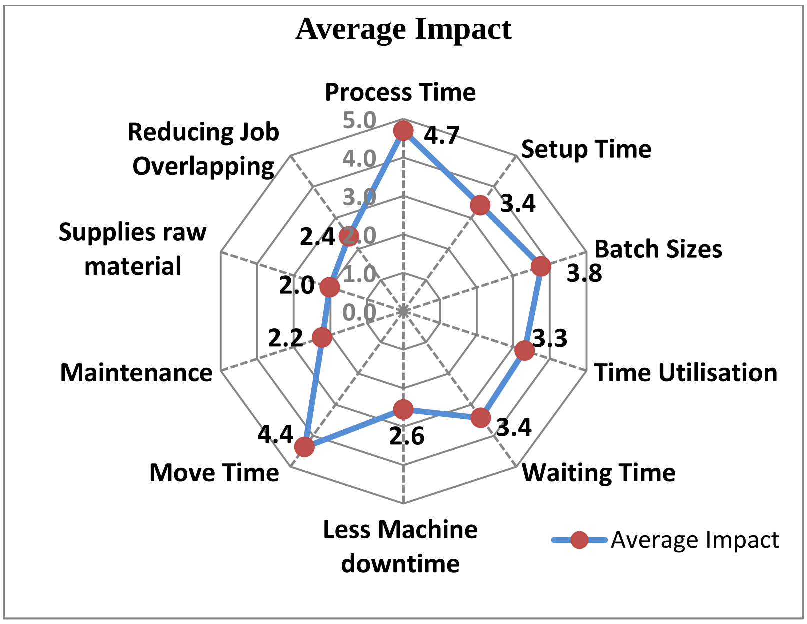

Figure 4.9 Average ranking of factors that have a significant impact on MLT reduction

Table 4.10 Summary of crosstab test (chi-square tests) for different variables (factors)

Chi-square tests (2-sided) Crosstab test Degree freedom = df	Process time (run time)		Setup time		Move time	
Factor	Chi-square	Asymp. Sig. (2-sided) P	Chi-square	Asymp. sig. (2-sided) P	Chi-square	Asymp. sig. (2-sided) P
Process time (run time)			24.736 3df	0.000	15.853 3df	0.001
Setup time	24.736 3df	0.000			21.048 9df	0.012
Batch sizes	31.652 4df	0.000	32.827 12 df	0.001	30.614 12df	0.002
Time utilization	24.059 3df	0.000	39.761 9 df	0.000	28.180 12df	0.001
Waiting time	27.713 3df	0.000	77.658 9df	0.000	30.775 9df	0.000
Less machine downtime	12.216 3df	0.016	40.300 12df	0.000	26.130 12df	0.010
Move time	15.853 3df	0.001	21.048 12df	0.012		
Maintenance	7.836 4df	**0.098**	26.141 12df	0.010	43.410 12df	0.000
Supplies raw material	4.700 4df	**0.319**	27.646 12df	0.006	51.676 12df	0.000
Reducing job overlapping	0.305 3df	**0.959**	8.407 9df	**0.494**	6.462 9df	**0.693**

Table 4.11 Summary of statistical and technical interpretation of the factors that have a significant impact on MLT reduction

Factor (1 less To 5 great) impact	N	Mean	SD	Z %	CV%	Top Box	Top 2Box
Process Time (run time)	160	4.7	0.46	93%	10%	69%	100%
Setup Time	160	3.4	0.66	18.1%	20%	1.9%	47%
Batch Sizes	160	3.8	0.74	37.8%	20%	15%	65%
Time Utilization	160	3.3	0.90	22.6%	27%	11.3%	39.4%
Waiting Time	160	3.4	1.07	29.9%	31%	18.8%	51.3%
Machine downtime	160	2.6	0.89	5.3%	35%	1.3%	15%
Move Time	160	4.4	0.70	69.9%	16%	48.8%	89.4%
Maintenance	160	2.2	0.83	1.7%	38%	0.6%	9.4%
Supplies raw material	160	2.0	1.06	3.2%	53%	3.1%	11.3%
Job Overlapping	160	2.4	0.69	1.1%	29%	0.0%	5%

4.4.1.6 Questions testing the factor solutions that have great impact on improving manufacturing lead time.

In this survey, the participants were invited to answer the following question:

Which of the following solutions would improve the reduction of the lead time in your company?

In this survey ideally you can compare the responses to an industry benchmark, a competitor or even a similar survey question from a prior survey because the question was just written for this survey. There's no historical or comparative data, therefore in most cases this data doesn't exist. This research study attempts to interpret the raw responses and asked participants to compare different factors using Likert scale for 5-point scales of rating questions, therefore to interpret survey responses 5 techniques such as: Top-Box, Top Two box, Net Top Box, Z-Score and CV coefficient of variation have been used (see Table 4.12). Also, a crosstabs test has been conducted and the assumptions for chi-square includes independent observations to summarize a single categorical variable as well as if the variables are related, then the results of the statistical test will be "statistically significant", determining if two discrete variables are associated for the factors that have great impact on manufacturing lead time reduction.

For more details on the crosstab test for different statements see appendices for the cross-tabulation test (chi-square test) of survey MLT.

These tests were hypothesized for each factor as follows:

Null hypothesis (H0): There is no association between process time (run time) and setup time.

Alternative hypothesis (H1): There is an association between process time (run time) and setup time. Tests are being conducted to find a significant association between all other factors. Table shows the cross-tabulation test (chi-square tests) indicated that there is a statistically significant association between setup time and process time (run time) (Pearson chi-square with 3 degree of freedom = 24.736, p = 0.000).

In this survey, the participants were invited to answer the following question:

Which of the following solutions would improve the reduction of the lead time in your company?

Figure 4.10 shows the participants’ answers regarding the opinion to improve lead time reduction in their company. It is remarkable that still roughly 99% of the participants think that optimization of the current factory layout strategy is a method to improve lead time reduction. The average rating of 4.9 indicates that the general sentiment among respondents is that optimization of the current factory layout strategy has a major solutions to improve lead time reduction.

Table 4.12 indicated that CV % (coefficient of variation), standard deviation, Top Box, Top 2Box and Net Top Box are: CV 6% as less value than other, 0.30, 90%, 100%, 90%, and Z-Score, which is a six-sigma technique, indicated that the percentile rank of optimization of the current factory layout strategy is 99.9%, which is more important than other solutions. Figure 4.10 shows that 98% of the participants think that optimization of the justified batch sizes is a method to improve lead time reduction, and the average rating of 4.64 indicates that the general sentiment among respondents is that (Optimization of the current factory layout & strategy) and justified batch sizes are a better solution to improve lead time reduction. Table 4.12 indicated that CV % (coefficient of variation), standard deviation, Top Box, Top 2Box, Net Top Box are: CV 6% and 12 % as less value than others, 0.54, 66.9%, 98.1%, 66.9%, and Z-Score, which is a six-sigma technique, indicated that percentile rank of (Optimization of the current factory layout & strategy) and justified batch sizes are 99.9% and 88.3%, which are more important than other solutions. Figure 4.10 shows that increase working stations capacity, improve company procedures, adopt one-piece flow, increase production control with scheduling, adopt group technology production and purchase equipment with shorter setup time received average ratings (4.24, 4.06, 4.03, 4.02, 3.98, 3.4 and 3.71, respectively). Most participants suggested solutions to improve lead time reduction should be prioritized such as: optimization of the current factory layout strategy, justified batch sizes and increasing working stations’ capacity.

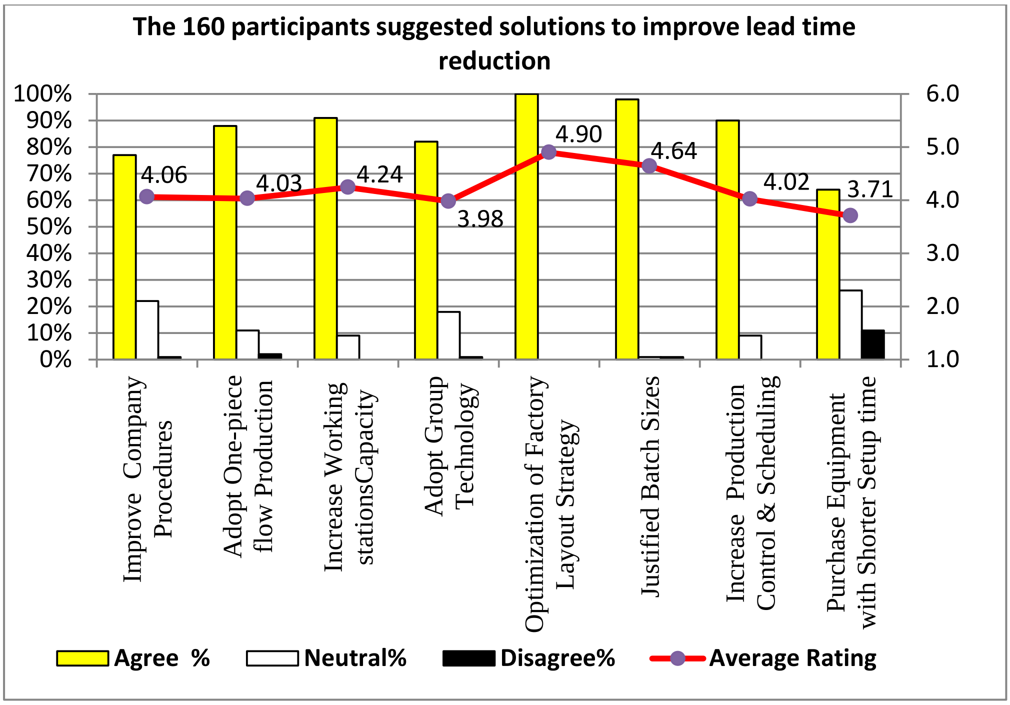

Figure 4.10 The respondents' opinion to improve lead time reduction

Table 4.12 Summary of statistical and technical interpret of solutions to improve lead time reduction

Solution (Weights of n to 1)	N	Mean	SD	Z %	CV %	Top Bo%	Top 2 Box%	Net top Box%
Improve company procedures	160	4.06	0.73	53.4	18	29.4	77.5	29.4
Adopt one-piece flow production	160	4.03	0.59	52.1	15	17.5	87.5	17.5
Increase working stations capacity	160	4.24	0.60	65.7	14	33.1	91.3	33.1
Adopt group technology	160	3.98	0.60	48.8	15	16.9	81.9	16.9
Optimization of the current factory layout & strategy	160	4.9	0.30	99.9	6	90	100	90
Justified batch sizes	160	4.64	0.54	88.3	12	66.9	98.1	66.9
Increase production control, scheduling	160	4.02	0.45	51.6	11	11.3	90.6	11.3
Purchase equipment with shorter setup time	160	3.71	0.88	36.9	24	17.5	63.8	17.5

4.5 Conclusion

The survey tested the hypothesis with firms in the Packaging for Oil & Gas sector; Basic Materials (paper and plastic) sectors and Industrials sector (cement) using a face-to-face procedure, which ensured the answers were in-depth and accurate. In addition, it was the major research technique for data collection in this study. Also, the research questions are: what major procedures should be considered before reducing lead time? What opportunities do manufacturers have to reduce lead times? How can we systematically review the potential methods for reducing lead time? The survey questionnaire conducted an expert system-based assessment tool. Also, the principles of QRM and TBC are considered in this survey that will provide a preliminary analysis of a firm's strengths and weaknesses. The survey questionnaire's aims and objectives are to: identify those areas of manufacturer operations that may require some attention; identify areas of managements, capital, defects, wasting time, delays and excessive lead time; highlight some of the non-technical parts of the manufacturer's operations that may be impeding their growth and competitiveness; and replicate to evaluate MLT outcomes. This can be done when other data collection systems (e.g. surveillance) are not feasible in order to answer the first research hypothesis and questions. The survey questionnaire stage will help further validate the argument of the research and also can help achieve MLT reduction. Therefore, the assessment questionnaire designed for this survey has several benefits to get early indications of potential problems or defects and lead to taking corrective action to avoid long MLT and late delivery time in the factory.

The outcomes of tests substantiated in this research study based on Suri, R. (2003) "QRM and POLCA", TDO solutions (2014) "TDO Solutions for Manufacturing and Technology questionnaire", Tricker, J. (2005)" ISO9001:2000 Audit procedures" and Heizer, J. and Render, B. (2008) "Principle of operations management"

The following conclusions can be drawn from the research conducted in this survey:

1. Finding, the result helps identify different areas of management that may be impeding the eight factories' growth, competitiveness and improvement of lead time. Therefore, this survey questionnaire can play critical roles in

ensuring that our data provides actionable insights that will allow manufacturers to make better decisions before reducing MLT.

2. Testing the importance of human resources factor:
    - Indicated that only 24% of staff have more than 3 years' experience compared with 76% of staff that have experience of between 1 and 3 years, which means a lack of skilled labour, technical staff and staff experience exists in the eight factories in the Kurdistan region.
    - The Mann-Whitney U test and different hypotheses indicated that there is a significant difference in staff level of experience with shortages of quality management, and shortages of skilled labour and technical staff, while the results suggest that there is no statistically significant difference between the staff who have different experiences within the shortages of skilled labour and technical staff.
    - In this survey, the results indicated that most of the eight factories have not provided enough more staff experience, staff technical, skilled labour and professional training to employees in order to improve companies' procedures and their performances. The results indicated the role of better human resources has a great impact on manufacturing efficiency. Accordingly, manufacturing lead time reduction will be improved towards sustainable manufacturing and also delivery performance will be improved. The results suggested that the level of experience with skills needed to keep production at the top efficiency requires planning, and also the severe shortage of manufacturing skills and years of experience today has the potential to impede the trend of steady growth in manufacturing companies. Staff experience, skills and different primary functions among the staff are directly linked to performance improvements in the manufacturing plant; also, they are engaged in continuous improvement and facilitate to reduce human error, handoffs, delay, down time, work in process, and lead time.
    - The Kruskal-Wallis test indicated there was statistically a significant difference between 'Improve company procedures' and 'Increase production control, scheduling' in all the categories of primary

function within their organization, thus they suggest from their own experiences that the best solutions would improve the reduction of lead time by improving their company procedures, increasing production control and scheduling in all areas of management practices, human resources and operations management because those two factors are more important factors to reduce lead time. Therefore, the overall trend of engineers, supervisors and technical staff, is valued more highly by thinking that improving procedures, production control and scheduling are proper solution factors to reduce MLT. The Kruskal-Wallis test indicated there is no significant difference in informing the customers when orders expected to be late in all the categories of primary function within staff's organization. It was found that all participants are informed that the order became late on delivery time across all eight factories, therefore long response manufacturing existed because of their responses to questions. This is an indicator for a long manufacturing lead time (MLT); amongst the different job types in this survey as well it was found that 90% of participants are informed that the order became late on delivery time across the eight factories, therefore long manufacturing lead time existed. This is an indicator that a Manufacturing Requirements Planning (MRP) system for work orders is not timely, inaccurate, and unreliable, This means that QRM not pursues the relentless reduction of lead time

- The assessment questionnaire gathered the information and evaluated the human resources strategies, motivation, commitment and level of experiences, and indicated that most of the eight factories needed improvement in human resources. Thus, this survey indicated that human resources in the eight factories have between average and low ranking average and low ranking. Therefore, all factories should place a greater emphasis on a better human resources policy that can improve company performance by increasing staff skills, abilities and training, which are seen as vital to sustained competitive advantage, thus it is a simple practical strategy for reducing lead times. Lack of human resources procedures and management practice may cause low flexibility, decreased resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times.

3-Testing the importance of critical management factors on lead time:

- 160 responses to management practices, quality management and operations management indicated that most of the eight factories have not provided enough professional training and feedback to employees and 51% of respondents have a lower level of professional training but 49% of others have no professional training. In total, 68% of participants suggested that their companies did not provide enough feedback to their employees in order to take pride in their work. This is insufficient monitoring of the system and the responsibilities of supervisors or managers are not clearly defined in the role of training, management and commitment to training
- The assessment questionnaire noted that most of the eight factories do not have enough quality assurance, quality control and traceability in place in their company procedures. This means that the quality management system has not been developed in accordance with the requirements of ISO 9001:2000; only 13% of the participants mention fully supporting company procedures. Therefore, these statements provide the major direction for reducing defects in each step, measures that should be taken before the next step. The survey results noted that the responsibility is not clearly defined in a written quality plan for the investigation, evaluation, and solution of quality problems.
- In total, 72% of the responses mentioned that the company maintained stock production. This affects decisions about batch size for products because 90% of respondents noted in this survey that the company informs their customers when orders are expected to be late. This is due to inventory build-ups (bottlenecks) at one or more particular points in the production process. This is one of the signals of improper MRP and lot-sizing decisions at most of the factories.
- The finding was that staff have limited ability to work due to the shortage of skilled labour and technical staff, quality management, planning for (lot or

batch) sizes policy, layout strategy for operation management because they are seriously affected. Staffs have limited ability to work, and also there are many factors such as: company policies, sudden changes in (production /transfer) batch size decision, no shifts are regularly scheduled per day which they are seriously limited staff ability to work.

- Results show that the shortage of equipment, machines and using technology, indicating that 21% of respondents seriously limited their ability to work and 67% of respondents limited slightly their ability to work. It seems that an overhaul of equipment and machines on their production floor is not defined as major refurbishing or replacement of equipment and machine during the average age or time in years and also measuring devices and machines are not periodically calibrated as a maintenance procedure.
- The shortages of different areas of management may cause limitations of staff ability to work and may cause a low level of flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, which will potentially affect critical delivery dates. Most of the eight factories have not used enough manufacturing technology and also quality of the equipment not used by the company, in terms of both physical condition and compatibility with current technology standards. All factories need improvement in those areas of management and corrective actions will be required.

4-Testing the importance of critical manufacturing variation and manufacturing technology factors:

- In this survey the participants were asked: what are the causes of variability of the workload? The respondents indicated that most of the factories have the causes of variability of workload and the average rating for the causes of variability was between 2.13 and 2.34 meaning that both controllable variation and random variation existed in the system. Those conditions means that inaccurate transfer batch size decisions will be taken at different times, also insufficient MRP will be applied and the amount of potential work in outstanding quotes is not known and is not used when forecasting shop loading due to insufficient operations management. It seems that random variation is a result of events beyond the immediate control of staff. This includes things such as natural variation in process time for the same type of part due to unplanned machine downtime or differences in machines, operators, or material; variation in the time between arrivals to each work station. The variability always generates the possibility that a batch of parts arriving at the workstation will find the workstation still busy processing a previous batch and that situation will cause long MLT. In addition, most of the factories were not aware of available shop hours and the projected work load and data for process planning were not documented. Increasing variability always degrades the performance of a production system.

- Using manufacturing technology: The survey results indicated that from 99% to 60% of respondents noted that most of the factories were not using the following technologies enough: CNC machine tools, programmable robotics, automated inspection, computer aided design (CAD), computer aided manufacturing (CAM) software and statistical process control (SPC). Those manufacturing technologies are very important to increase manufacturing efficiency and also lead to manufacturers being able to utilize capacity more effectively and control the causes of defects, order requirements and delays during the manufacturing process and quality of product. This is insufficient monitoring of the system and the responsibilities of supervisors or managers are not clearly defined in the role of manufacturing technology. It seems that most of the eight factories do not use enough manufacturing technology.. It seems that manufacturing technology has been identified as needing some attention and should be improved before reducing lead time.
- The survey results indicated an average rating range of between 1.6 and 2.6, meaning most of the respondents indicated that they have not received clear explanations from their supervisor. A main finding was that only 1% of respondents have received extremely clear reasons for equipment idle-time, down-time and also use of specific equipment and the cutting tool inserts or other jigs and fixtures, which indicated most of the factories have inappropriate measuring devices readily available and used to achieve the quality required to control quality product or manufacturing process. Manufacturing technology and manufacturing equipment, tools and

documentation, which need improvement and corrective action, should be considered. Using insufficient manufacturing technology in terms of equipment and tools may cause low flexible manufacturing, decrease resource efficiency, disruptions and unreliable lead times, and will potentially affect critical delivery dates.

- The Pareto chart shows that 20% of all problems, those three categories will present 80% of all lack of using documents and procedures therefore most of the factories had not been using enough quality control tools such as Statistical Process Control (SPC) in their company procedures. Lead time analysis, SPC, on hand inventory and work-in-process should be focussed on to achieve the greatest improvement because the few problems that occur most often result in the majority of problems in order to reduce lead time. These categories provide the opportunities for reducing defects and lead time at each step of the manufacturing process. The areas of manufacturing technology, management practice and operation management have been identified as needing attention, and they should be improved before starting to reduce lead time.

5-Testing the factors and solutions have a great impact on manufacturing lead time reduction:

- In this survey's data analysis: ranking scales to collect respondents' opinions have been conducted that rank each of the following factors in order of importance, from 1 (less impact) to 5 (great impact), also a crosstabs test has been conducted and the assumptions for the chi-square include independent observations to summarize a single categorical variable as well as if the variables are related, then the results of the statistical test will be 'statistically significant', which means determining if two discrete variables are associated for the factors which they have great impact on manufacturing lead time reduction.
- The cross-tabulation test (chi-square tests) indicated that there is a statistically significant association between independent factors such as: process time (run time), setup time, move time, batch sizes, time utilization, and machine downtime. A main finding indicated there is no statistically

significant association between process time and maintenance, also the factor of reducing job overlapping. It was found that there is no statistically significant association between setup time and factor of reducing job overlapping. Also, there is no statistically significant association between move time and the factor of reducing job overlapping.

- The average rating of 4.7 indicates that the general sentiment among respondents is that process time has a major impact on lead time reduction, also the CV % (coefficient of variation), standard deviation, Top Box, Top 2Box, Net Top Box are: CV 10% as less value than others factors,0.46, 69%, 100%, 69.4% and the Z-Score, which is a six-sigma technique, indicated that the percentile rank of process time is 93%, which is more than other factors. This means that the largest average ranking indicates the top answer. Move time has an average rating of 4.04, the Z-scored was 69.9% and net top box scored 38.8%, the move time indicating that improved system performance needs a strategy for process and product layout. Meanwhile, batch size, setup time, waiting time and time utilisation received average ratings (3.8, 3.4, 3.4 and 3.3, respectively). The finding indicated that process time, move time and batch sizes have top priority compared with other factors that have a significant impact on MLT reduction and should be targeted in most factories, therefore these factors can be viewed as having a major strategic role in reducing lead time. Since no organization can excel in all these factors simultaneously, the decision to focus on one or more of these factors provides a unifying directional force for competitive advantage. If a firm competes on quality without defects and lead time, then it should be evaluated in terms of its ability to deliver high-quality products in a timely. A main finding was that all the participants' indicated that the factor of process time has a significant impact on MLT reduction as the first choice and the second choice is the factor of move time while the third choice is the factor of batch sizes have a significant impact on MLT reduction that those factor should be considered and should be targeted by their companies towards lead time reduction.
- This survey illustrated the participants' answers regarding the solutions and/opinions to improve lead time reduction in their company. It is

remarkable that still roughly 99% of the participants agreed with optimization of the current factory layout strategy, which is a method to improve lead time reduction. The average rating of 4.9 indicates that the general sentiment among respondents is that optimization of the current factory layout strategy is a major solution to improve lead time reduction. Also, statistical and technical interpretation of solutions to improve lead time reduction indicated that CV % (coefficient of variation), standard deviation, Top Box, Top 2Box and Net Top Box are: CV 6% as less value than others, 0.30, 90%, 100%, 90% and Z-Score, which is a six-sigma technique, indicated that the percentile rank of optimization of the current factory layout strategy is 99.9%, which is more important than other solutions. Also, 98% of the participants think that optimization of the justified batch sizes is a method to improve lead time reduction, and the average rating of 4.64 indicates that the general sentiment among respondents is that justified batch sizes is a better solution to improve lead time reduction and Z-Score, which is a six-sigma technique, indicating that percentile rank of justified batch sizes is 88.3%, which is more important than other solutions.

- The survey results indicated that increased working stations capacity, improved company procedures, adopted one-piece flow, increase d production control with scheduling, adopted group technology production and purchasing equipment with shorter setup time received average ratings (4.24, 4.06, 4.03, 4.02, 3.98, 3.4 and 3.71, respectively) from most of the participants in this survey. Most of the participants suggested solutions to improve lead time reduction should be prioritized such as: optimization of the current factory layout strategy, justified batch sizes and increase working stations capacity.

6-This survey provides a preliminary analysis of major functional areas of management and makes the following recommendations : human resources procedures, management practices, quality management, information management, manufacturing technology and operation management, which needed improvement and corrective action should be considered and predictable because the eight factories have insufficient areas of management that may cause low flexible manufacturing, decreased resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, which will potentially affect critical delivery dates.

Chapter 5- Case Study

5. Case ZX Plastic Pipe

5.1 Introduction

All companies strive to reduce the gap between receipt of an order and shipment. Thus, many companies have come to develop, realise and implement systems that the old, traditional methods couldn't accomplish. Hoppe and Spearman (2001) stated that MRP has, for many years, been utilised by businesses to improve production efficiency and product delivery. On the other hand, one of the limitations of MRP has been its deterministic, fixed view of lead time—it does not take into account, for example, the capacity of each factory's machinery. Also, according to Hoppe and Spearman (2001), "the materials order placement, a fundamental feature of MRP, is most of the time, performed much earlier than necessary resulting in an exorbitant increase in inventory". In production management terms, this is called infinite capacity scheduling. These shortcomings of MRP have been successfully corrected by finite capacity scheduling, but Hoppe and Spearman (2001) did not mention how to apply this or which technical tools should be used. Therefore, this research will be focused on MRP, reschedule capacity planning, lot-sizing decision, splitting order, designing a work balance chart, queuing analysis using queuing theory and overall equipment effectiveness (OEE) in order to find simple strategy to reduce MLT. The main purpose for choosing this case study is ZX Plastic Pipe, in order to disseminate findings, because during the survey procedure, the samples were located across eight factories and one of the factories was ZX plastic pipe factory also 90% of participants noted in the survey that 8 factories informed their customers when orders are expected to be late. The interview was conducted face-to-face and a workshop procedure has been conducted that uses an interpersonal interaction to elicit answers pertinent to the research hypothesis. The research study found that the production manager was concerned that he may not have sufficient information to make a valid decision about a proper master production schedule or production orders for that situation. Also ZX factory has insufficient MRP and capacity planning that may cause low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, this will cause potentially affect critical delivery dates. This research choses this case study also this research has conducted a workshop with the production manager in order to brainstorm. In addition, the answers from the assessment questionnaire will help to identify those areas of the manufacturing process that may need attention as well as the solution that was relevant to the contribution of OR-Notes for MRP, which was published (see Beasly, 2012), while Beasley (OR-Notes, 2012) mentioned that the production planner should avoid a stock-out; therefore, Beasley asked the question, ‘in each and every period, should I order in this period and if so how much?’ However, Beasley did not mention that determining the system’s available capacity involves only two related decisions about ordering; in his example solutions, Beasley used lot-for-lot and fixed-period requirement (FPR) techniques for the quantity decision. Both are termed lot-sizing decisions. Also Beasley (2012) did not mention such key issues raised during the manufacturing process in filling an order when production time is greater than demand time. There are some principles of technical tools that are rarely studied, for example, a lot-sizing technique that is exactly what is required to meet the plan in terms of smoothing the load and minimising the impact of changed lead time include splitting order (lot splitting) when the workload exceeds work-centre capacity, available capacity and performance measures focused on time. Also, gaps in the literature could be identified for finding simple strategies to cope when the production time is greater than the demand time in terms of using time to measure supply chain performance. ZX group is made up of number of projects and companies. ZX plastic pipe factory is administrated by ZX Group and it was established in 2004. Their headquarters are based in Sulaimaniyah province in the Kurdistan region of Iraq. ZX products are divided into two parts, HDPE and LDPE, which are produced in different sizes ranging from 16 to 110 millimetres and the final product is wound around 100-metre reels and is used in the field of agriculture (for farming, gardening irrigation, and distributing sanitary water in houses and ranches). This research study has asked the following questions:

How can the production planner trade-off between lot sizes and available capacity times for the system?

How can the production planner provide feedback to the capacity plan and production plan? Is planning being kept valid at all times?

5.2 Definition of product

All plastic pipes are made from raw of materials which are PE (polyethylene) and PPRC (polypropylene). The raw materials of polypropylene have three colours: green, white, and grey see Figure 5.1. "The products of ZX Plastics are manufactured based on German standards DIN-8077/8078 which are perfect for being used in sanitary water applications resisting high temperature and pressure. In addition, those kinds of productions have played a direct role in the revitalization of the economic infrastructure" (ZX plastics on official website).

5.3 Description of current state

The factory has insufficient capacity planning. The processes of producing pipes have 8 procedures (raw material conveyor, extruder/ heating, trolley mounted die head, vacuum / pressure calibration system, pipe cooling trough, haul-off, auto rotary cutter and auto stock-piling unit). The bottlenecks within the production process most likely are (input of raw material for loading and setup temperature for Extruder/ heating processing) as shown the processes and location on figure 5.1. The purposes of this case will lead to finding the best description and theory-testing. *Refer to Figure 5.2*

Figure 5.1 Research workshop at ZX Plastics factory

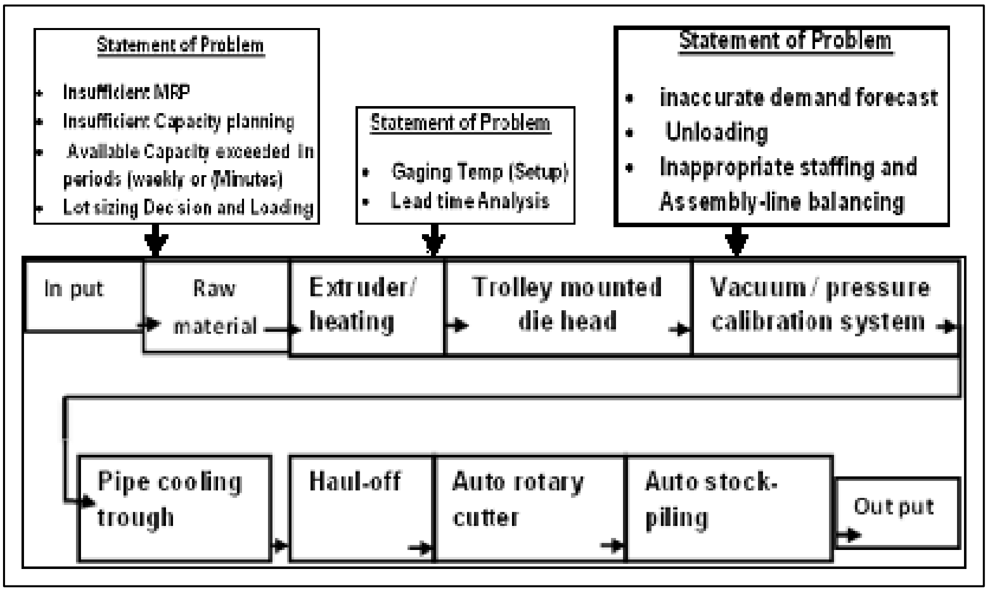

Figure 5.2 Process flow chart and Statement of problems in ZX plastic pipe

5.4 Diagnosis and problem definition

What problems exist and why do they exist in the delivery process of pipe products? And what are potential sources of information?

During the interview for the research survey, it appeared that the production manager has insufficient time to complete his production orders in the allotted seven days. The bottlenecks within the production process most likely are (input of raw material for loading and setup temperature for Extruder/ heating processing). Also, ZX has inadequate staff balancing, meaning that staffing and balancing work are inappropriately fixed, the work balance chart is inadequate for evaluating the operation times in work and ZX factory has insufficient MRP and capacity planning that may cause low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, this will cause potentially affect critical delivery dates. Pipes should be ready for shipping so as to be delivered on time but a problem occurs four times a year, It appears the ZX factory should develop a capacity plan for production orders and also needs to find proper tactics for smoothing the load and minimising the impact of changed lead times because the orders are expected to be late due to long MLT. A main finding, it is the set of mechanisms are not established to ensure that the design process operates efficiently and that all the information necessary for this efficient operation is available as well as it is appear that the set of mechanisms are not established to develop and improve employees' knowledge and/or skills in job-related areas. After additional one-on-one discussions with ZX leaders it was determined that the leaders had concerns that the average capacity system was not adequate due to material requirements planning (MRP) and the master production schedule. In addition, this research focused on all answers from the assessment questionnaire that will help to identify those areas of the manufacturing process that may need attention. The diagnosis is the actual measurement of MRP, production orders with using original data from ZX administrative MRP system, documents and interviews. It appears that ZX has the difficulty of forecasting the demanded quantities and there is a lack of order release mechanisms *see more details and statement of problems shown on* Figure 5.2. ZX 'standard' products are available for 7 days and ZX employees only work five days a week. Also, ZX 'standard' products are available for delivery next Monday but the initial load in the plastic centre exceeds capacity (capacity available hours) in 7 working days for delivery process so sometimes it takes 9 working days for each weekly batch size due to inaccurate of lot size decision for production orders daily as well as the unit load size not being properly specified and inaccurate MRP, therefore the infrequent movement of parts can exacerbate any line imbalance problem. In conjunction with this, a long lead time causes difficulties in creating a responsive and obstructs the possibilities of rapidly responding to customers and plastic pipes should be available for 7 days only, meaning Monday to next Monday products should be available. Lot sizing problems were also discussed in a general study about production planning and goods flow control by Graves (1999).

This research observed and investigated manufacturing processes. It appears that an amount of rush orders from the production planner will also increase with increased lead time because larger orders will fall outside of the time frame required for over available capacity and standard expediting, affecting costs by performing express expediting therefore capacity exceeded in periods for 5 working days due to inaccurate lot size decision as well as the unit load size is not properly specified, the infrequent moves of parts can exacerbate any line imbalance problem and there may be differences between operation schedules for an order and the manufacturing lead time for an item. In conjunction with this, a long lead time causes difficulties in creating a responsive service and obstructing the possibilities of rapidly responding to customers' demands. Therefore, According to Christopher (2011) forecasting error is increases as the lead time gets longer Larger forecasting error in turn causes increased demand volatility and a need to keep higher levels of safety stocks according to Christopher (2011), the difficulty of forecasting on demand quantities is positively related to lead time, as illustrated in Figure 5.3. Also, Christopher's research focuses on the effect of setup time on lot sizing from their previous research; the setting is the capacitated lot sizing problem (the single-machine lot sizing problem) with no stationary costs, demands, and setup times.

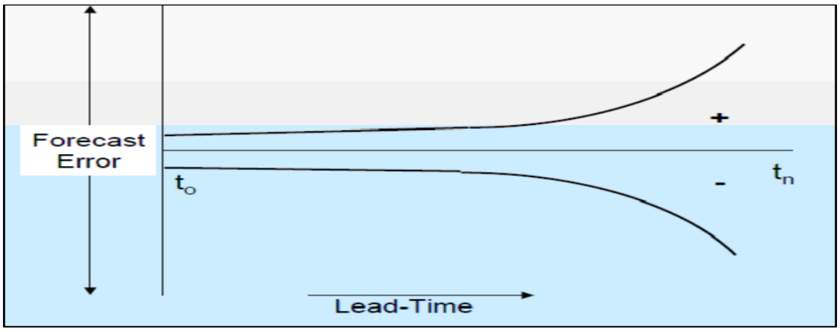

Figure 5.3 Lead time and forecast error

(Christopher, 2011)

Therefore the question is: What are potential sources of information about the problem? This case study typically relies on multiple sources of information and methods to provide as complete a picture as possible in order to reduce MLT and potential sources of information are included:

1- ZX administrative MRP system, master production schedule documents interviews, and operation-time data are usually obtained from experienced company employees.

2- Production planning orders report as well as including quarterly reports, Questionnaire/Survey results, face-to-face interviews, observation and mystery customer reports

.It is important to reduce manufacturing time through a proper MRP planning sheet. This case study aims to identify and quantify (where possible) the factors that influence and increase MLT. This stage of research methodology shows that the case study research method has been chosen to determine the factors which have been a great influence on manufacturing lead-time and to identify defects and delays during the manufacturing process. As discussed above as well as in the literature review with a sample MRP planning sheet, this will focus on material requirement planning (MRP) and capacity planning for the system.

5.4.1 Summary

ZX factory had a poor history of meeting their demands on time – they often had high demand backorders as well as an excessive inventory due to poor forecasting and scheduling. ZX also did very little to contain their costs and consistently incurred unnecessary additional production expenses. ZX factory has insufficient MRP and capacity planning that may cause low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, this will cause potentially affect critical delivery dates. They maintained a high work-in-process (WIP) inventory, leading to long production cycle times and manufacturing lead times. The high cycle times and WIP were the result of many factors including manufacturing inappropriate quantities of the two products (i.e. little to no forecasting was done), poor MRP, inappropriate lot-sizing decisions, poor utilisation of the machines, running inappropriate lots sizes weekly, and a lack of formal scheduling methodology. This affects decisions about batch size (lot size) and MRP for products because 90% of respondents noted in the survey that 8 factories informed their customers when orders are expected to be late. The set of mechanisms are not established to ensure that the design process operates efficiently and that all the information necessary for this efficient operation is available also inappropriate lead time analysis has been conducted to document all steps in a process also to quantify the times and distance of each step in a process.

5.5 Determine the data collection method

During the survey procedure, the samples were located across eight factories and one of the factories was ZX plastic pipe factory. This case study typically relies on multiple sources of information and methods to provide as complete a picture as possible in order to reduce MLT and potential sources of information are included:

- ZX administrative MRP system, master production schedule documents interviews, and operation-time data are usually obtained from experienced company employees.
- Production planning orders report as well as including quarterly reports,
- Questionnaire/Survey results, face-to-face interviews, observation and mystery customer reports have been conducted.

The interview was conducted face-to-face and a workshop procedure has been conducted that uses an interpersonal interaction to elicit answers pertinent to the research hypothesis. The sampling technique has been described, followed by techniques for data collection in research methodology. Also data collected in this case study from production planner. The responses to each question have been assigned with numerical values for the data analysis, so the data collection method will have a strong impact on this case study design. Step procedure for observing and evaluating have been taken for 2 weeks as workshop and tested production orders for a new production schedule and completed as well the new production orders for 2 weeks (1 to 14 Sept 2013) has been conducted then updated onto MRP programs in the ZX computer system and still met the order requirements under capacity available hours, which is 8 hours required / or limited. Also, the production planner’s action has been done underutilisation hours as daily production orders for 160 units during 5 days (Sunday to Thursday).

5.6 Data analysis procedures

What decisions or actions are likely to be influenced by the results?

Data analysis procedures for this case study were completed on 14 Sept 2013. The strategic important of forecasting has been conducted also other information related to the primary function of staff, experiences, skill, feedback and quality control are provided by statistical process control (SPC) as well as SPC, a standard methodology for measuring defects or variability and controlling quality and lead time during the manufacturing process, also applied. The statistical analyses that have been conducted include: overall multi-dimension constructs of measurement towards each factor, descriptive statistics, regression statistics and parametric tests. Statistical methods and various techniques have been conducted. The summary of the whole results was collected. In research methodology, the strategic importance of forecasting was carried out. One of the forecasting methods in this research methodology was average methods (moving-average) for equally weighted observations. This is a basic assumption behind averaging and smoothing models, and it is a time series which is locally stationary with a slowly varying mean (Heizer and Render, 2008). The study also used an exponential moving average (EMA), which uses an exponentially weighted multiplier to give more weight to recent lot sizing to determine the trend of order demand when compared with a weighted moving average. For more details on statistical methods and techniques see chapter 3, sections 3.2, 3.4, 3.5, 3.6, for an overview of statistical methods and techniques, limitations and ethical considerations, reliability and validity in this research study.

5.7 Methodology

5.7.1 Steps undertaken to address the problem

Furthermore, this research case study is based on the results of an assessment questionnaire designed for survey staff in 8 factories, including ZX. Therefore, most of the statements indicated that the factories do not competes on quality such as: defects and long lead-time could be expected during the process time. Therefore an assessment questionnaire is an effective assessment tool to help the researcher better understand the problems and opportunities confronting ZX operations and the answers will also help: to identify those areas of ZX operation that may need some attention and highlight some of the non-technical parts of ZX operation that may be impeding ZX growth and opportunities for reducing MLT.

This research observed and investigated an MRP planning sheet for an item (HDPE); it appears that ZX factory has difficulty forecasting the demanded quantities. This is positively related to lead time, which was causing an obstruction of rapidly responding to customers' demand and there is a lack orders release mechanisms. In addition, ZX has used inaccurate lot size decisions, therefore which kind of lot-sizing techniques should be considered for that problem at the right place. There may be differences between operation schedules for an order and the manufacturing lead time for an item at ZX. Therefore, I have decided to develop a material requirements plan as well as developing capacity planning for producing plastic pipes over an 8-week period and production orders for the next 5 days in the week.

In terms of the purposes of creating the reschedule capacity planning, this research has the following aims and objectives:

- To reduce MRP 'buckets' from weekly to daily to perhaps hourly. Buckets are time units in an MRP and lead to the convergence of finite capacity scheduling (FCS) and MRP. This is because sophisticated FCS systems modify the output from the MRP system to provide a finite schedule. This approach can integrate MRP with just in time (JIT). Making MRP more responsive to moving material rapidly in small batches with JIT procedure will reduce the WIP inventory. Consequently, lead time will be reduced because Little's Law mentioned that WIP is throughput multiplied by cycle time (Hopp & Spearman, 2001). Little's Law for a Kanban team WIP equal throughput by multiply to lead time (Lowe, 2014).
- To enable the production planner to utilise the capacity system more effectively and still meet the order requirements or customer demands, at least moving the work between time periods to bring it within capacity.
- To smooth the load and minimise the impact of changed lead time, consequently reducing the delivery time for products.
- To enable reschedule capacity planning in order to:

a) Reduce WIP and lower inventory level, which releases capital for other uses and leads to faster product throughput (that is, shorter lead times).

b) Reduce floor space and reduce move time.

- To control the waiting line (queuing model) lead to determine the flow through a production process, to design systems that optimise some criteria, to evaluate alternatives in an attempt to control/improve the situation, to analyse models of waiting lines that can help managers evaluate the cost and effectiveness of service systems.

- To monitor and improve the effectiveness of manufacturing processes (i.e. machines, manufacturing cells, assembly lines) and OEE in order to:

a) Analyse the plant operating time; the amount of time a facility is open and available for equipment operation.
b) Determine availability (downtime loss).
c) Identify performance (speed loss).
d) Identify quality loss (defects that require rework).

Road map of capacity planning shown on Figure 5.4

The road map of capacity planning should be carried out by the production planning department. Careful planning of the production system is required to improve efficiency. Such planning should first look at the available resources and capacity to determine the production schedules

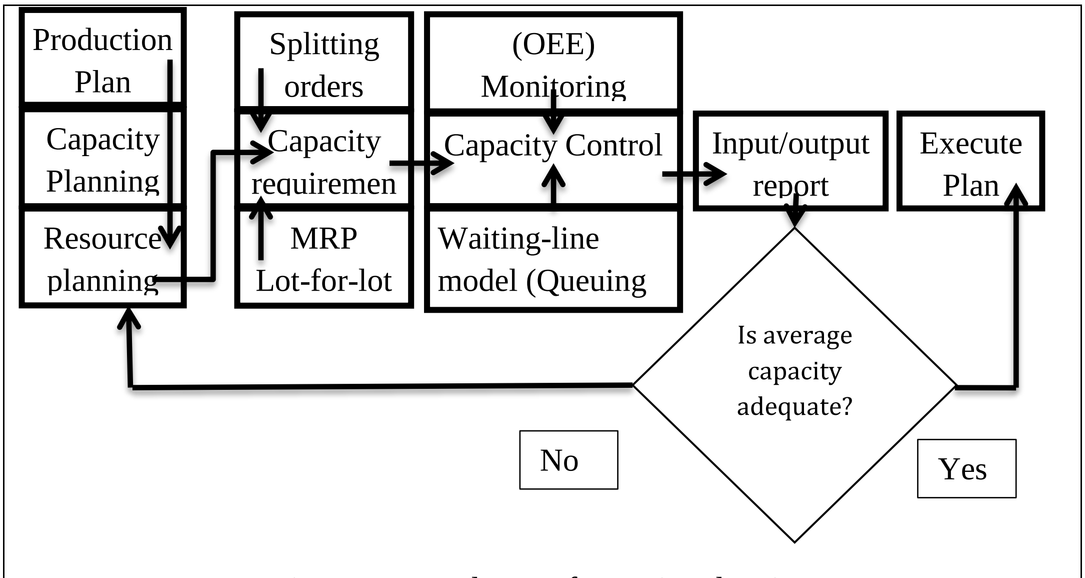

Figure 5.4 Road map of capacity planning

5.7.2 MRP phase

Brainstorming is an important step for planning to identify problems, objectives or the main purposes of carrying out the experiments, and the main factors that influence the results where is the factors are chosen according to their association with the problem or the main objective of the experiments and where the levels are chosen according to the depth of the investigation needed to meet the objective or identifying the main cause of the problem.

Materials requirements planning (MRP) is a dependent demand technique that uses a bill-of-material, inventory, expected receipts, and a master production schedule to determine material requirements (Heizer and Render, 2008). According to Beasley (2012), it is a technique with which a company / factory in the detailed planning of its production and a master production schedule sets out an aggregate plan for production therefore MRP translates an aggregate plan into an extremely detailed plan and MRP is also a computer-based system for planning and controlling inventory in a manufacturing process. A master production schedule tries to find which end items are to be produced and when end items will be needed! Heizer and Render (2008), stated that MRP system should produce units only as needed, with no safety stock and no anticipation of further orders.

In order to take a decision for lot-sizing or operational, it is depending on more techniques:
How should we determine to lot sizes? How should we split lots?
Should we use alternate routings? Therefore two related decisions are faced:

1-Timing
2-Quantity

The questions are: How should we determine lot sizes? What lead times should we use to drive our MRP system?
The research has taken to account that the manufacturing lead time for an item is the sum of its operation lead times, stated in manufacturing days and capacity planning uses manufacturing lead time, in conjunction with the work centre or shop calendar, to determine order release dates. According to Groover (2008), Suri (1998) and Hoppe and Spearman, (2001) , there may be differences between operation schedules for an order and the manufacturing lead time for an item due to any one of several reasons:

1. The item order quantity used to calculate the manufacturing lead time may be different than the actual order quantity for an operation, resulting in differences in the run time for an operation.
2. The shop and/or work centre calendars may be scheduled for more (or less) hours than the default calendars used to calculate manufacturing lead time.
3. Queue time for the first operation does not affect its start date; therefore, it may fall after the release date of an order and two successive operations may overlap.

Therefore this research has taken this strategy approach because this strategy aims to reduce MLT and capture customers' needs and to provide the right product or service within an acceptable time frame; this is the case, for reducing MLT.

5.7.2.1 Lot-sizing techniques

A lot-sizing decision is the process of, or techniques used in an MRP to determining lot size (batch size) and there are a variety of ways to determine lot size in an MRP system (Heizer and Render, 2008). Heizer and Render (2008) stated that "Net requirements plan depend on the logic of net requirements such as below:
Net Requirements = [Gross requirements + allocations] – [On hand + Scheduled receipts]".This research reviews a few of them:

1. Lot-for-lot: A lot-sizing technique that generates exactly what is required to meet the plan. When frequent orders are economical and the system and just-in-time (JIT) inventory techniques implemented, lot-for-lot (L4L) can very efficient and when setup costs are significant or management has been unable to implement JIT lot-for-lot can be expensive (Heizer and Render, 2008). This is our case because the lot-of-lot rule (by ordering as little as possible each time) will keep average inventory levels low, but will result in more orders on average as setup time will be increased and no extra on-hand inventory (Beasley, 2012).
2. Fixed order quantity (FOQ): It is a statistical technique using averages (such as average demand for a year) or the quantity ordered is an integer multiple

of the same fixed amount each time an order is made (Hoppe and Spearman, 2001; Beasley, 2012).

3. Fixed period requirements (FRP): The quantity ordered should be enough for fixed number of periods and both FRP and FOP rules have higher inventory level, but will result in less orders on average as setup time will be decreased (Hoppe and Spearman, 2001; Beasley, 2012). This is our case to compare with lot-for-lot, if we assumed the holding cost is equal to zero and the manufacturing system for all processes like the one-piece flow system at ZX factory for producing plastic pipes.

This research decided that the lot-for-lot technique was preferred for several reasons:

1. Ordering as little as possible each time will keep average inventory levels low, which is an important factor for reducing lead time because less working in process leads to a reduced cycle time and consequently leads to reduced MLT. It reduces lead times by reducing lot sizes. Therefore, our parts should be made in smaller batches that flow through the factory so that we can eliminate work in progress. The fundamental for relationship among WIP, cycle time, and throughput is known as Little's law (WIP = TH × CT) (see Hoppe and Spearman, 1990; Dessouky et al., 2002).

2. The lot-for-lot technique will help the production planner to utilise capacity more effectively and still meet the order requirements especially for daily production orders under the capacity available (minutes) for capacity requirements system (minutes) (Heizer and Render, 2008).

3. It tends to generate a smoother production schedule and the motivation behind using lot-of-lot policy is minimising inventory. If we order as much as is needed, there will be no ending inventory at all (Suri, 2003; Beasley, 2012).

4. Respecting the quantity decision the researcher ordered as late as possible, but never planned a void (stock out) and never ordered before needing to (Beasley, 2012).

5. ZX produces plastic pipes and all machines connected as a one-piece flow process, therefore it can reduce throughput time per part and /or manufacturing lead time because one-piece flow system leaded to reduce scrap and/or rework consequently decreased process time per part (Johnson, 2003). Because ZX has produced plastic pipes less setup time will be required even though setup orders will be increased so the setup cost is not expensive for using the lot-of-lot technique but will result in more orders on average and no cost of holding inventory will be occurred means no on-hand inventory is carried through the system therefore total holding cost = $0 (Heizer and Render, 2008; Hoppe and Spearman, 1990; Beasley, 2012).

Small lot sizes can reduce manufacturing lead time or throughput time because small lots reduce variability in the system and smooth production therefore small lot sizes can reduce cycle time and work-in-process inventory (WIP) if the setup times are not much larger than the unit run times (Dessouky et al., 2002). A reduction in the cycle time allows the manufacturer to respond more quickly to new customer orders or any changes in demand, and increases the likelihood of meeting the demand on time. Small lot sizes tend to reduce the cycle time because a lot spends less time at a machining centre, causing new arriving lots to wait less for the machines to become available. However, reducing the lot size too much can sometimes have the opposite effect by increasing the cycle time because machine utilisation may increase significantly due to an increase in the total setup times per unit period (Dessouky et al., 2002; Johnson, 2003; Hoppe and Spearman, 1990).

Therefore, this research has decided on using a lot-sizing technique which is lot-for-lot rule and this is called a lot-sizing decision so there is a research procedure for this case study in terms of aims and objectives.

5.7.2.2 Step procedure to determine lot sizes in MRP

Lot size decisions impact on inventory levels, manufacturing lead time, setup time, ordering cost, capacity requirement and availability but lot size decisions are impacted by number of level in bill of material, cost of setup or purchase order and cost of carrying an item to inventory, low level code of an item (Hoppe and Spearman, 2001; Heizer and Render, 2008).

During 8 days at ZX factory this research study inspected, tested and estimated for the material requirements plan for producing (polyethylene) pipes and normally the pipes ready for delivery process. It takes 9 days but due to inefficient planning, this research decided with the production planner to develop a material requirements plan over 8 weeks. The estimate of lead time between releasing an order to the shop floor and producing a finished pipe is 2 weeks. ZX currently has 270 pipes in stock and no safety stock (safety stock is stock held in reserve to meet customer demand if necessary). The forecast customer demand is for 160 pipes in week 1, 0 in week 2, 80 in week 3, 0 in week 4, 150 in week 5, 0 in week 6, 95 in week 7 and 70 in week 8. See Table 5.1. Therefore this research decided to choose a lot-sizing technique which is lot-for-lot. The ZX determined lot-sizing technique which was fixed period requirements (FPR), therefore a question is: *What the optimal size of the lot?*

Table 5.1 Gross material requirements plan sheet for item HDPE

Item: HDPE Safety Stock 0 in stock 270 Setup cost =$10 Holding cost =$0 Lead Time 2 weeks								
Week	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70

Step 1

ZX factory has gross material requirements equal to 555 pipes for 8 weeks and ZX currently has 270 pipes available therefore if these are used to meet the demand of 160pipes in week 1, ZX has 270 – 160 = 110 pipes left on-hand (in stock)as shown for step 1.Refer to Table 5.1.

Step 2

The production planner should need to order some more pipes in order to meet all of the forecast future demand over the 8 weeks planning period, therefore the production planner faces two related decisions about ordering: when to order?, how much to order?

For step 2 suppose we order nothing in week 1, nothing in week 2, etc. The situation by the time we reach the end of week 5 will be as shown in Table 5.2. To avoid a stock-out in week 5 we plainly need to order at least 120 pipes. We know that the lead time between ordering a pipe and receiving it is 2 weeks. Therefore, to avoid a stock-out in week 5 we must have ordered 120 pipes either in week 3, or in any week before week 3. In other words ordering:

125 pipes in week 1, or
125 pipes in week 2, or
125 pipes in week 3.

We know that the lead time between ordering a pipe and receiving it is 2 weeks. It would seem appropriate therefore to order 120 pipes in week 3. If we order these pipes earlier than week 3 we will be carrying extra inventory (stock) cost for a number of periods, as we know carrying stock costs money, ensuring that we have sufficient pipes available to meet forecast demand in week 5. Refer to Table 5.2 for step 2.

- **Step 3**

In the same manner we must have ordered 95 pipes and lead time between ordering a pipe and receiving it is 2 weeks, so requiring an order of 95 pipes in week 5. Refer to Table 5.2for step 3.

- **Step 4**

In the same way we must have ordered 70 pipes and lead time between ordering a pipe and receiving it is 2 weeks, therefore requiring an order of 70 pipes in week 6, refer to Table 5.2 for step 4. On which to base order decisions in weeks 7 and 8 because we are at the end of the planning period, these are usually taken as zero for week 7 and week 8 (Heizer and Render, 2008). All steps have been completed see Table 5.3 lot-for-lot technique (ZX)

Confirming phase

Verification and validation for research results will be considered in order to check whether the problem is solved and optimal performance is achieved through new setting of the parameters. To verify our procedure for calculation see Table 5.3, ZX has ordered 285 pipes and 270 pipes are in stock therefore the overall total is equal to 555 pipes so if we compute forecast customer demand for 8 weeks planning period as (160 + 0 + 80 + 0 + 150 + 0 + 95 + 70 = 555 pipes). Therefore we have sufficient pipes available to meet forecast demand for 8 weeks planning period. Gross requirements average per week is equal to 69 units.

Step procedure to determine FPR technique

Previously, Zahla factory had used inappropriate lot-sizing decision with fixed period requirements (FPR) rule, refer to Table 5.4and step procedures of week1 and week 2 have been done by same manner of lot-for-lot rule on-hand at end of week such as: step 1 and 2 were shown in the Table 5.2

To illustrate the FPR rule the production planner decided to order enough for 3 weeks when we make an order and we know that the lead time between ordering a pipe and receiving it is 2 weeks. The situation at the end of week 5 which is the same as step 2 for Table 5.2 but to decide the FPR order quantity a production planner continues that calculation until week 7. The quantity ordered must then be just sufficient to cover weeks 5 to 7 (i.e. to cover 3 weeks as required for a 3 week FPR), therefore the 3 week FRP order is 215 pipes in week 3 and on-hand at end of week 4 is 30 units therefore 215 pipes minus 30 pipes will leave 120 pipes, which subtracted from 215 pipes will leave 95 pipes on-hand at end of week 5 and week 6 (see Table 5.4). The production planner needs an order in week 6 to cover the stock-out in week 8. The production planner needs to place an order in week 6 to cover the stock-out in week 8 and at the end of the planning period the production planner usually ordered just sufficient (i.e. reverting to the LFL rule) and ordered 70 pipes in week 6 (refer to Table 5.4). The FPR rule applied to cover p periods. The production planner makes (at most) one order every p periods (ignoring any order necessary at the end of the planning period) (Beasley, 2012). Also the total costs of Lot-of-lot and FPR have been calculated.

Table 5.2 MRP lot-sizing: lot-for-lot technique

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Step1 Lead Time 2 weeks in stock 270								
Week (Period)	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70
On-hand at end of week	110							
Order Releases	?	?	?	?	?	?	?	?
Step2 Lead Time 2 weeks								
Week (Period)	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70
On-hand at end of week	110	110	30	30	-120			
Order Releases	0	0	120	?	?	?	?	?
Step3 Lead Time 2 weeks								
Week (Period)	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70
On-hand at end of week	110	110	30	30	0	0	-95	
Order Releases	0	0	120	0	95	?	?	?
Step4 Lead Time 2 weeks								
Week (Period)	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70
On-hand at end of week	110	110	30	30	0	0	0	-70
Order Releases	0	0	120	0	95	70	0	0

Table 5.3 Lot-sizing decision: lot-for-lot technique (ZX)

Item: HDPE Safety Stock 0 in stock 270 Setup cost =$50 Holding cost =$0 Lead Time 2 weeks Total cost =$430								
Week	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70
On-hand at end of week	110	110	30	30	0	0	0	0
Order Releases			120		95	70		

Gross requirements average per week = 69, Setup cost=3*50=$150

No Initial inventory Holding cost =$280, the sum of (110+110+30+30) for 8 weeks and

Total cost = $150+ $280= $430 for 8 weeks.

Table 5.4 Lot-sizing decision: FPR technique (ZX)

Item: HDPE Safety Stock 0 in stock 270 Setup cost =$50 Holding cost = $1/week Lead Time 2 weeks Total cost=$570								
Week	1	2	3	4	5	6	7	8
Demand	160	0	80	0	150	0	95	70
On-hand at end of week	110	110	30	30	95	95	0	0
Order Releases			215			70		

Gross requirements average per week = 69, Setup cost=2*50=$100

No Initial inventory so Holding cost = $470, the sum of (110+110+30+30+95+95) for 8 weeks and Total cost = 100+470=$570 for 8 weeks

5.7.3 Reschedule capacity planning phase and splitting orders

This approach is based on the determination of accurate capacity planning and lead-time estimates by using lot splitting as a tactic for smoothing the load and reducing MRP 'buckets' from weekly to daily under capacity available (minutes). Buckets are time units in the material requirements planning system (Heizer and Render, 2008). Obviously, the closed-loop MRP system provides information to the capacity plan, master production schedule, and ultimately to the production plan (Heizer and Render, 2008). Therefore the researcher and production planner proposed that the ZX computer system should have an upgrade and update the closed-loop of capacity planning in order to provide information to the capacity plan, master production schedule, production plan and especially for daily production orders, because the closed-loop of capacity planning (see Figure 5.4) as the same procedures for closed-loop MRP will provide feedback about workload and capacity available (minutes) then can reschedule all items in the net requirements plan as well as it will give input /output report in order to ensure or verify if the average capacity is adequate? (and realistic? for the desired master production schedule). The closed-loop capacity planning will increase the speed and accuracy of information for the ZX production planner.

Step procedure

In order to reduce the manufacturing lead time and smoothing load or minimise the impact of changed lead time, the production planner should have some tactics or at least one of them (Hoppe and Spearman, 2001; Heizer and Render, 2008), included the following:

1. Overlapping, which reduces the lead time, sends part of the work to the following operations before the entire lot is complete on the first operation.
2. Operations splitting: sends the lot to two different machines for the same operation. This involves an additional setup, but results in shorter throughput time, because only one part of the lot is processed on each machine time but increased setup costs.

3. Order, or, lot splitting breaking up the order into smaller lots and running part ahead of schedule,

From the literature review, previous research has clearly and consistently shown that flow time advantages accrue from splitting production lots into smaller transfer batches or sub-lots (Hoppe and Spearman, 2001; Karmarkar, 1993; Heizer and Render, 2008).
Asking the questions and this is the short term for operational decisions such as:
How should we split lots? Should we use alternate routings? How should we work overtime? What delivery dates should be promised?
Therefore, this research has chosen a lot splitting technique because the situation is that all machine processes are connected to each together with no space between them, they are connected together. ZX is producing plastic pipes as a one-piece flow and the processes of producing pipes have 8 processes such as raw material conveyor, extruder/ heating, trolley mounted die head, vacuum / pressure calibration system, pipe cooling trough, haul-off, auto rotary cutter and auto stock-piling unit – all are linked together. See Figure 5.2 for a process flow chart of the plastic pipes.
This research study decided splitting orders should be considered a logical technique for smoothing the load and minimising the impact of changed lead time. The production planner illustrated his ZX material resource planning for weekly demand for labour, machine-hours and payables for 160 units. Each pipe will take 15 minutes but ZX has only 480 minutes as the time available in work centre for a normal day except overtime and daily production orders, which are shown in Table 5.5.

Table 5.5 Daily production orders

Production Orders Daily (1Week) ZX.Co.Ltd C A System 8 Hours (Daily) Item: HDPE 1 Sept 2013					
Day	**1**	**2**	**3**	**4**	**5**
Orders	**30**	**34**	**31**	**30**	**35**

Step 1: compute the time available in work centre

Step 2 : compute the necessary time for production requirements

Step 3: compute new production schedule for units ordered

Step 4: production planner's action (splitting the order).

This research assigned two units from day two to day one's work, and two units from day five to day four's work and one unit to day three (or requested overtime), therefore no overtime was requested. See Table 5.6.

Table 5.6 Production order for new production schedule

Day	Units Ordered	Capacity Required (minutes)	Capacity Available (minutes)	Utilisation **Over** / (Under) (minutes)	New Production Schedule
1	30	450	480	(30)	32
2	34	510	480	**30**	32
3	31	465	480	(15)	32
4	30	450	480	(30)	32
5	35	525	480	**45**	32
Total	160	2400	2400		160

Sep 5: Testing:

Step procedure for observing and evaluating have been taken for 2 weeks as workshop and tested production orders for a new production schedule and completed as well the new production orders for 2 weeks (1 to 14 Sept 2013) then new production schedule updated onto MRP programs in the ZX computer system and still met the order requirements under capacity available hours, which is 8 hours required / or limited. Also, the production planner's action have been done underutilisation hours as daily production orders for 160 units during 5 days (Sunday to Thursday) as shown in Table 5.6, when the workload consistently exceeds work-centre capacity, the tactics just discussed before are not adequate. This may mean adding capacity for some weeks therefore the production planner's action should consider over time or need extra days to meet the order requirements; options include adding capacity via personnel, machinery, over time, or subcontracting. The research study found that make setups occur as frequently as possible (small lot sizes) as long as capacity is available.

5.7.3.1 Summary

This research explores the causes of excessive lead time and suggests practical, inexpensive strategies for reducing it. The bottlenecks within the production process most likely are (input of raw material for loading and setup temperature for Extruder/ heating processing). The researcher tested production orders for a new production schedule (new production orders). Therefore by splitting the order, the production planners are able to utilise capacity more effectively and still meet the order requirements and also the manufacturing lead time will be reduced from 9 days to 7 days as MLT reduced by 22.22%, because the process lead time started from Sunday and the next Sunday all 160 pipes will be ready for delivery process. ZX 'standard' products (units) are available for next Sunday delivery therefore the order-to-delivery cycle will be reduced. This research identified simple strategies for reducing manufacturing lead-time by three technical approaches such as: MRP lot sizing (lot -for-lot) technique, reduce MRP ‘buckets’ from weekly to daily production orders to perhaps hourly, using order splitting to improve when the workload consistently exceeds work-centre capacity. Lot splitting is known to offer numerous advantages over a lot-for-lot policy, such as decreasing flow times and lower congestion levels. Therefore ZX has reduced lead times (the time from when a customer order is taken until it is shipped) from months and weeks to days.

5.7.4 Design a work balance chart

How can ZX create a work balance chart? Or develop a work balance chart?

Efficient production in a work requires appropriate staffing and balancing work because the important step is reorganising people and machines into groups to focus on single products or product groups so that we can reduce work-in-process inventory also heightened sense of employee participation so that the products will be available and faster for next-day delivery. Also, a high level of training and flexibility should be required especially for the one-piece flow process or work cell. Once the work cell has the appropriate equipment located in the proper sequence, the next task is to staff and balance the work. The work balance chart used for evaluating operation times in work cells also can help identify bottleneck operations then with cross-trained employees can help address labour bottlenecks therefore it will give the opportunity to improve the operation’s efficiency and flexibility, appropriate staffing and cross-training led to reduce down time system then consequently will reduce WIP and MLT. This procedure involves two steps: determine the Takt time and the number of operators required. A work balance chart was created by the researcher at ZX. ZX expects 160 pipes delivered weekly. During 8 days in the ZX, this research study estimated and evaluated 5 operations are necessary for creating a work balance chart to put standard time required (minutes) and numbers of operations (see Table 5.7) and data collections were from thw ZX production planner in order to design the work balance chart. Therefore, the researcher recommends the production planner should have three steps to determine the Takt time and workers required in order to develop a work balance chart to help determine the time for each operation in the work, as well as total time:

Step 1: Determine Takt time, which is the pace (frequency) of productions units necessary to meet customer orders (Heizer and Render, 2008):

Takt time = total work time available / units required.

Takt time= (8 hours * 60)* 5 days (available) / 160 = 15 minutes

Step 2: Determine the number of operations required. This requires dividing the total operations time in the work by the Takt time (Heizer and Render, 2008):

Workers required = Total operation time required / Takt time

Workers required = 35 / 15 = 2.333 operators and round up which is equal 3 workers (operators).

Step 3: An alternative support procedure is splitting a job into multiple lots, which increases time spent on setups but might also decrease the time taken to perform an entire job by allowing portions of a job to be simultaneously processed on several machines / or 3 workers.

Insight: To produce one unit every 15 minutes will require 2.333 operators therefore with 3 operators this work will produce one unit each 11.666 minutes (35 minutes / 3 operators = 11.666) and 205 units per week will be delivered, 205 pipes during every Sunday (2400 minutes / 11.666 for each unit = 205 pipes) so ZX can produce more units, which will also lead to increase availability and the work cell producing the pipes is schedule for 8 hours during 5 days, therefore this approach will save time to any unexpected down time in the system or can control/ or reduce the causes of variability of workload on delivery time then WIP and MLT will be controlled or reduced because work balance used for evaluating operation times in work also can help identify bottleneck operations then lead to reduce work in process consequently will reduce MLT. Work balance for ZX plastic pipe production shown in Table 5.7 and will help to design work balance chart at ZX, also ZX can develop a work balance chart. Therefore, the production planner's only slight increases in production capacities can lead to significant reduction of manufacturing lead times and significant reduction of the work-in-process inventory.

Table 5.7 Work balance for pipe production

Work balance for Item: HDPE ZX Co. Ltd Sept 2013 Schedule for 8 Hours (Daily), Weekly 160 pipes ready for every next Sunday delivery					
Operations	Assemble	Stock-piling and polishing	Testing	Label	Pack for shipping
Standard time required (minutes)	15	8	4	2	6

5.7.4.1 Summary

Two tasks have been done for determining Takt time and workers required, which are required for the work balance chart. The staffing and balancing in work should be considered by a production planner because those two tasks are important steps for a simple strategy approach to increasing availability system because the efficient production in a work requires appropriate staffing. An appropriate work balance chart is used for evaluating operation times in work. Appropriate staffing and balancing work also can lead to reduced work in process. The researcher uses two equations and develops a work balance chart to help determine the time for each operation in the work, as well as total time by considering two steps for developing work balance chart at ZX. A work balance chart is also valuable for evaluating the operation times in work cells as well as total time. Appropriate staff and balancing work will lead to increase the operation's efficiency, improve performance and flexibility in order to save time and control /or reduce MLT also lead to quick response to customer. Also, this research has found that splitting a job into multiple lots increases time spent on setups but might also decrease the time to perform an entire job by allowing portions of job to be simultaneously processed by three workers as required for assembly line area in order to save time also small lots reduce variability in the system and smooth production lead to reduce MLT consequently the order-to-delivery cycle will be drastically reduced. This is acceptable in today's time-based competition.

5.7.5 Performance measure of queuing system (Waiting line)

5.7.5.1 Introduction

In this research "queuing theory" used quantitative analysis techniques. It is the study of waiting lines as well as analytical model of waiting lines can help managers evaluate the cost, wait time and effectiveness of service systems. Finding it important to implement the queuing theory because it is the mathematical analysis of how pipes moves through a system with queues also offers insight into understand, study of waiting lines and improve throughput in manufacturing sectors and services also queuing theory deals with problems which involve waiting because most waiting line problems are focused on finding the ideal level of service a firm should provide therefore in most cases, this service level is something management can control as well as organizations typically want to find the service level that minimizes the total expected cost . Queuing theory is an important part of operations and a valuable tool for the operations manager also for solving waiting lines in the field of business has recently gained considerable attention and to carried out more often at a systematic high level of abstraction in a strategic decision-making phase in order to create a list of "potential layouts". Characteristics of a queuing system that impact its performance, for example, queuing requirements of ZX plastic pipe factory will depend upon factors like:

How do pipes arrive in the factory? Are pipes arrivals more during manufacturing processes? Or is the pipe traffic more uniformly distributed? Thus the two factors can be expressed mathematically as probability distributions

How much time do pipes spend in the shop floor? Do pipes typically leave the shop floor in a fixed amount of time? Does the process time vary with the type of pipes?

How many services or multiphase system does the ZX have for producing pipe? Sampson, S. (2012) stated that "queuing theory is quantitative tools for service operations management; we can determine how long will a customer or their inputs have to wait in a queue to receive service?" Heizer, J. and Render, B. (2008) stated "three basic components of a queuing process are arrivals, service facilities, and the actual waiting line. The amount of waiting required of customers or their inputs will be a function of various factors, including: The rate at which pipes arrive, how fast the servers serve, and the way the service system is configured" therefore if ZX factory has an idea of pipes arrival rate, that information might be used to determine an optimal service system configuration. If ZX a factory has too much capacity, such as with too many servers working at too fast of a collective rate, then the servers could wind up spending most of their time in idleness. In this research study noted that the characteristics of a queuing system in ZX factory is single-channel as multiphase system see Figure 5.5. Also Sampson, S. (2012) stated that if we have too little capacity–with too few servers–then customers or their inputs may spend much of their time in idleness waiting to be served.

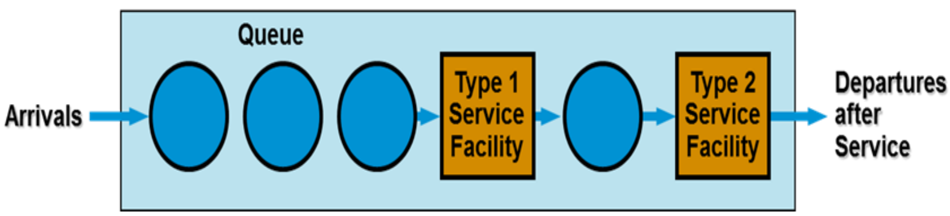

Figure 5.5 Single-Channel, Multiphase System

(Heizer and Render, 2008)

5.7.5.2 Performance measure of waiting line

In this procedure to control waiting lines at ZX factory therefore queuing theory can be used to analyse waiting-line production problems.

There are a number of procedures should be taken to account in the design of a queuing system:

- Creating queue configuration, this is how the queue is organized. There might be one queue feeding multiple servers, or each server having its' own queue.
- Queue discipline, or the way the next unit is selected from the queue to be served. A common queue discipline is first-in-first-out (FIFO) which is the same as first-come-first-served (FCFS) (Sampson, 2012).
- Queue size limits. Some queues will hold a limited number of pipes. Others will only hold a fixed number of pipes, after which subsequent pipes will be turned away.
- Number of service phases. Some services have the customer or inputs wait for a single service. With others, the customer waits to see the first server, then may wait to see another server, and perhaps a third, etc. (Beasley, 2012)

The characteristics of a queuing system in ZX have been considered by looking at the three parts of queuing system: (1) the arrival or inputs to the system, (2) the waiting line itself, and (3) the service facility. These three components have certain characteristics that must be examined before mathematical queuing models can be developed

5.7.5.3 Modelling with queuing theory

In this research may make the following assumptions:

- Units arrive independently from one another according to a Poisson distribution with average arrival rate of λ. (Sampson, 2012). This average arrival rate is stable throughout the time period under consideration.

- The service rate is from any general distribution (e.g. normal, uniform, etc.) with a mean of **μ.** Note that the average service time is 1/μ. (Sampson, 2012).
- There are multiphase phase of service and a single channel (server).
- The queue has limited capacity, and the queue discipline is FIFO.
- The "traffic intensity," identified by ρ or "rho," is calculated as λ/μ. For a single-server system like this rho is the average utilization of that server. (Sampson, 2012).
- **μ>λ**, which means that the average service rate is greater than the average arrival rate.
- Using M/M/1queuing system. "M means there is an arrival distribution, M means there is a service time distribution means there is probability distribution for the service process, and 1 means there is one server". (Heizer and Render, 2008).

In this research method assuming that service time for each pipe is constant but ZX factory has multiphase phase of service and a single channel server, it is a one server, and then it would probably be necessary to use the M/M/1equations (Sampson, 2012), also negative exponential distribution for service times on different arrival pipes units. Analysts should take to ensure observations fit the assumed distributions when applying this model. See Table5.8

Table5.8 Key measurements of waiting-line analysis.

Sources: (Heizer and Render, 2008).

Single-Channel Model with Poisson arrivals, FCFS and exponential service times (**M/M/1**) denoted: Arrival distribution **/** Service time distribution **/** Number of service channels open.	
Key measurements	Equations
Arrival rate (λ) lambda	1/(λ) Inter-arrival time
Service rate (μ)	1/ (μ) Average service time
Traffic intensity (p) or rho	rho $= \frac{\lambda}{\mu}$
Average server utilization(P).[The service unit is idle] or % of time mechanic is busy	$\rho = \frac{\lambda}{\mu}$
Average number of Units in the queue(Lq)	$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)}$
Average number of Units in the system(Ls)	$L = \frac{\lambda}{\mu-\lambda}$
Average waiting time in the queue(Wq)	$W_q = \frac{\lambda}{\mu(\mu-\lambda)}$
Average time in the system(Ws) Ws equal to MLT (Norman and Frazier, (2001)	$W = \frac{1}{\mu-\lambda}$
Probability (% of time) system is empty (P_0) (0 units) in the system	$P_0 = 1 - \frac{\lambda}{\mu}$
The Poisson distribution , e = 2.7183, *P*(X)= probability of X arrivals	$P(X) = \frac{e^{-\lambda}\lambda^X}{X!}$ for $X = 0, 1, 2, 3, 4, ...$

5.7.5.4 Summary

This section explained why the queuing theory is important for ZX factory (ZX), because queuing theory can improve delivery time / or lead time and maintaining customer loyalty also queuing theory and practice can help ZX factory to improve their MLT also a source of competitive advantage. Queuing theory (Waiting line) will determine the order of service to customer also in order to control capacity problems which they are very common in factories and one of them drivers of process redesign need to balance the cost of increased capacity against productivity and service. The queuing and waiting time analysis is particularly important in service system to check out if the number of orders arrived is greater the capacity of the service facility in ZX. It is appeared that ZX factory has lack of measure of queuing system as well as managing waiting line is important technique for ZX. The purpose of analysing waiting line in ZX to evaluate and control the flow of pipes to improve efficiency and productivity in operations also queuing theory attempts to solve problems in optimal manner so that facilities are fully utilized and waiting time is reduced to minimum possible also queuing theory techniques can be applied to problems such as planning, scheduling and sequencing of pipes to assembly lines system see Figure 5.4. Queuing theory is useful tools for measuring the queue's performance at ZX. The simple type of single queue is the M/M/1 queue also in this research method stated that the queuing system consists of two components (the queue and the server) and two attributes (the arrival rate is simply the inverse of the average inter-arrival time means the rate at which orders arrive, how fast the server serve (service rate (μ)), and the way the service system is configured which is multiply phases in the ZX factory (ZX). The main purpose of this queuing theory is to identify key operational measures that may be used to study process flows also they are linked together using the model of M/M/1 and Little's law. This research then presented two of examples that show how waiting-line analysis may be used to study performance as well as identify target areas for improvement.

5.7.6 Overall Equipment Effectiveness

5.7.6.1 Introduction

Overall equipment effectiveness (OEE) is an effective assessment tool to help manufacturers to reduce or eliminate the "Six Big Losses" that limit production because OEE is comprised of three factors: availability, performance, and quality (Vorne Industries Inc., 2008) see Table 5.9 also OEE tool reduces complex production problems into simple, and it is intuitive presentation of information

(Vorne Industries Inc., 2008). It helps manufacturers systematically improve their process with easy-to-obtain measurements also “as a baseline it can be used to track progress over time in eliminating waste from a given production asset. OEE can monitor the system in order to ensure manufacturing processes and machines are available. This is because availability is an important factor that is also associated with WIP. Little’s Law defines WIP as throughput multiplied by lead time “(Lowe, 2014) and (Vorne Industries Inc., 2008). “OEE it’s original development in Japan in the 1970’s OEE as well as OEE is the main tool of the total productive maintenance (TPM) improvement program and is used to reduce or eliminate the “Six Big Losses” that limit production” (Vorne Industries Inc., 2008).

During research observation for two weeks in ZX factory (ZX), it appears that ZX did not take to account the role of OEE, that is a great tool for managers furthermore that factory did no find the method how to reduce complex production problems into simple also ZX did not know that OEE tool can be used to compare the performance of a given production asset to industry standards as well as manufacturing performance in ZX becomes invisible therefore OEE could be used to tracking, reporting and analysing the system performance , OEE is a metrics for the plant floor. It is used to highlight where to focus resources. The result is dramatic improvements in productivity, which gives a rapid return on improvement in lead time. ZX needs staff to manually collect and process data also reporting and analysis become late therefore manual OEE data collection increases administration costs and introduces data inaccuracies. The result is poor quality information, delivered too late to be of maximum benefit. Using OEE tools will help ZX to track and improve their manufacturing performance (Vorne Industries Inc 2008) and it is technical tool could be used to enable reschedule capacity planning in order to reduce WIP and lower inventory level and leads to faster product throughput (that is, shorter lead times). What is considered a “good” OEE score? Vorne Industries Inc, (2008) stated the OEE benchmarks are:

- An OEE score of 100% is perfect production: manufacturing only good parts, as fast as possible, with no down time.
- An OEE score of 85% is considered world class for discrete manufacturers. For many companies, it is a suitable long-term goal.

- An OEE score of 60% is fairly typical for discrete manufacturers, but indicates there is substantial room for improvement.
- An OEE score of 40% is not at all uncommon for manufacturing companies that are just starting to track and improve their manufacturing performance. It is a low score and in most cases can be easily improved through straightforward measures (e.g. by tracking down time reasons and addressing the largest sources of down time – one at a time). Vorne Industries Inc, (2008)

ZX factory can achieve world class OEE level, when ZX a fully connected OEE system comes into its own, when fast access to highly accurate information is crucial to target efficiency improvements and a way of easily seeing what progress is being made also OEE gives manufacturers a consistent way to measure the effectiveness of TPM (Total Productive Maintenance) and other initiatives by providing an overall framework for measuring production efficiency

Table 5.9 The factors that contribute to OEE losses. *Source (Vorne Industries Inc, 2008)*

OEE Loss	OEE Factor
Planned Shutdown	Not part of the OEE calculation.
Down Time Loss	• *Availability* is the ratio of Operating Time to Planned Production Time (Operating Time is Planned Production Time less Down Time Loss). • Calculated as the ratio of Operating Time to Planned Production Time. • 100% *Availability* means the process has been running without any recorded stops.
Speed Loss	• *Performance* is the ratio of Net Operating Time to Operating Time (Net Operating Time is Operating Time less Speed Loss). • Calculated as the ratio of Ideal Cycle Time to Actual Cycle Time, or alternately the ratio of Actual Run Rate to Ideal Run Rate. • 100% *Performance* means the process has been consistently running at its theoretical maximum speed.
Quality Loss	• *Quality* is the ratio of Fully Productive Time to Net Operating Time (Fully Productive Time is Net Operating Timeless Quality Loss). • Calculated as the ratio of Good Pieces to Total Pieces. • 100% *Quality* means there have been no reject or rework pieces.

5.7.6.2 Calculating OEE

The OEE calculation is based on the three OEE factors which are: Availability, performance and quality and the best option requires having the full set of underlying data for each product run: operating time, planned production time, ideal cycle time, total pieces, and good pieces. In that case you can use the following calculations which are shown on Table 5.10. Therefore it is important to understand the assumptions you are making to make sure that you understand the final OEE result because OEE measures how effectively time is used to produce a quality product. OEE is one of those metrics that is easily calculated and can be applied to any process, department, or the entire organization. (Vorne Industries Inc, 2008)

Step procedures

In this research method, the following definitions of time at ZX are collected from production planner see Table 5.6 production order for new production schedule for 1 week on 1 Sept 20013 and Table 5.7 work balance for pipe production for item (HDPE) in order to calculate OEE (refer to Table 5.10 and Table 5.11)

- Schedule for 8 Hours (Daily) and weekly 160 pipes ready for delivery
- Planned Production Time, planned down time as scheduled down time events and unplanned (Process/Equipment) down time as unscheduled down time events
- Available time and an 8 hour shift are scheduled to produce item (HDPE).
- Total pipes and reject pipes, shift length and breaks

Table 5.10. Performance calculation. *Source (Vorne Industries Inc, 2008)*

OEE Factors	Formulas are used to calculate each of the OEE and overall OEE
Availability	Availability = Operating Time / Planned Production Time *Availability takes into account Down Time Loss*
Performance	Performance = Ideal Cycle Time / (Operating Time / Total Pieces). *Run Rate is the reciprocal of Cycle Time, Performance can also be calculated as*: Performance = (Total Pieces / Operating Time) / Ideal Run Rate *Performance takes into account Speed Loss* *Notice: Ideal Cycle Time is the minimum cycle time that your process can be expected to achieve in optimal circumstances,* *Ideal Cycle Time is the theoretical maximum throughput of the machine or process.*
Quality	Quality = Good Pieces / Total Pieces *Quality takes into account Quality Loss*
Overall OEE	OEE = Availability x Performance x Quality *OEE takes into account all three OEE Factors*

Table 5.11 Calculating OEE worksheet. *Source (Vorne Industries Inc, 2008)*

	A	B	C	D	E	F	G
1	Fill in the highlighted areas with your production data for a single shift. In some cases, you may have to convert units to simplify the calculation. For example, 3600 PPH (Pieces per Hour) is 60 PPM (Pieces per Minute).						
2	**Zhala Factory**		**Notice**	**P= Pipes**	**P = Per**	**M= Minute**	
3	**Item (HDPE) = Pipe**	**01-Sep-13**		**MPP**	**Minute per Pipes**		
4	**Production Data**						
5	**Shift Length**	8	Hours =	480	Minutes		
6	**Short Breaks**	2	Breaks @	15	Minutes Each =	30	Minutes Total
7	**Meal Break**	1	Breaks @	30	Minutes Each =	30	Minutes Total
8	**Down Time**	20	Minutes				
9	**Ideal Run Rate**	0.0833	PPM (Pipes Per Minute)				
10	**Total Pieces**	32	Pipes	**MAX Rate**	**Service Rate**	**5 PPH**	**Item**
11	**Reject Pieces**	4	Pipes		**Service time**	**12 MPP**	**Pipes**
12							
13							
14	**Support Variable**	**Calculation**				**Result**	
15	**Planned Production Time**	Shift Length - Breaks				420	Minutes
16	**Operating Time**	Planned Production Time - Down Time				400	Minutes
17	**Good Pieces**	Total Pieces - Reject Pieces				28	Pipes
18							
19							
20	**OEE Factor**	**Calculation**				**My OEE%**	
21	**Availability**	Operating Time / Planned Production Time				**95.24%**	
22	**Performance**	(Total Pieces / Operation Time) / Ideal Run Rate				**96.04%**	
23	**Quality**	Good Pieces / Total Pieces				**87.50%**	
24	**Overall OEE**	Availability x Performance x Quality				**80.03%**	
25	**OEE Factor**	**World Class OEE%**	**Zhala factory OEE%**				
26	**Availability**	90.00%	**95.24%**				
27	**Performance**	95.00%	**96.04%**				
28	**Quality**	99.90%	**87.50%**				
29	**Overall OEE**	85.00%	**80.03%**				
30	World Class Overall OEE for discrete manufacturing plants is generally considered to be 85% or better. Studies indicate that the average Overall OEE score for discrete manufacturing plants is approximately 60%.						

In this research method finds that the concepts of OEE are quite simple and really help to focus on the underlying causes of productivity loss because OEE score can delve even deeper into productivity losses by understanding the "Six big losses" (Vorne Industries Inc, 2008). The OEE worksheet is an important tool because it is a best practise way to monitor and improve the effectiveness of your manufacturing processes also it takes the most common and important sources of manufacturing productivity loss, places them into three primary categories and distils them into metrics that provide an excellent gauge for measuring where you are - and how you can improve! (Vorne Industries Inc, 2008). OEE is metrics for plant floor because it is easily interpreted for example the efficiency (the ratio of target to actual; how far ahead or behind production is running in terms of a percentage).

5.7.7 A complementary framework

5.5.7.1 Hypothetical transactions on reducing move time

The major components of non-value added lead-time are: wait time, move time and down time (Warren et al., 2004); therefore, the manufacturers or practitioners should understand the relationships between operation time and non-operation time in order to find potential methodologies that could reduce lead time in the manufacturing process, therefore reducing move time is important because one of the components of MLT or throughput time. It is a reasonable factor that leads to increase manufacturing lead-time and should be considered by practitioners or production planners before making a decision for manufacturing planning in order to reduce lead-time. ZX factory should optimise factory layout in order to reduce lead time. ZX factory should consider management, communication, long-term flexibility and best use of space because supervision and communication need to be considered in any layout. “Communication equipment (notice and performance boards etc.) and supervisor work stations must be accessible and close to where the action is and layouts need to be challenged and potentially changed periodically. Any design should be made with future requirements in mind” (Heizer and Render, 2008). Best use of space in the work stations is a great impact factor on process-oriented layout, work-cell layout and reducing move time because a lean principle is to minimise the production footprint or to fit as much in as practically possible. Changing the factory layout can potentially work towards that goal but using the space sometimes limited to be changed for arranging the departments to fit the shape of the building and its non-moveable area.(such as loading dock and stairways) also in all cases, layout design must consider how to achieve the following (Heizer and Render, 2008): (1)Higher utilization of space, equipment, and people. (2) Improved flow of information, materials, or people. (3) Improved the procedures of loading, un-loading, number of moving and move time. In this research assumptions for example: designing a process layout or work-cells layout and increase resource access such as robot machine loading/ unloading system productivity. The following step procedures are:

Step 1: When designing a process layout or work-cells layout, the most common tactic is to arrange departments or work centres so as to minimize the cost of material handling or so as to minimize material movement. In other words, departments with large flows of parts or staff between them should be placed next to one another. Material handling in this approach depend on (1) the number of loads (or staff) to be moved between two departments during some period of time and (2) the distance-related material movement of moving loads (or people) between departments. Material movement is assumed to be a function of distance between departments. The objective can be expressed as follows:

Minimize material movement = $\sum_{i=1}^{n}\sum_{j=1}^{n}$ Cij Xij…. (Heizer and Render, 2008). Where: (n) total number of work centres or departments, (i, j) individual departments, (Xij) number of loads moved from department i to department j, (Cij) distance to move a load between department i and department j. In this research method assumed that (Cij) that this is only slight modification of the cost-objective equation shown in the (chapter 9, p257) see (Heizer and Render, pp. 357-372, 2008) for minimizing material movement instead of (Cij) equal cost to move a load between department **i** and department **j**.

Step 2: Production planner at ZX factory should analyse records to determine the number of material movements among departments so as to minimize the total movement) distance travelled) of material in the facility during one month.in order to to improve material flow in the facility, using the process-layout method.

Step 3: Creating Interdepartmental activity matrix. ZX factory have different lines with departments and one the department was produced HDPE (pipes) also have four work areas in the same department. A work area is set aside for assembling, stock-piling and polishing, testing, (labelling and shipping) of final serving, although different areas may be worked for each of these functions. Giving the following interdepartmental activity matrix should be depended on records to determine the number of material movements among departments with a distance of 10 feet between adjacent areas. The current layout is shown in Table 5.12 and shows how to calculate of total area see Table 5.13

Table 5.12 Number of material movements (loads) between departments

	Assembly (A)	Stock-piling and polishing (B)	Testing (C)	Labelling and shipping (D)
Assembly (A)	-	7	193	12
Stock-piling and polishing (B)		-	4	82
Testing (C)			-	222
Labelling and shipping (D)				-

Table 5.13 Present layout

Present layout (10) feet and number of loads	10 feet	10 feet	10 feet	10 feet
	A	**B**	**C**	**D**
Work Area	Load * Distance		$\sum_{i=1}^{n}\sum_{j=1}^{n}$ Cij Xij	
A to B	7 * 10		70	
A to C	193*20		3860	
A to D	12*30		360	
B to C	4*10		40	
B to D	82*20		1640	
C to D	222*10		2220	
Total			8190	

From the activity matrix, C and D should be next to each other and A should be next to C. See Table 5.14. The other relationships are minor by comparison. One possible solution is minimizing material movement from 8190 feet to 7000 feet thus reduced material movement by 13.43% . Also further improvement is possible. For 4 work areas arrangements, there are actually 24 (or 4*3*2*1) potential arrangement, “manufacturer may not find optimal solution and may have to be satisfied with “reasonable” one. Therefore ZX factory should develop a preferred layout in order to reduce a material movement which is leading to reduce move time consequently MLT will be reduced “Heizer, J. and Render, B. (2008) and Johnson, D.J. (2003)”.

Table 5.14 Possible layout

Possible layout (10) feet and number of loads	10 feet	10 feet	10 feet	10 feet
	B	A	C	D
Work Area	Load * Distance		$\sum_{i=1}^{n}\sum_{j=1}^{n}$ Cij Xij	
A to B	7 * 10		70	
A to C	193*20		1930	
A to D	12*30		240	
B to C	4*10		80	
B to D	82*20		2460	
C to D	222*10		2220	
Total			7000	

Step 4: Increase resource access:

Move time can also be reduced by increasing access or using manufacturing technology such as programmable robotics, in this research method proposed robot machine loading system productivity for one-handed gripper and two-handed gripper. Measuring the typical operation sequence is shown in Table 5.15. Machine operation cycle time unloading machine, move to conveyor,

"Robot, can be used to move parts through a variety of paths and are flexible in that it can be directed to follow more than one path, it is important for controlling material handling also robot can reduce unnecessary movements by selecting the shortest path to reach the destination of units for loading and unloading machine quickly" Asfahl, (1992). This will reduce both number of moving and move time also robots are exponentially being incorporated into factories: bringing with them incredible precision, productivity and flexibility also robots more accurate and high quality work and rarely make mistake consequently work in process will be reduced this will reduce MLT because robots save time by being able to produce a greater magnitude. During the observations in ZX Factory, production planner recorded data for typical operation sequence which is shown on Table 5.15.

Assuming an average per cent system downtime in (ZX) and also assume that the robot has no other duties and waits at the machine.

(A)Assuming a one-handed gripper and (B) Assuming a two-handed robot gripper

“Production rate (units/shift) = 1Unit/ Total operation cycle time * 60 min/hour*8hur/shift* the production percent efficient for eight-hour shift” Asfahl, (1992).

Table 5.15 The typical operation sequence

Average operation time	Minute
Machine operation cycle (service time)	15
Robot picks up new part from to conveyor	1.5
Move robot hand from conveyor to machine	0.46
Robot loads parts into machine	0.35
Robot unloads part from machine	0.30
Move robot hand from machine to conveyor	0.45
Robot puts the finished part on conveyor (deposit part)	0.2
Total operation cycle time	17.76
Assuming an average percent system downtime (ZX)	20%
The production percent efficient for 8-hour shift (ZX)	80%

Production rate = 1unit /17.76 * 60 min/hour * 8hour/shift *0.80

Production rate (approximate) = 22 units/shift using one-handed gripper

(B) For two-handed gripper

The appropriate operation sequence would be: Machine operation cycle (service time) is 15min, Robot loads parts into machine is 0.35 min ,Robot unloads part from machine is 0.30 and total operation cycle time will be 15.65 min.

Note in the case of the two-handed gripper that the robot operations of move to the conveyor, deposit part ,pick up new part, and move to “the machine could all be performed by the robot during the machine operation cycle and are therefore omitted from sequence” Groover, M. (2001). The improved production level could be computed as:

Production rate = 1unit /15.65 * 60 min/hour * 8hour/shift *0.80

Production rate (approximate) = 25 units/shift using two-handed gripper

Therefore, two-handed gripper makes possible a per-shift production increase of

25- 22/ 22 = 13.60% .Without purchasing any additional robot or machine equipment. Also increased the efficiency of production rate when robot used double-hand gripper

Chapter 6 - Results and Discussion of ZX Plastic Pipe

6.1.1 The role of lot-sizing decision in MRP

A lot-sizing decision is a process used in an MRP to determine lot size (batch size) and there are a variety of ways to undertake it in an MRP system (Heizer and Render, 2008). During the interview for the research survey, it appeared that the production manager had insufficient time to complete his production orders in the allotted seven days. The ZX factory has insufficient MRP and capacity planning that may cause low flexible manufacturing, decrease resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, this will potentially affect critical delivery dates. Pipes should be ready for shipping so as to be delivered on time but a problem occurs four times a year. To make a decision for lot-sizing or operation depends on more techniques: How should we determine lot sizes? Or should we use alternate routings? Therefore, two related decisions are faced: first is timing and the second is quantity. Over 8 days at the factory this research study inspected, tested and estimated the material requirement plan for producing (polyethylene) pipes and making the pipes ready for the delivery process. It takes 9 days but due to inefficient planning, this research decided with the production planner to develop a material requirement plan over 8 weeks. The estimate of lead time between releasing an order to the shop floor and producing a finished pipe is 2 weeks. ZX currently has 270 pipes in stock and no safety stock (safety stock is stock held in reserve to meet customer demand if necessary). The forecast customer demand is for 160 pipes in week 1, 0 in week 2, 80 in week 3, 0 in week 4, 150 in week 5, 0 in week 6, 95 in week 7 and 70 in week 8 (See Table 5.1). Therefore this research decided to choose a lot-sizing technique which is lot-for-lot. The factory determined lot-sizing techniques which were fixed period requirements (FPR). The ZX factory has gross material requirements equal to 555 pipes for 8 weeks and currently has 270 pipes available therefore if these are used to meet the demand of 160 pipes in week 1, ZX has 270 – 160 = 110 pipes left on-hand (in stock) as shown in step 1(refer to Table 5.1). To verify our procedure for calculation, see Table 5.3. ZX ordered 285 pipes and 270 pipes are in stock therefore the overall total is equal to 555 pipes so if we compute forecast customer demand for an 8 week planning period as (160 + 0 + 80 + 0 + 150 + 0 + 95 + 70 = 555 pipes). Therefore we have sufficient pipes available to meet forecast demand for an 8 week planning period. Gross requirements averages per week are equal to 69 units. Previously, Zahla factory made inappropriate lot-sizing decisions with a fixed period requirements (FPR) rule, (refer to Table 5.4) and step procedures of week 1 and week 2 were done in same manner of lot-for-lot rule on-hand at end of the week such as: step 1 and 2 (shown in the Table 5.2). To illustrate the FPR rule the production planner decided to order enough for 3 weeks also using alternate routings which is a 3-week moving average (forecasting) applied and is shown in Figure 5.6. Three week moving averages did not order demand direction, but rather defined the current direction with a lag moving average because the values are based on past demand, despite this lag, a moving average helps smooth demand pipes action and filter out the noise. Furthermore can be used to identify the direction of the trend therefore the production planner at ZX should maintain the desirable inventory level to avoid stock-out for MRP. Also it appears that the 3-week moving average (forecasting) of pipes are inappropriate for both lot-sizing decisions and MRP at the factory because referring to Table 5.3, it appears that using a lot-of-lot technique that generates exactly what is required to meet the plan, avoided stock-out and also fixed the order releases for week 3 at 120 pipes, week 5 at 95 pipes and week 6 at 70 pipes for accurate order releases when lead time is fixed for 2 weeks. Therefore a 3-week moving average forecasting caused stock-out for pipes consequently MLT will be increased to meet customer demand on promise delivery time, forecasts are always wrong (Doane and Seward, 2009).

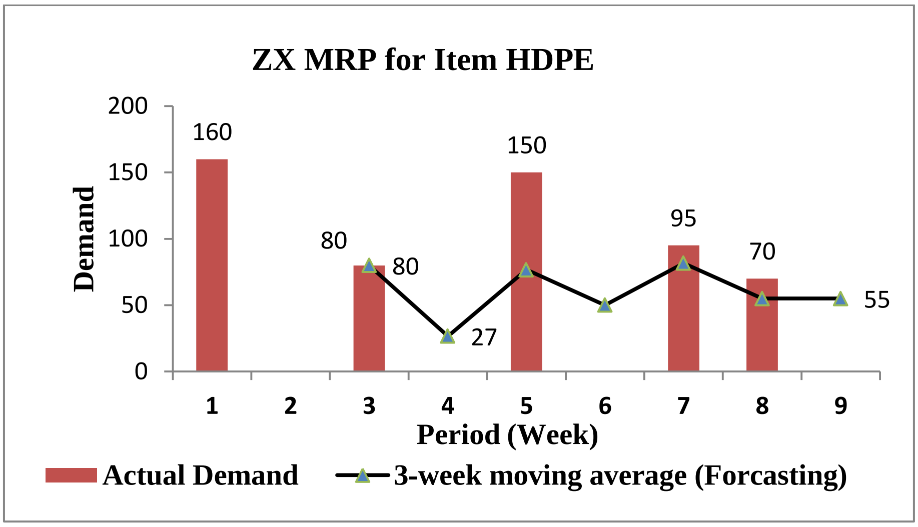

Figure 5.6 Actual demand and 3-weeks moving average (forecasting) of pipes

6.1.2 The reasoning behind the lot-for-lot ordering policy

1- The lot-for-lot ordering policy and order production was as much as needed - with respect to the timing decision we always ordered as little as possible, i.e. just enough to avoid a stock-out. Furthermore, it can be compatible to reduce MRP 'buckets' from weekly to daily when MRP can be integrated with just-in-time (JIT). Buckets are time units in an MRP system (Heizer and Render, 2008; Beasley, 2012).

2- The motivation behind using the lot-for-lot policy is in minimising inventory. If we order as much as is needed, there will be no ending inventory at all so no extra on hand inventory leading to a reduced WIP, consequently reducing cycle time and MLT. Lead time depends on cycle time (Lead time = cycle time * WIP or Lead time = WIP/Throughput), which was explained in law (Little's Law) theory (Hoppe and Spearman, 2001; Beasley, 2012).

3- Using lot-for-lot techniques in MRP systems allows production planners to move the work between time periods to smooth the load or at least bring it within capacity also allowing the manufacturer to respond more quickly to new customer orders or any changes in demand (Heizer and Render, 2008). Therefore, small lot sizes tend to reduce the cycle time because a lot spends less time at a machining centre, causing new arriving lots to wait less for the machines to become available, therefore small lot sizes are the main factor to reducing cycle time as well as MLT (Graves, 1999; Dessouky et al., 2002).

4- Although the number of setups will be increased and the number of setups has less significance because ZX has adopted a one-piece flow so all manufacturing processes run through 8 processes, only one setup procedure is required for all processes per batch size (lot size) in each week. It is like the one-piece flow and production processes need short changeover times meaning less setup time is required between machines, therefore the number of setups and setup time have less impact on manufacturing lead time that should be increased through the overall processes. In one-piece flow, the focus is on the product or on the transactional process, rather than on the waiting, transporting, and storage of either. One-piece flow methods need short changeover times (Hoppe and Spearman, 2001; Johnson, 2003).

6.1.3 Comparative analysis of Lot-for-Lot and FPR

The lot-for-lot (L4L) technique is compared with fixed period requirements (FPR). The L4L technique is very suitable for this case study especially in MRP lot-sizing decisions because there is no holding cost but three separate setups yielding a total cost of $150 (shown in Table 5.3), even though the setup cost is $150, which is greater than the setup cost for FPR, which is $100. L4L minimises inventory holding costs which are $470, but maximises ordering cost, while FPR has a total cost of $570 for 8 weeks but FPR has two separate setups during 8 periods shown in Table 5.4. Setup time and cost are not significant because product process in ZX is like a one-piece flow. In one-piece flow, the focus is on the product or on the transactional process, rather than on the waiting, transporting, and storage of either. The one-piece flow methods need short changeover times (Hoppe and Spearman, 2001; Johnson, 2003) through 8 processes only one setup procedure is required for all processes by each batch size (lot size) meaning setup time does not increase even though the number of setups is higher and does not impact much more on manufacturing lead time because the one-piece flow procedure may lead to reducing scrap and/or rework therefore manufacturing throughput time will be reduced in the terms of rework

(Johnson, 2003). In actual practice, lead times are related to the level of WIP because flow time equals WIP and is divided by throughput rate as with Little's Law (Hoppe and Spearman, 2001), therefore lot-for-lot will keep average inventory levels low when ZX adopted lot-for-lot decisions, therefore making setups occur as frequently as possible (smaller lot sizes) if capacity is available (Hoppe and Spearman, 2001). Table 5.4 shows that the FPR rules will have higher inventory levels because of increasing lot sizes too much, for example the FPR order is 225 units in week 3, which will cause more waiting in a queue when a batch arrives and finds the system busy (it simply takes longer for the current batch to finish, as well as increasing batch sizes will obviously increase the time spent for a batch to finish) therefore work-in-process will be increased and consequently MLT will be increased referring to Little's Law (Hoppe and Spearman, 2001). If the lot size is large the number of setups is reduced, and a lot needs a longer time to be processed and more work will arrive during the time the lot is being processed; an arriving lot also sees more work waiting ahead of it and thus will have a longer waiting time for using FRP, finding lot size dynamically for given demand values, and estimating the WIP and lead-time of a lot realistically by considering both therefore lot-for-lot techniques are more acceptable and feasible than the FPR rule because a lot-for-lot technique will keep average inventory levels low. The FPR rule will have higher inventory levels, but will result in fewer orders on average therefore the FPR rule has fewer setups but holding costs will be considered as costs, if setup costs have more significant values during the manufacturing processes the FPR will be more acceptable because the quantity ordered should be enough for a fixed number of periods and will have fewer setups also setup time will decrease but process time will be increased, consequently MLT will be increased. Using the lot-for-lot technique is acceptable for both the pull and push system because using lot-for-lot as a lot size decision has an important impact on the lead time, which in turn affects inventory levels and costs. This research study answered two questions about (timing – when to order? quantity – how much to order?), as well as what lead times should we use to drive our MRP system and what general lead times should we quote customers? Furthermore the factory needs to develop a capacity plan for producing plastic pipes.

6.2.1 The Important role of rescheduling capacity planning phase and splitting orders

This research and production planner proposed that their computer system should have an upgrade and update the closed-loop of capacity planning to provide information to the capacity plan, master production schedule, production plan and especially for daily production orders. This was because the closed-loop of capacity planning (see Figure 5.4) as the same procedures for closed-loop MRP will provide feedback about workload and capacity available (minutes) then all items can rescheduled in the net requirement plan as well as it will give input /output reports in order to ensure or verify if the average capacity is adequate (and realistic for the desired master production schedule). The closed-loop capacity planning will increase the speed and accuracy of information for the ZX production planner.

This research study decided that splitting orders should be considered a logical technique for smoothing the load and minimising the impact of changed lead time. The production planner illustrated his ZX material resource planning for weekly demand for labour, machine-hours and payables for 160 units. Each pipe will take 15 minutes but ZX has only 480 minutes of the time available in the work centre for a normal day except overtime and daily production orders, which are shown in Table 5.5. How should we split lots? Should we use alternate routings? And what delivery dates should be promised? In order to reduce the manufacturing lead time and smooth load or minimise the impact of changed lead time, the production planner should have some tactics or at least one of them is order, or lot splitting, breaking up the order into smaller lots and running part ahead of schedule, From the literature review, previous research has clearly and consistently shown that flow time advantages accrue from splitting production lots into smaller transfer batches or sub-lots (Hoppe and Spearman, 2001; Karmarkar, 1993; Heizer and Render, 2008).

Figure 5.7 shows that the case study aims to provide a logical tactic for smoothing the load and minimising the impact of changed lead-time. One such tactic includes order or lot splitting at the factory that produces plastic pipes. ZX factory's production planner has insufficient time to complete their production orders in the allotted seven days. Pipes should be ready for shipping so as to be delivered on time, but a problem occurs four times during the year. The pipes take 15 minutes each but only 480 minutes of production time is available in the factory each day, and employees only work five days a week. Figure 5.7 shows that the capacity was exceeded in the (A) period on day two and day five because the required capacities were 510 minutes for day two and 525 minutes for day five. As they have only 480 minutes available in the work centre each day, they assigned two units from day two to day one's work, and two units from day five to day four's work and one unit to day three (or requested overtime). As shown for the (B) period, the average available capacity is adequate, at 480 minutes, and has become equal to the required capacity. Therefore by splitting the order, the production planner is able to utilise the factory's capacity more effectively and still meets order requirements. This tactic will lead to controlling and reducing lead-time, it is a tactic for smoothing the load and minimising all units ordered in the requirement plan, meaning a trade-off between the capacity required (minutes) and capacity available (minutes). Also Table 5.6 and Figure 5.7 indicated that the utilisation over capacity available (minutes) at (A) while the (B) period after the new production schedule by lot splitting breaking up the order into smaller lots and running part of it ahead of schedule and the utilisation under capacity available (minutes).

Also alternative procedures may be applied for new production schedules, there is an opportunity the factory may be able to do forecasting on daily demand under capacity available time using exponential smoothing methods as a technical analysis between actual demand and exponential smoothing forecasting for future demand direction. The aim is to estimate the current inventory level and use it as a forecast of future demand by applying different Alpha (ἀ) smooth (or weighting constant ($0 \leq$ ἀ ≤ 1) for exponential smoothing is shown in Figure 5.8 , It appears that Alpha values (ἀ = 0.1 and 0.3) moderate smoothing and moderate adaptation for new production scheduled Figure 5.8 indicated that pipe orders (32 units predicted by using ἀ = 0.1 and 31 units as ἀ = 0.3) for exponential smoothing average because the exponential smoothing average are more reactive to the last units ordered as actual demand before new production scheduled (Table 5.6) also the same last units ordered on day 5 for new production scheduled which is shown in Figure 5.8

This research study recommends that the production planner should be considered or taken into account for situations such as (bottleneck) also other alternative tactics. Operations splitting and overlapping are only possible for fixed and period lot sizes. When the workload consistently exceeds work centre capacity, this tactic just discussed is not adequate. “This may mean adding capacity via personnel, machinery, over time, or subcontracting” (Heizer and Render, 2008). The observations show that manufacturing lead time reduced from 9 days to 7 days as MLT reduced by 22.22%.

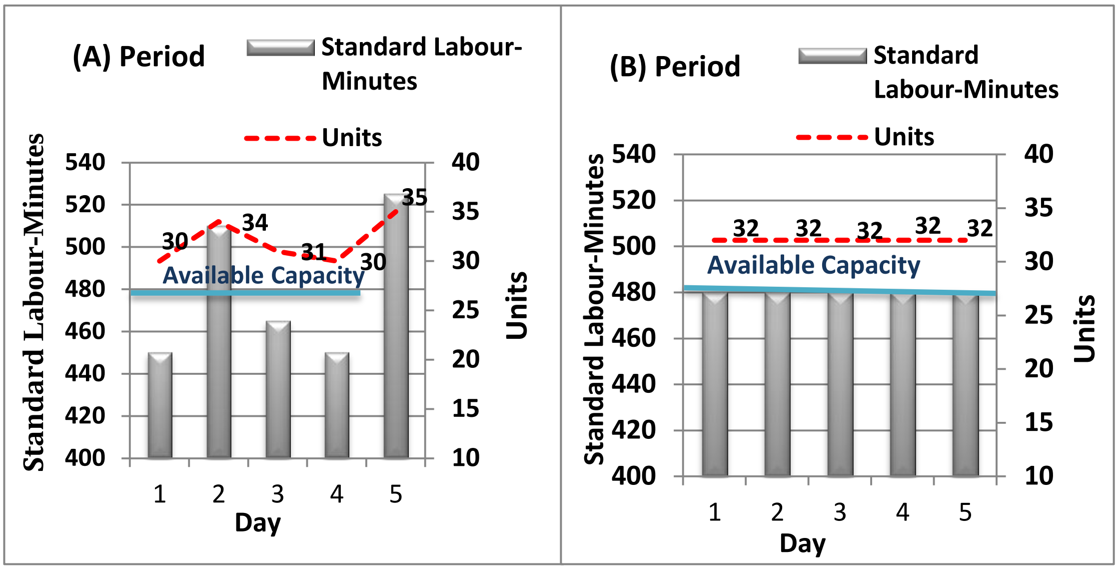

Figure 5.7 (A) period resource requirements (B) period smoothed resource requirements for ZX plastic pipes

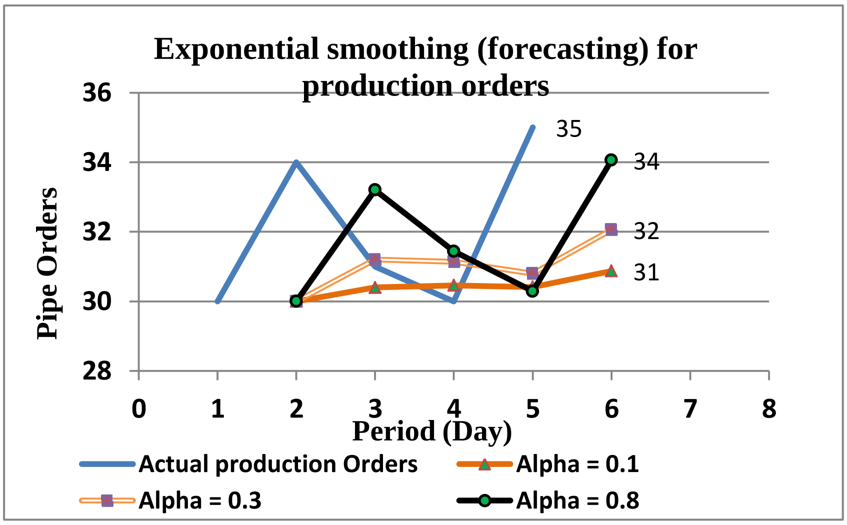

Figure 5.8 Actual demand vs. exponential smoothing average (forecasting)

6.2.2 The Important role of staffing and balancing work cell

Designing or developing a work balance chart is a very important procedure for daily production. Efficient production requires appropriate staffing and balancing work because the important step is reorganising people and machines into groups to focus on single products or product groups so that we can reduce work-in-process inventory, also heightening the sense of employee participation so that the products will be available and faster for next-day delivery. Also, a high level of training and flexibility should be required especially for the one-piece flow process or work cell. Once the work cell has the appropriate equipment located in the proper sequence, the next task is to staff and balance the work. This procedure involves two steps: determining the Takt time and the number of operators required. ZX expects 160 pipes delivered weekly. This research study estimated and evaluated 5 operations are necessary for creating a work balance chart to put standard time required (minutes) and numbers of operations (see Table 5.7 and Figure 5.9).

Insight: To produce one unit every 15 minutes will require 2.333 operators therefore with 3 operators this work will produce one unit each 11.666 minutes (35 minutes / 3 operators = 11.666) (see Figure 5.9) and 205 units per week will be delivered, 205 pipes during every Sunday (8 hours per day and 5 days are available 2400 minutes / 11.666 for each unit = 205 pipes) therefore ZX can produce more units, which may also lead to an increase in availability and the work cell producing the pipes is scheduled for 8 hours for 5 days, therefore this approach may save time if there is an unexpected downtime in the system or can control or reduce the causes of workload variability on delivery time then WIP and MLT will be controlled or reduced because work balance used for evaluating operation times in work also can help identify bottleneck operations then leading to reduced work in process consequently reducing MLT. Appropriate staff and balancing work will lead to increasing the operation's efficiency, improve performance and flexibility in order to save time and control /or reduce MLT also leading to a quick response to the customer. Also, this research has found that splitting a job into multiple lots increases time spent on setups but might also decrease the time to perform an entire job by allowing portions of the job to be simultaneously processed by three workers as required for the assembly line area in order to save time. Also small lots reduce variability in the system and smooth production leads to reduce MLT consequently the order-to-delivery cycle will be drastically reduced. This is acceptable in today's time-based competition. Some consideration must be given to determining the bottleneck operation because bottleneck operations can constrain the flow through the work and the cross-trained team are required for balancing work. However, if the imbalance is a machine constraint, then an adjustment in machinery, process, or operations may be necessary. The splitting and overlapping are only possible for fixed lot sizes and period lot sizes.

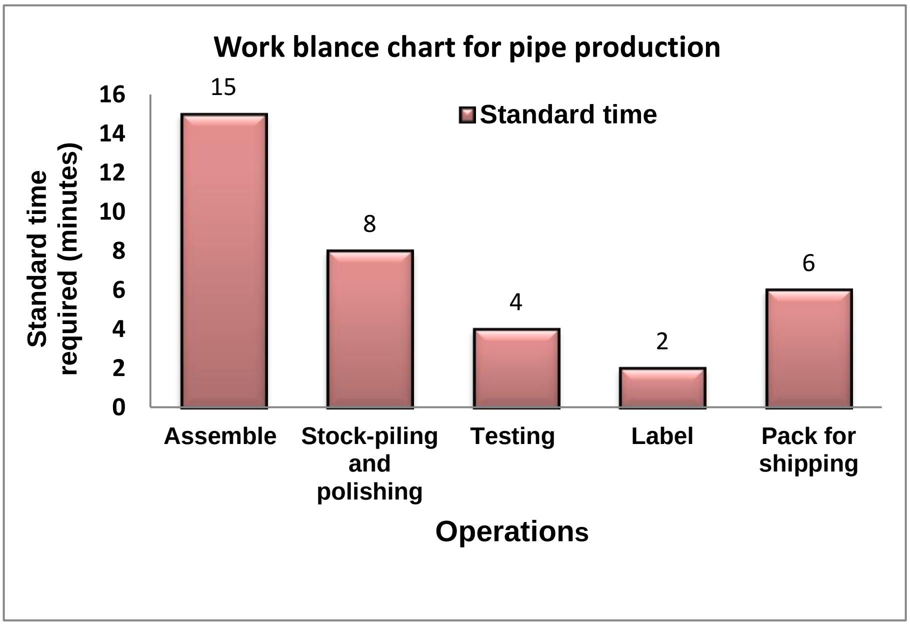

Figure 5.9 Work balance chart for ZX plastic factory

6.3.1 The role of evaluating of queuing system (Waiting line)

In this research queuing theory has been applied because it provides a better understanding of waiting lines so as to develop an adequate service with tolerable waiting times, also it is a quantitative analysis technique. "Queuing theory is valuable tool for the operations manager also for solving waiting lines in the field of business has recently gained considerable attention" (Norman and Frazier, 2001) and, also to be carried out more often at a systematic high level of abstraction in a strategic decision-making phase in order to create a list of "potential layouts" at ZX factory. Characteristics of a queuing system that impact its performance, for example, queuing requirements of ZX plastic pipe factory will depend upon factors like: How do pipes arrive in the factory? Are pipe arrivals more during manufacturing processes? Manufacturing processes? Or is the pipe traffic more uniformly distributed? Thus the two factors can be expressed mathematically as probability distributions. How much time do pipes spend on the shop floor? Do pipes typically leave the shop floor in a fixed amount of time? Does the process time vary with the type of pipes? How many services or multiphase systems does the ZX have for producing pipe?

In designing queuing systems this research needs to aim for a balance between services to pipes. A performance measure of the waiting line at the factory is shown in Figure 5.10**.** Figure 5.10 and Table 5.16 illustrated that inputs have two different arrival rates such as (λ=2, λ =3 units per hour) for each data input and one constant factor is service rate (μ = 4 units per hour) for both arrival rates, also indicating that the model of the M/M/1 queuing system is the simplest queuing system, has a Poisson arrival distribution, an exponential service time distribution and a single channel (one server) in order to design a system that optimise some criteria of minimising the average wait time for customers and meeting a desired service level.

	A	B	C	D	E	F
1	Model 1 (M/M/1 Queue):					
2		Single server, Infinite population, Poisson arrivals, FCFS, **Exponential service time,** Unlimited queue length				
3						
4	**Inputs**					
5		Units of time	hour			
6		Arrival rate (lambda)	2	Units per	hour	
7		Service rate (mu)	4	Units per	hour	
8						
9	**Outputs**					
10		**Direct outputs from inputs**				
11		Mean time between arrivals	0.500	hour	30 Minutes	
12		Mean time per service	0.25	hour	15 Minutes	
13		Traffic intensity	0.5			
14						
15	**Summary measures**					
16		Utilization rate of server	50.0%			
17		Average number of units waiting in line (Lq)	0.5	Units		
18		Average number of units in system (L)	1	Units		
19		Average time waiting in line (Wq)	0.25	hour	15 Minutes	
20		Average time in system (W)	0.5	hour	30Minutes	
21		Probability of no units in system (P0)	50.0%	(this is the probability of empty system)		
22						
23		Distribution of number of units in system				
24		n (Units)	P(n in system)			
25		0	0.500000			
26		1	0.250000			
27		2	0.125000			
28		3	0.062500			

Figure 5.10 Summary measures of waiting line at the factory

This research presents mathematical models for analysing waiting lines following assumptions that: the model is M/M/1, service rate (μ) is 4 units per hour, which is constant for both two arrival rates and the average service rate is greater than the average arrival rate. All data inputs are shown in Table 5.16. Figure 5.11, Figure 5.12 and Table 5.16 illustrated the distribution for $\lambda = 2$ and $\lambda = 3$ units per hour. This means that if the average arrival rate is $\lambda = 2$ units per hour, the probability of zero units arriving in any random hour is about 50%, the probability of 1 unit is about 25 %, 2 units about 12.5%, 3 units about 6%, 4 units about 3%, and so on. The chances that 9 or more will arrive are virtually nil. Arrivals, of course, are not always Poisson distributed, while Figure 5.12 illustrates that if the average arrival rate is $\lambda = 3$ units per hour, the probability of zero units arriving in any random hour is about 25% less than the arrival rate was $\lambda = 2$, probability of 1 unit is about 18.7 %, 2 units about 14%, 3 units about 10.5%, 4 units about 7% so on. Therefore Figure 5.12 indicated that the probability of (1, 2, 3, and 4) units arriving in any random hours more than probability arriving units in Figure 5.11, , means if the arrival rate increased the probability of the number of arriving units in any random hour will be increased. Furthermore arrivals, of course, are not always Poisson distributed.

Figure 5.11 and Figure 5.12 and Table 5.16 presented two possible arrival rates in the ZX system if the arrival rate (λ) increased from 2 to 3. The probability waiting pipes will be increased by 30% also the probability of number of pipes decreasing in the system from 505 to 25% (refer to Figure 5.13 and Table 5.16), also the average waiting time in line increased, the average waiting time in the system increased consequently increasing MLT and probability of a number of pipes in the system decreasing when arriving due to a more complex congestion system occurring. Also Table 5.16 indicates that the average number of pipes waiting in the queue (Lq) and average number of pipes in the system (Ls) increased therefore the production planner at the ZX factory should consider the workloads because based on the queuing theory the actual lead time is highly dependent on actual workloads and lot sizes (Karmarkar, 1987) also see Table 5.16 when arrival rate increased from 2 to 3 units per hour this indicated that the probability of waiting in the system will be increased. Figure 5.13 illustrates the both the probability (wait $\geq$ t) is quite slow when service time in the system increased 2 hours and so on for both arrival pipes. Figure 5.13 illustrates the both the probability (wait $\geq$ t) quite slow when service time in the system increased as 2 hour and so on for both arrival pipes. Table 5.16

shows that the important factor is traffic intensity (p) or rho; it is a measure of the congestion of the system. If it is near to zero there is very little queuing and in general as the traffic intensity increases (to near 1 or even greater than 1) the amount of queuing increases especially when arrival rate (λ) equal to 3, while arrival rate (λ) equal 2 the traffic intensity (rho) will be decreased and the amount of queuing will be decreased in the system also average server utilisation (P) decreased from 75% to 50%, 50 % of time machine is busy also both average time in the system (Ws) means MLT decreased from 60 minutes to 30 minutes in the system and average time waiting in line (queue) also decreased from 45 to 15 minutes only as shown on Table 5.16. Figure 5.13 shows that if service times follow a negative exponential distribution, the probability of any very long service time is low. In some cases finding that although the assumption of exponentially-distributed arrival and service times may seem unrealistic; this M/M/1 model has wide application and can also serve as a useful first pass in the analysis of more complex congestion systems.

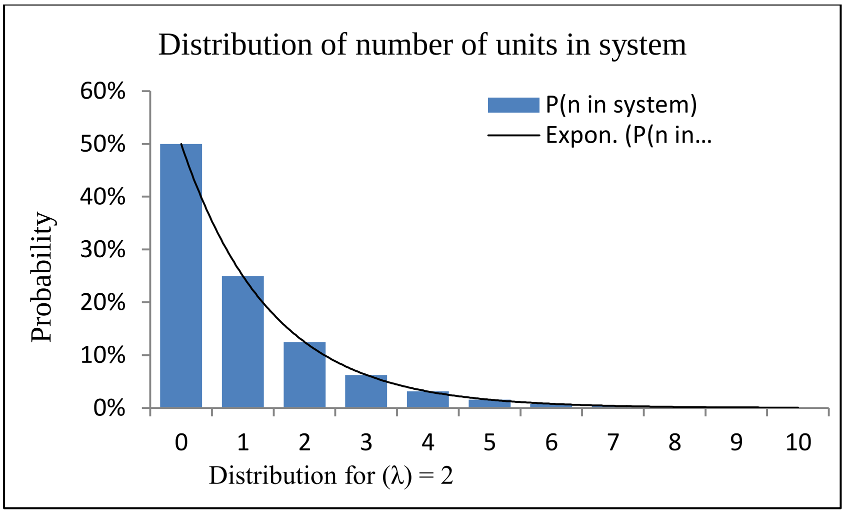

Figure 5.11 Probability of pipes arriving in system (λ = 2)

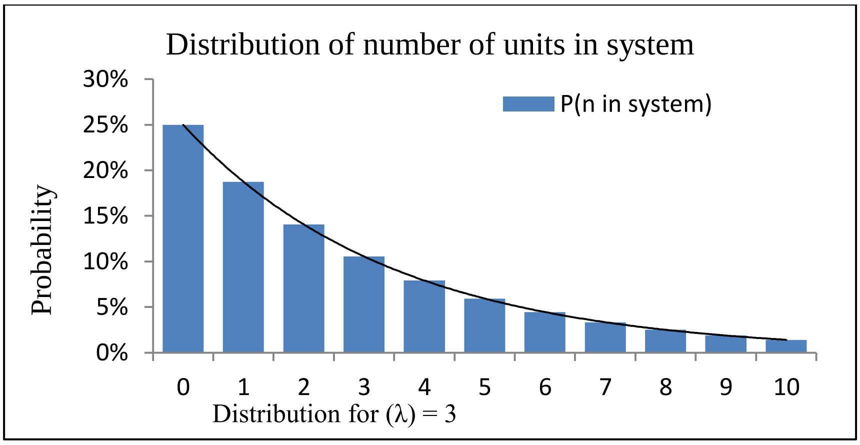

Figure 5.12 Probability of units arriving in system (λ = 3)

This research study finds all this increases congestion and consequently inflates lead times and creates excess inventories therefore in a time-based production environment that is exactly what we want to avoid and the basic question is how to handle congestion, how to take advantage of the trade-offs between various performance measures such as work-in-process, lead-times and investment in capacity. An insight from queuing theory is a great help to install some capacity more than expected demand. Indeed, capacity can be used to buffer the system against unexpected events (instead of the standard inventory buffers) because a large batch will cause a long lead time (batching effect), but on the other hand very small batches will increase the capacity utilisation (the setup time portion), congestion starts and consequently lead times will go up again as well as the production planner at ZX should focus on uncertainty and variability in order to reduce MLT.

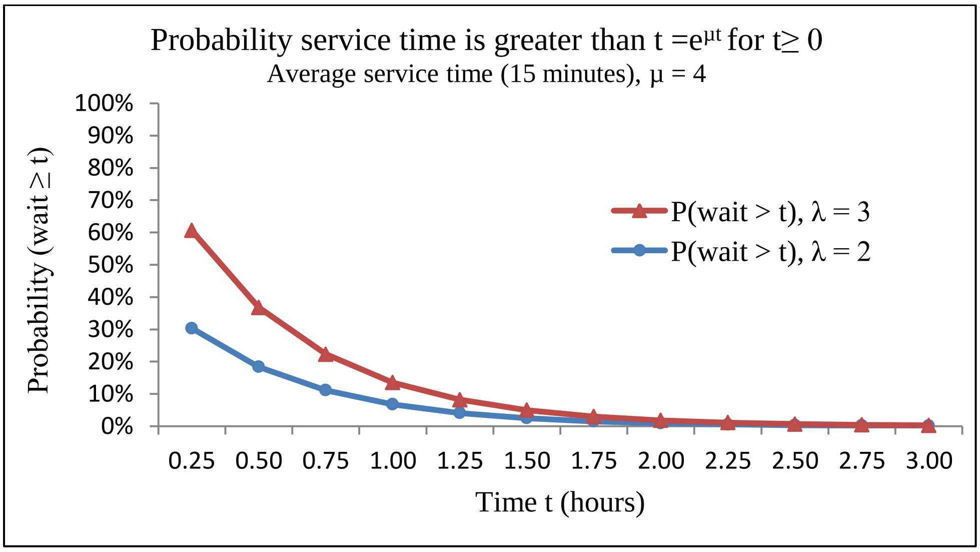

Figure 5.13 Negative exponential distribution for service times on different arrival pipes

Table 5.16 Key measurements of system performance

Single-Channel Model with Poisson arrivals, FCFS and exponential service times (M/M/1) denoted: Arrival distribution / Service time distribution / Number of service channels open. Service rate (μ) = 4 pipes per hour and λ is unit per hour		
Key measurements	Arrival rate (λ) = 2	Arrival rate (λ) = 3
Mean time between arrivals (inter-arrival)	0.50 hour (30 min)	0.33 hour (20 min)
Mean time per service	0.25hour(15min)	0.25 hour (15 min)
Traffic intensity (p) or rho	0.5	0.75
Average server utilization (P).[The service unit is idle] or % of time mechanic is busy	50%	75%
Average number of units waiting in the queue (Lq)	0.5 units	2.25 units
Average number of units in the system(Ls)	1 unit	3 units
Average waiting time in the queue (Wq)	0.25 hour (15 min)	0.75 hour (45 min)
Average time in the system (Ws) Ws equal to (ts) = MLT Norman and Frazier, (2001)	0.5 hour (30 min)	1 hour (60 min)
Probability (% of time) system is empty (P_0). no units in system	50%	25%

Finding that small lot size (pipes) tend to reduce MLT because pipes spend less time at a machining centre, causing new arriving pipes to wait less for the machines to become available. Therefore, the waiting line model has significant tool to control the waiting line (queuing model) lead to determine the flow through a production process, to design systems that optimise some criteria, to evaluate alternatives to control/improve manufacturing efficiency and capacity planning *(Heizer, J. and Render, B. (2008) and Beasley, E.J. (2012))*, also to analyse waiting lines that can help managers evaluate the cost and effectiveness of service systems. Waiting line analysis could be used to enable the production planner to utilise the capacity system more effectively and still meet the order requirements or customer demands *(Heizer, J. and Render, B. (2008)).* The main purposes of analysing waiting line in ZX are: to evaluate and control the flow of pipes, to improve efficiency and productivity in operations. The queuing theory attempts to solve problems in an optimal manner so that facilities are fully utilised.

6.4.1 The role of overall equipment effectiveness (OEE)

ZX factory can achieve world class OEE level, when ZX a fully connected OEE system comes into its own, when fast access to highly accurate information is crucial to target efficiency improvements and a way of easily seeing what progress is being made also OEE gives manufacturers a consistent way to measure the effectiveness of TPM (Total Productive Maintenance) and other initiatives by providing an overall framework for measuring production efficiency. The application of OEE tools will help ZX to track and improve their manufacturing performance (Vorne Industries Inc 2008) and it is technical tool could be used to enable reschedule capacity planning in order to reduce WIP and lower inventory level and leads to faster product throughput (that is, shorter lead times). Figure 5.14 illustrates the OEE measures how effectively time is used to produce a quality product after research study has been done and rescheduled on capacity planning at ZX.

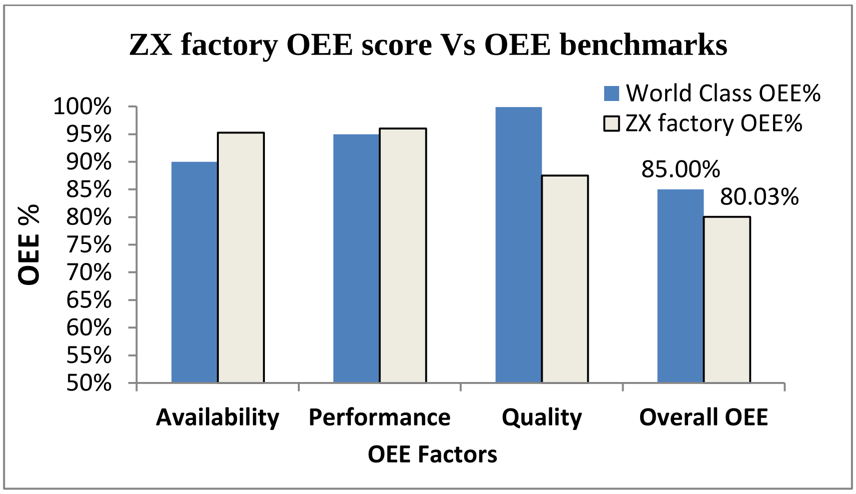

Figure 5.14 Benchmark ZX factory OEE score against world class OEE

It is important for ZX to recognise that a standard industry definition for OEE does not exist. This research has established the following definitions of time to be used to calculate OEE: Planned production time, Planned downtime, Unplanned downtime, Operating time and production data which they are: shift length, short breaks, ideal cycle time, total pipes and reject pipes (see Table 5.11). Figure 5.14 shows that overall OEE score of 80.03% is accepted but it is near to record of OEE (world class) score of 85% is considered world class for discrete manufacturers. “For many companies, it is a suitable long-term goal while OEE score of 100% is perfect production: manufacturing only good parts, as fast as possible, with no down time also the OEE score of 60% is fairly typical for discrete manufacturers, but indicates there is substantial room for improvement” (Vorne Industries Inc , 2008). Therefore, the results show that there is down time in the system during the record of definitions of all factors associated with downtime which is 20 minutes (refer to Table 5.11) it seems due to unplanned maintenance and equipment failure sometimes due to material shortages at ZX therefore the engineering department should know there is flexibility on where to set the threshold between a breakdown, which means downtime loss and a small stop which is speed loss. The important factor for calculating OEE is; how do production planners determine ideal cycle time? It is easy looking for nameplate capacity (the design capacity specified by the equipment builder or design engineer), ZX factory has nameplate capacity mentioned and the maximum throughput of the machine or process is 12 minutes for one unit (piece) refer to Table 5.11. The results show that the quality score of 87.50% less than a quality (world class) score of 99.90%, this result indicated that there are rejected pipes during the manufacturing process at ZX, which are 4 pipes from total 32 pipes during weekly observation for each day (refer to Table 5.11), but indicates there is substantial room for improvement, therefore the production planner should take into account quality loss at ZX due to (scrap or rework and incorrect assembly), thus may be due to improper setup. Table 5.11 illustrates the availability score of 95.24% which is greater than world class score of 90%. Availability considers downtime loss due to the event of setup/changeover or operator shortages therefore the production planner at ZX should address this loss through a setup time reduction program for example SMED. Table 5.11 illustrates that the performance score of 96.04% which is greater than world class of 90%, 96.04% is considered world class for the discrete manufacturer, it is a suitable long-term goal for the factory. In this research during daily recording data sometimes performance is capped at 100%, therefore the production planner should be able to ensure that if an error is made in specifying the ideal cycle time or Ideal run rate the effect on OEE will be limited also cycle time that your process can be expected to achieve in optimal circumstances so performance takes into account speed loss. This research recommended the production planner at ZX to recognise that improving OEE is not the only objective should look at the data for production shift as well. The results find that the production planner should take into account the following lists of six big losses and shows how they relate to OEE loss (Vorne Industries Inc, 2008) for the following six big losses: Breakdowns relate to downtime loss, Setup and adjustments relate to downtime loss, Small stops relate to speed loss, reduced speed relate to speed loss, start-up rejects relate to quality loss and production rejects relate to quality loss. Therefore (Six Big Losses) are the most common causes of efficiency loss in manufacturing also they are leading to increasing MLT (Vorne Industries Inc, 2008).

6.5.1 The role of hypothetical transactions on reducing move time

ZX factory has an opportunity for overall daily productivity to be improved to reduce move time which led to reducing MLT. The major components of non-value added lead-time are: wait time, move time and down time (Warren et al., 2004); therefore, the manufacturers or practitioners should understand the relationships between operation time and non-operation time in order to find potential methodologies that could reduce lead time in the manufacturing process. In this research assumptions for example: designing a process layout or work-cells layout and increase resource access as using robot machine loading/ unloading system productivity in order to reduce move time which is led to reduce MLT, the assumptions based on two factors, first is designing layout strategy and the second is increasing resource access such as using robots because those two factors are suitable for reducing move time, distance and number of moves also they have the following objectives:

- To provide optimum space for organising equipment and facilitating movement of pipes, the move distance can sometimes be reduced by reorganising the equipment to optimise the material handling between departments in a job shop/functional layout.
- To provide optimum number of moves requiring material handling equipment such as technological improvements that allow more sequential operations to be done by a single machine to reduce the number of movement or to reduce the number of work loading and work unloading work (for example Robot)

The second procedure is the process layout procedure that they follow involves six steps (*Heizer, J. and Render, B. (2008)*):

1. Construct a “from-to matrix”
2. Determine the space requirements
3. Develop an initial schematic diagram
4. Determine the cost or number of material movements of process layout
5. Try to improve the layout by trial and error or by a more sophisticated computer program approach

6. Prepare a detailed plan arranging the departments to fit the ship of the building and its none-movable areas.

Material handling in this approach depends on (1) the number of loads (or staff) to be moved between two departments during some period and (2) the distance-related material movement of moving loads (or people) between departments. Material movement is assumed to be a function of the distance between departments and the objective is minimised material movement *(Heizer, J. and Render, B. (2008))*. A work area is set aside for assembling, stock-piling and polishing, testing, (labelling and shipping) of final serving, although different areas may be worked for each of these functions. Giving the following interdepartmental activity matrix should depend on records to determine the number of material movements among departments with a distance of 10 feet between adjacent areas. See (Table 5.12, Table 5.13 and Table 5.14).

Figure 5.15 illustrates the present layout was changed to possible layout and the distance between departments reduced from 8190 feet to 700 feet, this assumption leads to the process being minimised, material movement leads to reduced move time between departments consequently MLT will be reduced. For ZX factory to have an effective and efficient manufacturing unit, it is important that special attention is given to facility layout. Facility layout is an arrangement of different aspects of manufacturing in an appropriate manner as to achieve desired production and short MLT results. A possible layout is a feasible layout.

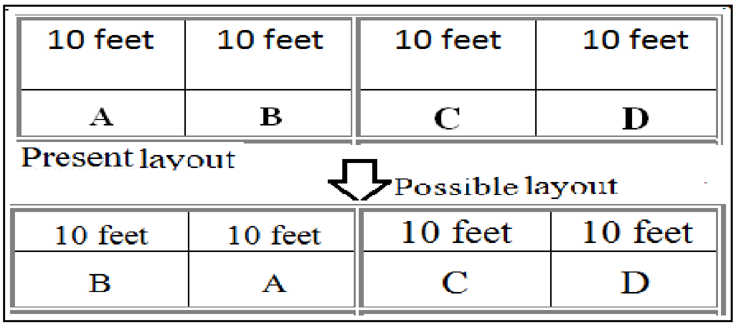

Figure 5.15 Adjacent areas of process-Oriented layouts

Also the factory has an opportunity for overall daily productivity to be improved because the analysis of robot machine-loading applications becomes a bit more complicated when a single robot has the task of feeding a machine tool in an organised sequence of activities. If the production planner or engineers at ZX has timed and planned the operation carefully, the robot can be programmed to anticipate cycle completions at appropriate station (between conveyor and machine tool) and move to this station in advance to shorten machine idle time while waiting for the robot. The double-handed gripper on the robot was essential to enable the robot to service the (machine, conveyor) sequence with any degree of efficiency. The result indicated that double-handed increased the production efficiency 13.60 % and production rate increased from 22 pipes using the one-handed gripper to 25 pipes/shift using double-handed gripper for more details see section 5.5.7.1 for step 4, also measuring the typical operation sequence is shown in Table 5.15. The machine operation cycle time unloading machine, move to the conveyor. Therefore contrast this usual machine loading application in which a double-handed gripper can significantly reduce handling time and robot moves between machine tool and conveyor while the waiting time can also be reduced by increasing access to the resource by using a double-handed gripper. Because using a double-hand gripper not only that subject increased the total efficiency also the number of movements decreased between machine and conveyor consequently move time decreased. The production planner must take care of machine tools, equipment at the station and the reason for down time from the result of electrical mechanical malfunctions of the robot, machine tool and fixtures. Figure 5.16 illustrates the research opinion how to reduce move time. Figure 5.16 indicates that reductions in move time can be accomplished by reducing either the time required per move or the number of moves required. The time required per move can be reduced by increasing the speed of the material handling equipment (which may not be possible due to safety implications), or by reducing the move distance required. While if the speed of the material handling system is increased through the installation of other automated handling equipment such as a robot:

It is questionable how realistic this option would be when functional layout is used also move distance can sometimes be reduced by reorganizing the equipment to optimize the material handling between departments in a job shop/functional layout, the amount of reduction is greater if the equipment performing sequential operations on a part is grouped to form manufacturing cells (Johson, D., 2003).

In some cases, technological improvements that allow more sequential operations to be done by a single machine can achieve the same result (for example, a robot).

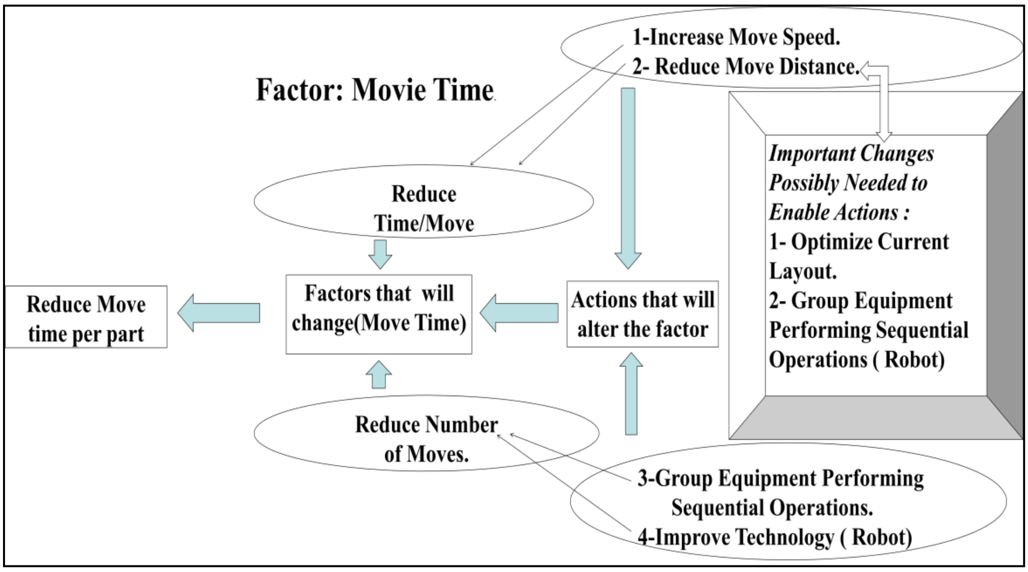

Figure 5.16 Reducing move time per part

6.6. Conclusion

A case study was used to validate this research. Due to limited resources, costs and time, only a small portion of the sufficiently sophisticated staff members in the Kurdistan region was requested to participate in this research. They were also hesitant to commit to the case study and were cautious about making sources available. The main purpose of this case study was to identify simple strategies for reducing manufacturing lead-time (MLT) in the ZX plastic factory in the Kurdistan region of Iraq. The framework was designed to provide guidance to industry practitioners/technicians in reducing MLT. In particular, this case study was conducted to assess the manufacturing sector and the strategy of factories in the Kurdistan region in terms of quick response to customers.

The outcomes of tests substantiated in this research study based on Heizer, J. and Render, B. (2008) “Principle of operations management”, Beasley, E.J. (2012) “Operations research (OR- Notes)”, Johnson, D.J. (2003) “A framework for reducing manufacturing throughput time”, Groover, M. (2001)” Automation, production & computer integrated manufacturing” and Hoppe, W.J. and Spearman, M.L. (2001) Factory physics and Vorne Industries Inc (2008) “The fast guide to OEE”.

The following conclusions can be drawn from the research conducted in this case study:

1- Steps undertaken to address the problem

- Finding that the ZX factory has insufficient MRP and capacity planning that may cause low flexible manufacturing, decrease resource efficiency, cause inaccurate demand forecasts, disruptions and unreliable lead times. This will potentially affect critical delivery dates. Pipes should be ready for shipping so as to be delivered on time but a problem occurs four times a year, so the ZX factory should develop a capacity plan for production orders. During the interview for the research survey, it appeared that the production manager has insufficient time to complete his production orders in the allotted seven days.

2- The role of lot-sizing decision in MRP

- Finding the motivation behind using the lot-of-lot technique in the MRP system, that generates exactly what is required to meet the plan, avoid stock-out and also fix the order releases for week 3 at 120 pipes, week 5 at 95 pipes and week 6 at 70 pipes for accurate order releases when the lead time is fixed for 2 weeks as well as finding that the MRP system can immediately reflect the effects of changed order quantities. In addition, a production planner can change the master schedule and quickly see the effects on capacity, inventory status, or the ability of the system to meet the promise to their customers.

3- The reasoning behind the lot-for-lot ordering policy

- The results indicated that a lot-for-lot ordering policy has a significant impact on order production as much as it is needed, with respect to the timing decision the production planner always ordered as little as possible, i.e. just enough to avoid a stock-out. Furthermore, it could be compatible to reduce

MRP ‘buckets’ from weekly to daily when MRP can be integrated with just-in-time (JIT), thus leading to reduce MLT.

- Finding the motivation behind using the lot-for-lot policy is minimising inventory. If we order as much as it is needed, there will be no ending inventory at all so no extra on hand inventory and it leads to reduced WIP consequently reducing cycle time and MLT. It is clear that the lot-for-lot technique in MRP systems allows production planners to move the work between time periods to smooth the load or at least bring it within capacity also allowing the manufacturer to respond more quickly to new customer orders or any changes in demand.
- Results show that the number of setups will be increased consequently increasing setup time. Finding the number of setups has less significance because ZX has adopted a one-piece flow so all manufacturing processes run through 8 processes only. One setup procedure is required for all processes per batch size (lot size) each week. It is one-piece flow and production processes need short changeover times meaning less setup time is required between machines, therefore the number of setups and setup time have less impact on manufacturing lead time that should increase through the overall processes

4- Comparative analysis of L4L and FPR

- Results show that the L4L technique is very suitable for this case study especially in an MRP lot-sizing decision because there are no holding cost just three separate setups yielding a total cost of $150, even though the setup cost is $150, which is greater than the $100 setup cost for FPR. L4L minimises the inventory holding cost which is $470, but maximises the ordering cost, while FPR has a total cost of $570 for 8 weeks but FPR has two separate setups over 8 periods.
- Finding that setup time and cost are not significant because product process in ZX is a one-piece flow. In the one-piece flow, the focus is on the product or on the transactional process, rather than on the waiting, transporting, and storage of either. The one-piece flow methods need short changeover times (Hoppe and Spearman, 2001; Johnson, 2003). Using the lot-for-lot technique is acceptable for both the pull and push system because using lot-for-lot as a

lot size decision has an important impact on the lead time, which in turn affects inventory levels and costs.

5- The important role of rescheduling the capacity planning phase and splitting orders

- Designing the closed-loop capacity planning has significant impact on reducing MLT at ZX. It also provides feedback about workload and capacity available (minutes) then all items can be rescheduled in the net requirements plan as well as it will give an input /output report to ensure or verify if the average capacity is adequate (and realistic for the desired master production schedule) and especially suitable for daily production orders.
- Finding that splitting orders is the best tactic for smoothing the load and minimising the impact of the changed lead time at the ZX factory. This tactic will lead to controlling and reducing lead-time, it is tactic for smoothing the load and minimising all units ordered in the requirement plan, meaning a trade-off between the capacity required (minutes) and available (minutes)
- The results indicated that manufacturing lead time decreased from 9 days to 7 days as MLT reduced by 22.22%. Splitting and overlapping are only possible for fixed sizes and period lot sizes by using splitting orders and rescheduling capacity planning.

6- The Important role of staffing and balancing work cell

- Finding that the design of a work balance chart provides accuracy of planning, the output of each process matches customer demand and better adherence to the plan for the daily production pipes at the factory thus ZX can produce more units, which will also lead to increase availability and the work cell producing the pipes is scheduled for 8 hours over 5 days. This approach will save time for any unexpected downtime in the system or can control or reduce the causes of variability of workload on delivery.
- The results indicated that takt time decreased from 15 minutes. To produce one pipe every 11.66 minutes will require 3 operators instead of 2 operators therefore ZX can produce more units, from 160 pipes to 205 pipes weekly which is scheduled for 8 hours over 5 days, this approach will save time if

there is any unexpected downtime in the system or could control or reduce the causes of variability of workload on delivery time and also can help identify bottlenecks in operations. Therefore, the production planner's only slight increase in production capacities can lead to a significant reduction of manufacturing lead times and significant reduction of the work-in-progress. Consequently the pace of production meets customer demand.

7- The role of evaluating of a queuing system (Waiting line)

- Finding that waiting line model has significant tool to control the waiting line (queuing model) led to determining the flow through a production process, designing systems that optimise some criteria, evaluating alternatives in an attempt to control/improve manufacturing efficiency and capacity planning. Also the procedure of analysing waiting lines that can help a production planner at the factory to evaluate the cost and effectiveness of service systems is carried out more often at a systematic high level of abstraction in a strategic decision-making phase in order to create a list of "potential layouts" at the ZX factory. In this research a mathematical model for analysing waiting lines has been made by the following certain assumptions are: The model is M/M/1, service rate (μ) is 4 units per hour, which is a constant service rate for both two arrival rates and the average service rate is greater than the average arrival rate.
- Results show that the important factor is traffic intensity (p) or rho; it is a measure of the congestion of the system. If it is near to zero there are very little pipe queuing and, in general, as the traffic intensity increases (to near 1 or even greater than 1) the amount of queuing increases especially when arrival rate (λ) equals 3, while arrival rate (λ) equals 2, the traffic intensity (rho) will decrease and the amount of queuing will be decreased in the system. Also average server utilisation (P) decreased from 75% to 50% - 50% of time machine is busy. Also both average time in the system (Ws) decreased meaning MLT decreased from 60 to 30 minutes in the system and average time waiting in line (Wq) also decreased from 45 to 15 minutes. In some cases finding that although the assumption of exponentially distributed arrival and service times may seem unrealistic this M/M/1 model has wide

applications and can also serve as a useful first pass in the analysis of more complex congestion systems.

- Finding that a small lot size (pipes) tend to reduce MLT because pipes spend less time at a machining centre, causing new arriving pipes to wait less for the machines to become available. Therefore, in a time-based production environment that is exactly what must be avoided and the basic question is how to handle congestion, how to take advantage of the trade-offs between various performance measures such as work-in-process, lead-times and investment in capacity.

8- The role of overall equipment effectiveness (OEE)

- Finding that the ZX factory can achieve a world-class OEE level, when the factory is a fully connected OEE system. The application of OEE tools will help ZX to track and improve their manufacturing performance (Vorne Industries Inc 2008), it is a technical tool that could be used to enable reschedule capacity planning at the factory in order to reduce WIP and inventory level thus leading to faster product throughput (that is, shorter lead times). Finding that OEE can identify the root cause of production losses such as: availability, performance and quality loss allows effective targeting of resources for accelerated efficiency gains and best machine utilisation.
- The results indicated that the ZX factory's overall OEE score of 80.03% is acceptable and is near the record of OEE's (world-class) score of 85% for discrete manufacturers. Also the availability score of 95.24% and performance score of 96.06% are both higher than world class which is a score of 90%. Therefore both availability and performance indicate that the average capacity is adequate, this is fair feedback to execute capacity planning and a quality score of 87.50% is less than world-class quality score of 99%, this indicated a rejection of pipes during the manufacturing process at ZX but indicates that the factory needs improvement on the quality of production. Downtime was recorded at 20 minutes for daily observation, availability takes into account downtime loss due to the event of setup/ changeover or operator shortages therefore the production planner should address this loss through a setup time-reduction program for example SMED (Single-Minute Exchange of Dies).

9- The role of hypothetical transactions on reducing move time

- Finding that the factory has an opportunity to improve overall daily productivity in order to reduce move time which led to reducing MLT. The assumption is based on two factors, first designing a layout strategy and the second increasing resource access such as using a robot because the two factors are suitable for reducing move time, distance and number of moves. The objective of the facility layout planning is to design effective workflow to make equipment and workers more productive also every time material has to be moved from one part of the factory to another a delay occurs. Layout covers any delays in movement. It is important that special attention is given to facility layout.
- The result shows that the present layout was changed to possible layout and the distance movement between departments reduced from 8190 to 700 feet, this assumption leads to the process being minimised, material movement leads to reduced move time between departments consequently MLT will be reduced.
- The results indicated the double-handed gripper of the robot was essential to enable the robot to service the (machine, conveyor) sequence with any degree of efficiency. The result indicated that double-handed increased the production efficiency 13.60 % also production rate increased from 22 pipes using the one-handed gripper To 25 pipes/shift using a double-handed gripper. If the production planner or engineers at ZX timed and planned the operation carefully, the robot can be programmed to anticipate cycle completions at an appropriate station (between conveyor and machine tool) and moves to this station in advance to shorten machine idle time while the machine tool waits because double-handed grippers one each robot are a key to the success of the robot application thus one hand holds the unfinished pipe, while the other hand unloads the finished pert from the machine. Therefore, reductions in move time can be accomplished by reducing either the time required per move or the number of moves required.

Chapter 7- Conclusions and Future Work

7.1 Conclusions

This thesis has successfully proposed a study and investigated reducing manufacturing lead time in factories in the Kurdistan region of Iraq, where lead time has become a major issue. Finding the suitability of this research methodology designed to obtain reliable, quality data and right decision. Most of the techniques are inexpensive and pretty uncomplicated. This study reviews various tools and different techniques that are available for modification and that should be considered in the manufacturing sector to find or suggest practical, inexpensive strategies to reduce lead time. The research methodology strategies were based on a survey and case study and found a significant opportunity exists to reduce the manufacturing lead time in the manufacturing sector. The survey questionnaire illustrated that 90% of 160 participants are informed that the order was late on delivery time across the eight factories, therefore long manufacturing lead time existed. Thus, what major procedures should be considered before reducing lead time needed to be looked it. The outcomes of tests substantiated in this research study based on section 4.5 and section 6.6. The main conclusions of this thesis are as follows:

7.1.1 Summary of Findings with regard to research questions

The current subsection is aimed at presenting the thematic findings of the study by aligning those to the research questions and objectives. Basically, the outcomes of present research are measured in the light of the mile stones defined at the beginning of the study in order to assess the reliability of the findings.

Table 7: Summary of Findings in light of Research Objectives and Questions

Research questions and Objectives	**Findings**
Causes of Delay	• Chapter 4 and 5 presents major outcomes of the surveys and case study. • Ineffective managing for seven areas of management and ineffective forecasting for material requirements, capacity planning, inaccurate demand analysis, decreased resource efficiency ,

Research questions and Objectives	Findings
• Conduct a comprehensive literature review in thematic approach to identify the factors that reflect firms' dynamic capabilities in the context of reducing lead time. • Capacity Planning Process	• Chapter 2 in this thesis represents a comprehensive literature review on how MLT will be reduced and the factors have significant impact on lead time • Chapter 2 is exploring the literature which has extracted different processes. • Closed loop capacity is considered to be most effective in light of literature and findings of current research .
Variables associated with production line and their relationship with performance parameters	• The academic strand in the area has identified different variables alongside the case study's outcomes. • Work balance chart provide accuracy of planning, fully-connected OEE system can create best OEE level
Lead Time Reduction through Survey Questionnaire	
Research questions and Objectives	**Findings**
• Opportunities to reduce lead time	• Chapter 4 resulted in the outcomes of survey which has explained different potential opportunities. • Manufacturing in Kurdistan Region of Iraq needs to search around for better strategies of production and distribution.
• Systematic review of potential methods to reduce lead time	• Literature has provided the systematic review as per theoretical aspects while quick view tool and ISO9001:2000 audit procedures are solutions and findings have presented the practical aspects. • Assessment questionnaire and a pilot test could prove effective for the companies to assess the success rate of a potential strategy
• Processes that should be considered before reducing lead time	• Current procedures should be carefully assessed such as the analysed companies were using manufacturing assessment requirements.
Lead Time Reduction through tools and techniques	
Research questions and Objectives	**Findings**
• Combining different tools and techniques	• Chapter 4, 5& 6 have identified the case study results which dealt with the experiments. • Combination of strategies could be proven effective like hybrid strategy for just in time and lot for lot technique

Research questions and Objectives	**Findings**
• Processes that should be considered before reducing lead time	• Current procedures should be carefully assessed such as the analysed companies were using fixed period requirements • But the lot for lot is more effective technique.
Lead Time Reduction through tools and techniques	
• Tactic for smoothing load	• Chapter 5 has concluded the best practices. • Splitting orders is considered as most significant
• Best tool for monitoring the processes and system	• Dealt in chapter 7 , chapter 4 and chapter 6 are finding the best tools for monitoring • Assessment questionnaire • Minutes of daily progress and input/output report
• Modes of eliminating variability	• Findings and literature have contributed to explore the modes of reducing variability in processes • Best techniques are Assessment Questionnaire, Waiting line model and the application of OEE tools
Research hypotheses : *Interrelationships of research questions and hypothesis*	
• Characteristics of a research hypothesis and a statistical hypothesis	• Developing the research hypothesis of 2 hypotheses are conducted in terms of expected results of this research study, through the research hypotheses, findings relationship of statements and testability, which they have found the factors and different variables which they have great impact on MLT reduction. • Research obtains statistically significant findings • Findings: there are answerable to the research questions as well as a significant opportunity exists to reduce the manufacturing lead time in the manufacturing sector with the application of survey questionnaires also with the implementation of various tools and techniques

7.1.2 Conclusions regarding the literature review

An extensive literature review was conducted which provided insight into lead-time in the manufacturing sector. It highlighted that little work had been conducted on manufacturing lead-time reduction. It also highlighted the survey of everything that has been written about lead time, manufacturing throughput time and quick-response manufacturing.

The current literature provides a great background on how to modify procedures in order to reduce lead time also to develop a framework that will enable the identification of the factors that affect manufacturing lead time (MLT) and manufacturing throughput time. It highlighted the advantages of various tools and techniques that can be used to optimise manufacturing lead time and quick-response manufacturing (QRM) and to find further potential methodologies.

7.1.3 Conclusions regarding the survey questionnaire

The survey questionnaire stage will help further validate the argument of the research and also can help achieve MLT reduction and the assessment questionnaire designed for this survey has several benefits for getting early indications of potential problems or defects and lead to taking corrective action to avoid long MLT and late delivery time in the factory. The survey tested the hypothesis with firms in the Packaging for Oil sector; Basic Materials (paper & Steel) sector, and Industrials sector (cement) using a face-to-face procedure, which ensured the answers were in-depth and accurate. In addition, it was the major research technique for data collection in this research study. The outcomes of tests substantiated in this research study based on section 4.5

It was found that:

- The survey questionnaire conducted an expert system-based assessment questionnaire. Also, the principles of QRM and TBC are considered in this survey that will provide a preliminary analysis of a firm’s strengths and weaknesses. The survey questionnaire can be used to identify areas of manufacturer operations that may require some attention; identify areas of management, capital, defects, wasting time, delays and excessive lead time; highlight some of the non-technical parts of the manufacturer’s operations that may be impeding their growth and competitiveness and replicate to evaluate MLT outcomes. This can be done when other data collection systems (e.g. surveillance) are not feasible in order to answer the research hypothesis and questions. The survey questionnaire can play a critical role in ensuring that our data provides actionable insights that will allow manufacturers to make better decisions before reducing MLT.

- Finding, the result helps identify different areas of management that may be impeding the eight factories' growth, competitiveness and improvement of lead time. The survey questionnaire can play a critical role in ensuring that our data provides actionable insights that will allow manufacturers to make better decisions before reducing MLT. Finding the survey questionnaire covers the general functional requirements of MLT reduction.

- Finding the survey questionnaire provided more test hypotheses which they formulated to address the research problem and the factors which have a great impact on MLT thus will be tested by using Mann-Whitney U test and Kruskal-Wallis test, and Spearman's chi-square test and correlation analysis. Finding that it is critical within the TBC/QRM in practice may be risked without assessment questionnaire tools such as (Quick View) has been conducted in this research survey in order to find a significant opportunity exists to reduce the manufacturing lead time. Finding that survey questionnaire provides usable data.

- Finding that the survey questionnaire is a powerful research approach, it provides a preliminary analysis of major functional areas of management and makes the following recommendations: human resource procedures, management practices, quality management, information management, manufacturing technology and operation management, which needed improvement. Corrective action should be considered and predictable therefore the survey indicated that the eight factories have insufficient areas of management that may cause low flexible manufacturing, decreased resource efficiency, inaccurate demand forecast, disruptions and unreliable lead times, which will potentially affect critical delivery dates.

7.1.4 Conclusions regarding the case study

This case study's aim was to identify simple strategies for reducing manufacturing lead-time (MLT) in the ZX plastic factory. The framework was designed to provide guidance to industry practitioners/technicians in reducing MLT, also to find or suggest practical, inexpensive strategies to reduce lead time. In particular, this case study was conducted to assess the manufacturing sector and the strategy of factories in the Kurdistan region in terms of quick response to customers in order to find potential methodologies that can reduce lead-time in the manufacturing process. The outcomes of tests substantiated in this research study based on section 6.6.

- Finding that the ZX factory has insufficient material requirement planning (MRP) and capacity planning that may cause low flexible manufacturing, decrease resource efficiency, cause inaccurate demand forecasts, disruptions and unreliable lead times. This will potentially affect critical delivery dates. Pipes should be ready for shipping so as to be delivered on time but a problem occurs four times a year, so the ZX factory should develop a capacity plan for production orders. During the interview for the research survey, it appeared that the production manager has insufficient time to complete his production orders in the allotted seven days.
- Finding the lot-for-lot technique (L4L) is more efficient than fixed period requirements (FPR). The results indicated that a lot-for-lot ordering policy has a significant impact on order production as much as it is needed, with respect to the timing decision the production planner always ordered as little as possible, i.e. just enough to avoid a stock-out. Furthermore, it could be compatible to reduce MRP 'buckets' from weekly to daily when MRP can be integrated with just-in-time (JIT), thus leading to reduced MLT. Furthermore the survey questionnaire illustrated that 90% of 160 participants are informed that the order became late on delivery time across the eight factories.
- Designing the closed-loop capacity planning has significant impact on reducing MLT at ZX. It also provides feedback about workload and capacity available (minutes) then all items can be rescheduled in the net requirements plan as well as it will give an input /output report to ensure or verify if the average capacity is adequate (and realistic for the desired master production schedule) and especially suitable for daily production orders.

- Finding that splitting orders is the best tactic for smoothing the load and minimising the impact of the changed lead time at the ZX factory. This tactic will lead to controlling and reducing lead-time, it is a tactic for smoothing the load and minimising all units ordered in the requirement plan, meaning a trade-off between the capacity required (minutes) and available (minutes). The results indicated that manufacturing lead time decreased from 9 days to 7 days as MLT reduced by 22.22%.
- Finding that the design of a work balance chart provides the accuracy of planning, the output of each process matches customer demand and better adherence to the plan for the daily production pipes at the factory thus ZX can produce more units. Also the results indicated that takt time decreased from 15 minutes. To produce one pipe every 11.66 minutes will require 3 operators instead of 2 operators therefore ZX can produce more units, from 160 pipes to 205 pipes weekly which is scheduled for 8 hours over 5 days.
- Finding the waiting line model is significant tool to control the waiting line (queuing model) led to determining the flow through a production process, designing systems that optimise some criteria, evaluating alternatives in an attempt to control/improve manufacturing efficiency *(Heizer, J. and Render, B. (2008))* Finding the procedure of analysing waiting lines that can help a production planner at the factory to evaluate the cost and effectiveness of service systems is carried out more often at a systematic high level of abstraction in a strategic decision-making phase in order to create a list of "potential layouts". The results show if the arrival pipes rate (λ) decreased to 2 pipes per hour with constant service time, the traffic intensity (rho) will decrease also average server utilisation (P) decreased from 75% to 50% means that 50% of the time the machine is busy. Also both average times in the system (Ws) decreased meaning MLT decreased from 60 to 30 minutes in the system and average time waiting in line (Wq) also decreased from 45 to 15 minutes.
- Finding that the ZX factory can achieve a world-class OEE level, when the factory is a fully-connected OEE system. The application of OEE tools will help ZX to track and improve their manufacturing performance *(Vorne Industries Inc (2008)).* it is could be used to enable rescheduling capacity

planning at the factory. Finding the OEE can identify the root cause of production losses such as: availability, performance and quality loss allows effective targeting of resources for accelerated efficiency gains and best machine utilisation. The results indicated that the ZX factory's overall OEE score of 80.03% is acceptable and is near the record of OEE's (world-class) score of 85% for discrete manufacturers.

- Finding the role of hypothetical transactions on reducing move time factory has an opportunity to improve overall daily productivity in order to reduce move time *(Johnson, D.J. (2003))* which led to reducing MLT. The assumption is based on two factors, first designing a layout strategy and the second increasing resource access such as using a robot because the two factors are suitable for reducing move time, distance and number of moves. The result shows that the present layout was changed to possible layout and the distance movement between departments reduced from 8190 to 700 feet, this assumption leads to the process being minimised, material movement leads to reduced move time between departments consequently MLT will be reduced. Also the results indicated the double-handed gripper of the robot was essential to enable the robot to service the (machine, conveyor) sequence with any degree of efficiency. The result indicated that double-handed increased the production efficiency 13.60 % also the production rate increased from 22 pipes using as the one-handed gripper To 25 pipes/shift using a double-handed gripper. Therefore, reductions in move time can be accomplished by reducing either the time required per move or the number of moves required.

7.1.5 Regarding the Research Hypothesis

- There is a significant opportunity exists to reduce the manufacturing lead time in the manufacturing sector with the application of survey questionnaires in order to provide products and services to customers more quickly'
- There is a significant opportunity exists to reduce the manufacturing lead time in the manufacturing sector with the implementation of various tools and techniques in order to provide products and services to customers more quickly'

7.2 Future Work

- Designing a survey questionnaire based on both a manufacturing assessment and the application of ISO 9001: 2000 for audit procedures in order to get early indications of potential problems or defects and leading to taking corrective action to avoid long MLT and late delivery time in the factory also to identify areas for capital and time investment that will provide a preliminary analysis of a firm’s strengths and weaknesses in order to MLT.
- The application of key performance indicators (KPIs). This is the best technical tool because KPIs can be used to discover: equipment reliability, number of incidents (stoppage), mean time between (MTBF) and mean time to repair (MTTR) because availability related to MTBF and MTTR in order to improve machine reliability. Therefore, downtime, reliability, utilisation, MTBF and MTTR are important factors that should be considered in order to reduce lead time in terms of non-operational time, which is one of the main components of MLT. Therefore KPIs can monitor the system in order to ensure manufacturing processes and machines are available to achieve short MLT. KPLs can identifying opportunities for reducing lead time as well as supporting the production planner to utilise capacity more effectively.
- Development of a framework that enables finding the impact of three tactics on smoothing the load and minimizing lead time include the following:
- Overlapping, which reduces the lead time, sends pieces to the second operation before the entire lot is completed on the first operation.
- “Operations splitting send the lot to two different machines for the same operation. Order splitting involves breaking up the order and running part of it head of schedule”. (Heizer and Render, 2008).

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Appendix

Appendix1: Survey MLT (Sample Form, Pre-test and Pilot)

Analytical investigation on Lead-Time reduction in manufacturing industry between work stations

Please, let's know how to identify simple strategies for reducing manufacturing lead time. This survey will take not more than 15 minutes of your time and will provide us with precious information to improve our research study on manufacturing management. Thank you for taking time to respond to this form.
*** Required**

---

1. How long you have been working within your organization? *

- ☐ **Between 1 To 3 years**
- ☐ **More than 3 years**

2. What is your primary function within your organization? *

- ☐ **Engineer**
- ☐ **Technical**
- ☐ **Manager**
- ☐ **Supervisor**
- ☐ **Not specified**

3. Do you inform your customers when orders are expected to be late?

	Mostly	Often	Rarely	None
Customer / Contractor	☐	☐	☐	☐

4. **Does your Company provide professional training for all employees regardless of their level of employment? ***
Training the staff and employing skilled people with high level of knowledge may reduce manufacturing lead-time or throughput time in the (factory / company). How do you describe your company regarding this matter? Relate to the management practices. For example: To provide guidance to the industry practitioner on how to reduce manufacturing throughput time

- ☐ **Company provide high level of training**
- ☐ **Company provide less level of training**
- ☐ **Company provide no training**

5. Does your company provide feedback to employees on their performance? *

Training the staff and employing skilled people with high level of knowledge may reduce manufacturing lead-time or throughput time in the (factory / company). How do you describe your company regarding this matter? Relate to the management practices. For example: To provide guidance to the industry practitioner on how to reduce manufacturing throughput time

- ☐ **Yes**
- ☐ **No**

6. Which of the following shortages are likely to limit your ability to work?

	Seriously	Slightly	Not at all
Skilled labour & Technical staff	☐	☐	☐
Quality management	☐	☐	☐
Planning for (Lot or Batch) sizes Policy	☐	☐	☐
Equipment, Machine & Technology	☐	☐	☐
Layout Strategy for Operation Management	☐	☐	☐

7. To what extent the following have limited your current abilities?

	Seriously	Slightly	Not at all
Company policies	☐	☐	☐
The high level of production rate during every day?	☐	☐	☐
Stock supply and/or in time deliveries	☐	☐	☐
Lack of communication on workshop floor	☐	☐	☐
Sudden changes in (Production /Transfer) Batch Size decision	☐	☐	☐
No shifts are regularly scheduled per day	☐	☐	☐

Any other :

8. Do you have in place Quality Assurance, Quality Control and traceability in company procedures?

- ☐ **Not required**
- ☐ **Fully supported**

- Supported with modifications or customizations
- Not sure

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? *

	1 Less impact	2	3	4	5 Great impact
Process Time (Run time)					
Setup Time.					
Batch Sizes					
Time Utilisation					
Waiting Time.					
Less Machine downtime					
Move Time					
Maintenance					
Supplies raw material					
Reducing Job Overlapping					

10. What are the causes of variability of the workload?
Controllable variation & Random variation

	Seriously	Slightly	Not at all
Things under your control			
Things out of your control			

11. Does your company maintain stock production and does this affect your batch size?
In the term of controlling inventory & to support manufacturing lead-time reduction

- Yes
- No

12. Which of the following solutions would improve the reduction of the lead time in your company? *

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Improve Company Procedures					
Adopt One-piece Flow Production					
Increase Working stations Capacity					
Adopt group Technology					
Optimization of the Current Factory Layout & Strategy					
Justified Batch Sizes					
Increase Production Control, Scheduling					
Purchase Equipment with Shorter Setup Time					

13. Does your company currently using some of the following technologies?

Please indicate Yes or No to the following statements: .Relate to Manufacturing Technology means quick view to manufacturing assessment

	Yes	No
CNC Machine Tools		
Programmable Robotics		
Programmable Controllers (PLCs)		
Production Planning and Inventory Control System (MRP or similar)		
Automated Inspection		
Coordinate Measuring Machine (CMM)		
Computer Aided Design (CAD) & Computer Aided Manufacturing (CAM) soft wares		
Statistical Process Control (SPC)		

14. Do you have or have received clear explanations of the followings from your Supervisor: *

	Extremely clearly	Moderately clearly	Slightly clearly	Not at all clearly
Equipment idle-time and reasons				
Equipment down-time and reasons				
Use of specific equipment				
Use of the cutting tool inserts or other jigs and fixtures				

15. Does your company use the following documents and procedures?

	Yes	No
Master Production Scheduling (MPS).		
Bills of Material (BOM).		
On hand Inventory and Work-In-Progress (WIP).		
Work orders.		
Lead time analysis.		

16. How, overall, would you rate your company for the job organisation? *

- **Excellent**
- **Good**
- **Average**
- **Poor**

17. Any comments or suggestions for your company in order to reduce the manufacturing lead time?

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Appendix2: Survey MLT (Stamps of the Company's Director

Ministry of justice
Legal Translator
Rizgar Abdulsattar Mustafa
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Mobile: +9647701585436
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وزارة العدل
المترجم القانوني
رزكار عبد الستار مصطفى
رقم الاجازة : (٢-٢٠٠١)
رقم الجوال: ٩٦٤٧٧٠١٥٨٥٤٣٦ +
البريد الالكتروني : rizgarpiskandi@gmail.com

Kurdistan Region – Iraq
Visiting the factories in Kurdistan / Names and Stamps of the Companies Directors
September / 2013
Survey :PhD research

Diar Omarr Plastic factory The Company Stamp (Stamped)	Farhad hussein Darwish Factory of Asia Oil The Company Stamp (Stamped)
Shwan Dnwan Majeed Deputy Co. Krman Company for Steal industry The Company Stamp (Stamped)	Nawroz Nokan company for Stoon Industry The Company Stamp (Stamped)
Taslooja Cement factory Faramosh Barzinji The Company Stamp (Stamped)	Ismaeel Ahmad .H. Bamok co. for Plastic pipes The Company Stamp (Stamped)
Hurer Fatah Muhamad ALA Company for Soft drinks & Drinking Watters The Company Stamp (Stamped)	Dana Kamal Rifaat Peramagroon press Company The Company Stamp (Stamped)

Appendix 2.1: Sample of Pre-test and Pilot (validity) Processing for next designing FORM

9/2/13 Analytical investigation on Lead-Time reduction in manufacturing industry between work stations

pre-Test	1 Less impact	2	3	4	5 Great impact
Process Time (Run time)	○	○	○	○	◉
Setup Time.	○	○	○	◉	○
Batch Sizes	○	○	○	◉	○
Time Utilisation	○	○	◉	○	○
Waiting Time.	○	○	○	◉	○
Machine downtime	○	○	◉	○	○
Move Time	○	○	○	◉	○
Maintenance	○	○	◉	○	○
Supplies raw material	○	○	◉	○	○
Job Overlapping	○	○	◉	○	○

10. What are the causes of variability of the workload?
Controllable variation & Random variation

	Seriously	Slightly	Not at all
Things under your control	○	◉	○
Things out of your control	◉	○	○

11. Does your company maintain stock production and does this affect your batch size?
In the term of controlling inventory & to support manufacturing lead-time reduction

○ Yes
◉ No

12. Which of the following solutions would improve the reduction of the lead time in your company? *

Needed 5 Scale

	1 Strongly Agree	2 Agree	7 Neutral	4 Disagree	Strongly D. Added Column
Improve Company Procedures	◉	○	○	○	
Adopt One-piece Flow Production	○	◉	○	○	
Increase Working stations Capacity	○	◉	○	○	
Adopt group					

https://docs.google.com/forms/d/1bo5uaoxcl6UO5DP7rjz6QKeJOxAUrZx_hrq67YZyfD0/viewform 3/5

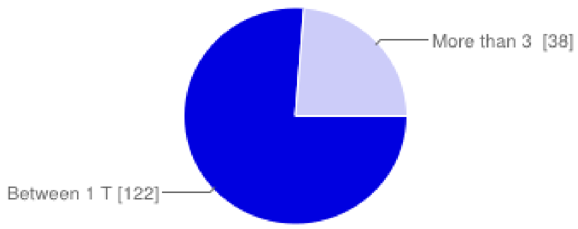
Appendix3: 160 responses of survey MLT (Frequency and Percentage)

Summary of 160 responses

View all responses

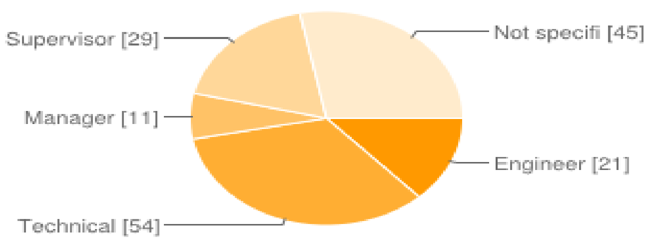
Summary

1. How long you have been working within your organization?



Between 1 To 3 years	**122**	76%
More than 3 years	**38**	24%

2. What is your primary function within your organization?

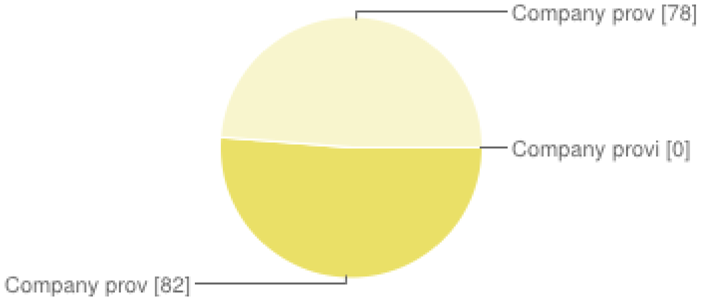


Engineer	**21**	13%
Technical	**54**	34%
Manager	**11**	7%
Supervisor	**29**	18%
unspecified job	**45**	28%

3. Do you inform your customers when orders are expected to be late? Customer / Contractor

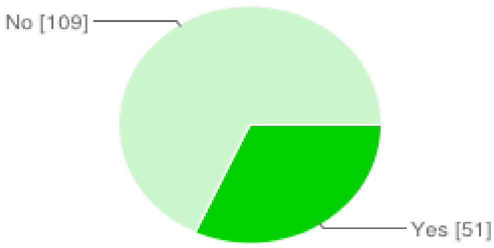
Mostly	**59**	37%
Often	**85**	53%
Rarely	**16**	10%
None	**0**	0%

4. Does your Company provide professional training for all employees regardless of their level of employment?



Company provide high level of training	**0**	0%
Company provide less level of training	**82**	51%
Company provide no training	**78**	49%

5. Does your company provide feedback to employees on their performance?



Yes	**51**	32%
No	**109**	68%

6. Which of the following shortages are likely to limit your ability to work? [Skilled labour & Technical staff]

Seriously	**109**	69%
Slightly	**46**	29%
Not at all	**4**	3%

6. Which of the following shortages are likely to limit your ability to work?[Quality management

Seriously	**26**	17%
Slightly	**114**	73%
Not at all	**17**	11%

6. Which of the following shortages are likely to limit your ability to work?[Planning for (Lot or Batch) sizes Policy]

Seriously	**88**	55%
Slightly	**72**	45%
Not at all	**0**	0%

6. Which of the following shortages are likely to limit your ability to work?[Equipment, Machine & Technology]

Seriously	**34**	21%
Slightly	**107**	67%
Not at all	**19**	12%

Layout Strategy for Operation Management [6. Which of the following shortages are likely to limit your ability to work?]

Seriously	**152**	95%
Slightly	**7**	4%
Not at all	**1**	1%

7. To what extent the following have limited your current abilities?[Company policies]

Seriously	**19**	12%
Slightly	**112**	70%
Not at all	**29**	18%

The high level of production rate during every day? [7. To what extent the following have limited your current abilities?]

Seriously	**63**	39%
Slightly	**93**	58%
Not at all	**4**	3%

Stock supply and/or in time deliveries [7. To what extent the following have limited your current abilities?]

Seriously	**62**	39%
Slightly	**96**	60%
Not at all	**2**	1%

Lack of communication on workshop floor [7. To what extent the following have limited your current abilities?]

Seriously	**1**	1%
Slightly	**81**	51%
Not at all	**76**	48%

Sudden changes in (Production /Transfer) Batch Size decision [7. To what extent the following have limited your current abilities?]

Seriously	**141**	88%

Slightly	**19**	12%
Not at all	**0**	0%

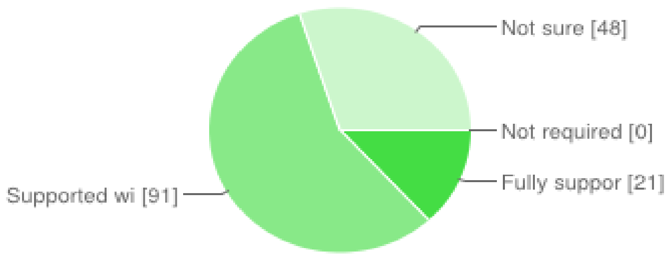
No shifts are regularly scheduled per day [7. To what extent the following have limited your current abilities?]

Seriously	**15**	9%
Slightly	**130**	82%
Not at all	**13**	8%

Any other:

Lack of research worker for society problem Equipment Technology Quality of material Qualiy of material Shortages of New Equipments Lack of permission for Engineer to do special task of activities Input for quality of Material Dealy of Raw materials orders on time and Law quality of Raw materials Lack of Raw material Lack of Equipments skill of repairing of specific equipments & devices Nil Qualiy of raw material Skill of staffs and quality production I Shape Layout strategy work stations Capacity quality material nil

8. Do you have in place Quality Assurance, Quality Control and traceability in company procedures?



Not required	**0**	0%
Fully supported	**21**	13%
Supported with modifications or customizations	**91**	57%
Not sure	**48**	30%

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]

1 Less impact	**0**	0%
2	**0**	0%
3	**0**	0%
4	**49**	31%
5 Great impact	**111**	69%

Setup Time. [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**0**	0%
2	**13**	8%
3	**72**	45%
4	**72**	45%
5 Great impact	**3**	2%

Batch Sizes [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**1**	1%
2	**3**	2%
3	**52**	33%
4	**80**	50%
5 Great impact	**24**	15%

Time Utilisation [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**0**	0%
2	**30**	19%

3	**67**	42%
4	**45**	28%
5 Great impact	**18**	11%

Waiting Time. [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**0**	0%
2	**43**	27%
3	**35**	22%
4	**52**	33%
5 Great impact	**30**	19%

Less Machine downtime [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**16**	10%
2	**65**	41%
3	**55**	34%
4	**22**	14%
5 Great impact	**2**	1%

Move Time [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**0**	0%
2	**2**	1%
3	**15**	9%
4	**65**	41%
5 Great impact	**78**	49%

Maintenance [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**25**	16%
2	**91**	57%
3	**29**	18%
4	**14**	9%
5 Great impact	**1**	1%

Supplies raw material [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**62**	39%
2	**57**	36%
3	**23**	14%
4	**13**	8%
5 Great impact	**5**	3%

Reducing Job Overlapping [9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company?]

1 Less impact	**11**	7%
2	**81**	51%
3	**60**	38%
4	**8**	5%
5 Great impact	**0**	0%

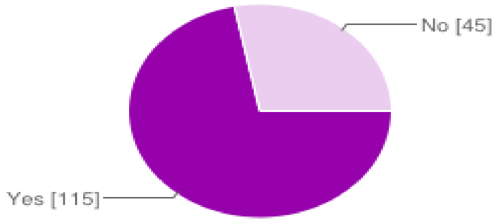
10. What are the causes of variability of the workload?[Things under your control]

Seriously	**22**	14%
Slightly	**136**	85%
Not at all	**2**	1%

Things out of your control [10. What are the causes of variability of the workload?]

Seriously	**56**	35%
Slightly	**103**	64%
Not at all	**1**	1%

11. Does your company maintain stock production and does this affect your batch size?



Yes	**115**	72%
No	**45**	28%

12. Which of the following solutions would improve the reduction of the lead time in your company?[Improve Company Procedures]

Strongly Agree	47	29%
Agree	77	48%
Neutral	35	22%
Disagree	1	1%
Strongly Disagree	0	0%

Adopt One-piece Flow Production [12. Which of the following solutions would improve the reduction of the lead time in your company?]

Strongly Agree	**28**	18%
Agree	**112**	70%
Neutral	**17**	11%
Disagree	**3**	2%
Strongly Disagree	**0**	0%

Increase Working stations Capacity [12. Which of the following solutions would improve the reduction of the lead time in your company?]

Strongly Agree	**53**	33%
Agree	**93**	58%
Neutral	**14**	9%
Disagree	**0**	0%
Strongly Disagree	**0**	0%

Adopt group Technology [12. Which of the following solutions would improve the reduction of the lead time in your company?]

Strongly Agree	**27**	17%
Agree	**104**	65%
Neutral	**28**	18%
Disagree	**1**	1%
Strongly Disagree	**0**	0%

Optimization of the Current Factory Layout & Strategy [12. Which of the following solutions would improve the reduction of the lead time in your company?]

Strongly Agree	**144**	90%
Agree	**16**	10%
Neutral	**0**	0%
Disagree	**0**	0%
Strongly Disagree	**0**	0%

Justified Batch Sizes [12. Which of the following solutions would improve the reduction of the lead time in your company?]

Strongly Agree	**107**	67%
Agree	**50**	31%
Neutral	**2**	1%
Disagree	**1**	1%
Strongly Disagree	**0**	0%

Increase Production Control, Scheduling [12. Which of the following solutions would improve the reduction of the lead time in your company?]

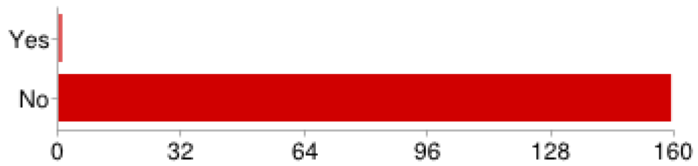
Strongly Agree	**18**	11%
Agree	**127**	79%
Neutral	**15**	9%
Disagree	**0**	0%
Strongly Disagree	**0**	0%

Purchase Equipment with Shorter Setup Time [12. Which of the following solutions would improve the reduction of the lead time in your company?]

Strongly Agree	**28**	18%

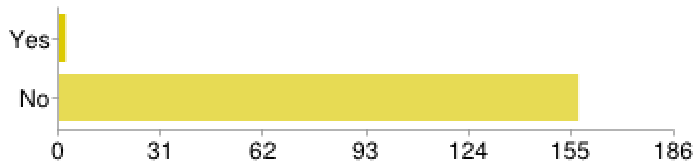
Agree	**74**	46%
Neutral	**41**	26%
Disagree	**17**	11%
Strongly Disagree	**0**	0%

13. Does your company currently using some of the following technologies?[CNC Machine Tools]



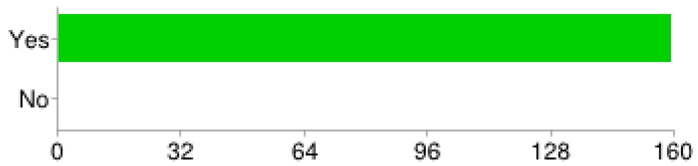
Yes	**1**	1%
No	**159**	99%

Programmable Robotics [13. Does your company currently using some of the following technologies?]



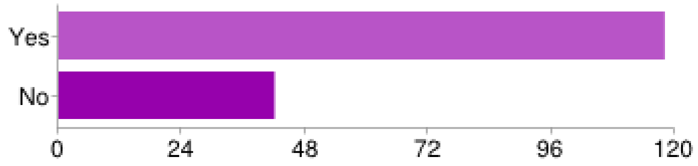
Yes	**3**	1%
No	**157**	99%

Programmable Controllers (PLCs) [13. Does your company currently using some of the following technologies?]



Yes	**159**	99%
No	**1**	1%

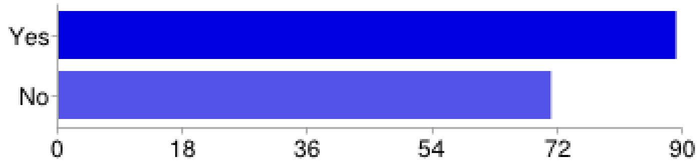
Production Planning and Inventory Control System (MRP or similar) [13. Does your company currently using some of the following technologies?]



Yes **118** 74%

No **42** 26%

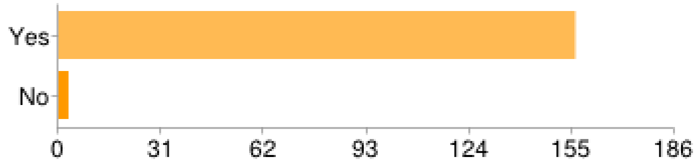
Automated Inspection [13. Does your company currently using some of the following technologies?]



Yes **89** 56%

No **71** 44%

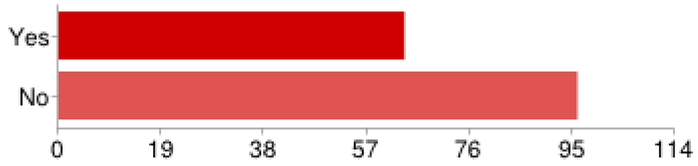
Coordinate Measuring Machine (CMM) [13. Does your company currently using some of the following technologies?]



Yes **156** 98%

No **4** 2%

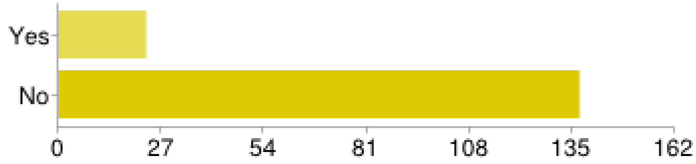
Computer Aided Design (CAD) & Computer Aided Manufacturing (CAM) soft wares [13. Does your company currently using some of the following technologies?]



Yes **64** 40%

No **96** 60%

Statistical Process Control (SPC) [13. Does your company currently using some of the following technologies?]



Yes	**23**	14%
No	**137**	86%

14. Do you have or have received clear explanations of the followings from your Supervisor?[Equipment idle-time and reasons]

Extremely clearly	**1**	1%
Moderately clearly	**0**	0%
Slightly clearly	**128**	80%
Not at all clearly	**31**	19%

Equipment down-time and reasons [14. Do you have or have received clear explanations of the followings from your Supervisor:]

Extremely clearly	**0**	0%
Moderately clearly	**11**	6%
Slightly clearly	**73**	46%
Not at all clearly	**76**	48%

Use of specific equipment [14. Do you have or have received clear explanations of the followings from your Supervisor:]

Extremely clearly	**1**	1%
Moderately clearly	**45**	**28%**
Slightly clearly	**114**	**71%**

Not at all clearly **0** 0%

Use of the cutting tool inserts or other jigs and fixtures [14. Do you have or have received clear explanations of the followings from your Supervisor:]

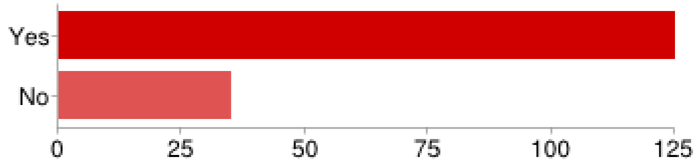
Extremely clearly **1** 1%

Moderately clearly **90** 56%

Slightly clearly **69** 43%

Not at all clearly **0** 0%

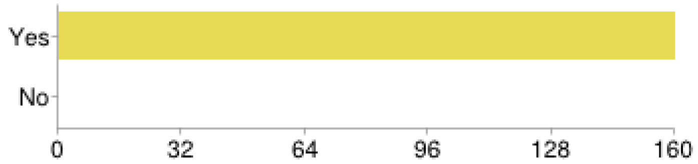
15. Does your company use the following documents and procedures?[Master Production Scheduling (MPS)]



Yes **125** 78%

No **35** 22%

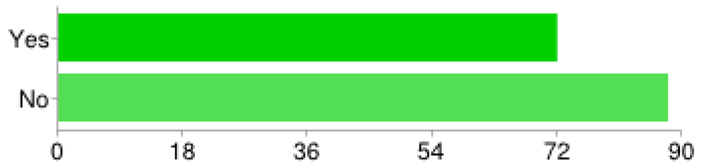
Bills of Material (BOM). [15. Does your company use the following documents and procedures?]



Yes **160** 100%

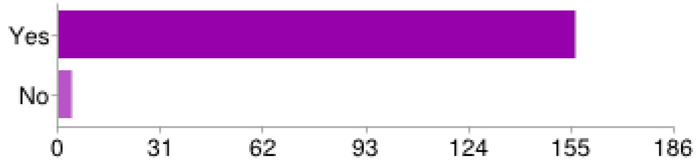
No **0** 0%

On hand Inventory and Work-In-Progress (WIP). [15. Does your company use the following documents and procedures?]



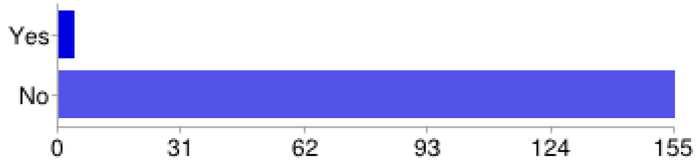
Yes	**72**	45%
No	**88**	55%

Work orders. [15. Does your company use the following documents and procedures?]



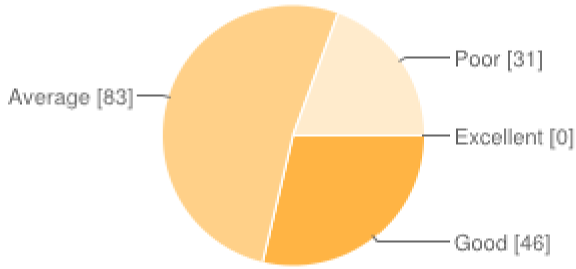
Yes	**156**	98%
No	**4**	2%

Lead time analysis. [15. Does your company use the following documents and procedures?]



Yes	**5**	3%
No	**155**	97%

16. How, overall, would you rate your company for the job organisation?



Excellent	**0**	0%
Good	**46**	29%
Average	**83**	52%
Poor	**31**	19%

17. Any comments or suggestions for your company in order to reduce the manufacturing lead time?

Changing Layout Strategy from I To U shape Improving tools for Root causeanalysis(RCA) Changing in Layout strategy controlling the environment of pollution in the area of production by increasing on fillter devices Purchase Equipment with shorter Setup time changing from I shape To U shape of Layout strategy N il using more sensor devices for quality control processing Packed Machine for all in one by one process time Process of heating should be at the same time in the process of output improvement on skill of repairing for specific equipments Changing in Layout Strategy from I To U shape Nil improving in Quality of raw material increasing in adopt Group Technology Equipment & Adopt GroupTechnologyimproving on quality materials increase in the volume of storing clay for press processing to reduce MLT improve capacty of dry process procedure

Appendix4: Kruskal-Wallis test of survey MLT

Kruskal-Wallis Test

The Kruskal-Wallis nonparametric tests are used to test the significance of the difference amongst the categories of primary function within your organization (independent variable). The nonparametric tests do not make assumptions about the parameters of a distribution, nor do they assume that any particular distribution is being used.

The Kruska-Walis one way analysis of variance test

This is a test for several independent Samples and it compares two or more groups of cases on one variable. The Kruska-walis tests for multiple independent samples are used in determining whether or not the dependent variables differ between two or more ranks.

The Kruskal-Wallis test uses ranks of the original values and not the values themselves in its test. The sum and average rank for each tank within dependent variables are shown in the table below.
NPar Tests

Kruskal-Wallis Test

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
3. Do you inform your customers when orders are expected to be late? [Customer / Contractor]	Engineer	21	87.45
	Technical	54	88.06
	Manager	11	67.50
	Supervisor	29	75.38
	unspecified job	45	74.67
	Total	160	

Test Statistics[a,b]

	3. Do you inform your customers when orders are expected to be late? [Customer / Contractor]
Chi-Square	4.809
df	4
Asymp. Sig.	.307

a. Kruskal Wallis Test

b. Grouping Variable: 2. What is your primary function within your organization?

There was no statistically significant difference in "Customer / Contractor" in all the categories of primary function within your organization (chi-square statistic= 4.809, P-value = 0.307). There was no statistically significant difference between the "Customer / Contractor" in all the categories of primary function within your organization (H(2) = 4.809, P-value = 0.307).

NPar Tests

Kruskal-Wallis Test

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
6. Which of the following shortages are likely to limit your ability to work? [Skilled labour & Technical staff]	Engineer	21	69.76
	Technical	53	82.74
	Manager	11	69.09
	Supervisor	29	79.05
	unspecified job	45	84.83
	Total	159	
6. Which of the following shortages are likely to limit your ability to work? [Quality management]	Engineer	21	70.57
	Technical	54	79.50
	Manager	11	64.77

	2. What is your primary function within your organization?	N	Mean Rank
	Supervisor	29	81.26
	unspecified job	43	86.44
	Total	158	
6. Which of the following shortages are likely to limit your ability to work? [Planning for (Lot or Batch) sizes Policy]	Engineer	21	71.17
	Technical	54	77.09
	Manager	11	102.68
	Supervisor	29	85.88
	unspecified job	45	80.06
	Total	160	
6. Which of the following shortages are likely to limit your ability to work? [Equipment, Machine & Technology]	Engineer	21	77.57
	Technical	54	75.56
	Manager	11	68.77
	Supervisor	29	84.79
	unspecified job	45	87.90
	Total	160	
6. Which of the following shortages are likely to limit your ability to work? [Layout Strategy for Operation Management]	Engineer	21	80.48
	Technical	54	80.92
	Manager	11	83.73
	Supervisor	29	81.98
	unspecified job	45	78.27
	Total	160	

Test Statistics[a,b]

	6. Which of the following shortages are likely to limit your ability to work? [Skilled labour & Technical staff]	6. Which of the following shortages are likely to limit your ability to work? [Quality management]	6. Which of the following shortages are likely to limit your ability to work? [Planning for (Lot or Batch) sizes Policy]	6. Which of the following shortages are likely to limit your ability to work? [Equipment, Machine & Technology]	6. Which of the following shortages are likely to limit your ability to work? [Layout Strategy for Operation Management]
Chi-Square	3.597	4.882	5.469	4.061	1.347
df	4	4	4	4	4
Asymp. Sig.	.463	.300	.243	.398	.853

a. Kruskal Wallis Test

b. Grouping Variable: 2. What is your primary function within your organization?

There was no statistically significant difference in “Skilled labour & Technical staff” in all the categories of primary function within your organization (chi-square statistic= 3.597, P-value = 0.463). There was no statistically significant difference between the “Skilled labour & Technical staff” in all the categories of primary function within your organization (H(2) = 3.597, P-value = 0.463).

There was no statistically significant difference in “Quality management” in all the categories of primary function within your organization (chi-square statistic= 4.882, P-value = 0.300). There was no statistically significant difference between the “Quality management” in all the categories of primary function within your organization (H(2) = 4.882, P-value = 0.300).

There was no statistically significant difference in “Lot or Batch) sizes Policy” in all the categories of primary function within your organization (chi-square statistic= 5.469, P-value = 0.243). There was no statistically significant difference between the “Lot or Batch) sizes Policy” in all the categories of primary function within your organization (H(2) = 5.469, P-value = 0.243).

There was no statistically significant difference in “Equipment, Machine & Technology” in all the categories of primary function within your organization (chi-square statistic= 4.061, P-value = 0.398). There was no statistically significant difference between the “Equipment, Machine & Technology” in all the categories of primary function within your organization (H(2) = 4.061, P-value = 0.398).

There was no statistically significant difference in “Layout Strategy for Operation Management” in all the categories of primary function within your organization (chi-square statistic= 1.347, P-value = **0.853). There was no statistically significant difference between the "Layout Strategy for Operation Management" in all the categories of primary function within your organization (H(2) = 1.347, P-value = 0.853).**

NPar Tests

Kruskal-Wallis Test

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	Engineer	21	82.14
	Technical	54	82.78
	Manager	11	90.45
	Supervisor	29	77.41
	unspecified job	45	76.56
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	Engineer	21	86.98
	Technical	54	84.38
	Manager	11	71.82
	Supervisor	29	77.38
	unspecified job	45	76.96
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	Engineer	21	83.07
	Technical	54	87.54
	Manager	11	91.27
	Supervisor	29	65.86
	unspecified job	45	77.66
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]	Engineer	21	87.10
	Technical	54	86.92
	Manager	11	77.73
	Supervisor	29	75.78
	unspecified job	45	73.44
	Total	160	
9. Which of the following	Engineer	21	90.38

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]	Technical	54	88.61
	Manager	11	73.64
	Supervisor	29	75.48
	unspecified job	45	71.07
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	Engineer	21	90.45
	Technical	54	81.18
	Manager	11	89.64
	Supervisor	29	72.21
	unspecified job	45	78.16
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	Engineer	21	101.07
	Technical	54	82.79
	Manager	11	71.59
	Supervisor	29	69.14
	unspecified job	45	77.66
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	Engineer	21	78.29
	Technical	54	70.85
	Manager	11	78.77
	Supervisor	29	84.52
	unspecified job	45	90.94
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	Engineer	21	73.43
	Technical	54	73.07
	Manager	11	78.95
	Supervisor	29	89.28
	unspecified job	45	87.43
	Total	160	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]	Engineer	21	88.36
	Technical	54	72.95
	Manager	11	96.64
	Supervisor	29	79.17
	unspecified job	45	82.80
	Total	160	

Test Statistics[a,b]

	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]
Chi-Square	1.756	1.921	5.935	3.175	5.442
df	4	4	4	4	4
Asymp. Sig.	.780	.750	.204	.529	.245

There was no statistically significant difference in “Process Time (Run time)” in all the categories of primary function within your organization (chi-square statistic= 1.756, P-value = 0.780). There was no statistically significant difference between the “Process Time (Run time)” in all the categories of primary function within your organization (H(2) = 1.756, P-value = 0.780).

There was no statistically significant difference in “Setup Time” in all the categories of primary function within your organization (chi-square statistic= 1.921, P-value = 0.750). There was no statistically significant difference between the “Setup Time” in all the categories of primary function within your organization (H(2) = 1.921, P-value = 0.750).

There was no statistically significant difference in “Batch Sizes” in all the categories of primary function within your organization (chi-square statistic= 5.935, P-value = 0.204). There was no statistically significant difference between the “Batch Sizes” in all the categories of primary function within your organization (H(2) = 5.935, P-value = 0.204).

There was no statistically significant difference in “Time Utilisation” in all the categories of primary function within your organization (chi-square statistic= 3.175, P-value = 0.529). There was no statistically significant difference between the “Time Utilisation” in all the categories of primary function within your organization (H(2) = 3.175, P-value = 0.529).

There was no statistically significant difference in “Waiting Time” in all the categories of primary function within your organization (chi-square statistic= 5.442, P-value = 0.245). There was no statistically significant difference between the “Waiting Time” in all the categories of primary function within your organization (H(2) = 5.442, P-value = 0.245).

Test Statistics[a,b]

	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]
Chi-Square	2.759	8.075	6.094	4.408	4.290
df	4	4	4	4	4
Asymp. Sig.	.599	.089	.192	.354	.368

a. Kruskal Wallis Test

b. Grouping Variable: 2. What is your primary function within your organization?

There was no statistically significant difference in “Less Machine downtime” in all the categories of primary function within your organization (chi-square statistic= 2.759, P-value = 0.599). There was no statistically significant difference between the “Less Machine downtime” in all the categories of primary function within your organization (H(2) = 2.759, P-value = 0.599).

There was no statistically significant difference in “Move Time” in all the categories of primary function within your organization (chi-square statistic= 8.075, P-value = 0.089). There was no statistically significant difference between the “Move Time” in all the categories of primary function within your organization (H(2) = 8.075, P-value = 0.089).

There was no statistically significant difference in “Maintenance” in all the categories of primary function within your organization (chi-square statistic= 6.094, P-value = 0.192).

There was no statistically significant difference between the “Maintenance” in all the categories of primary function within your organization (H(2) = 6.094, P-value = 0.192).

There was no statistically significant difference in “Supplies raw material” in all the categories of primary function within your organization (chi-square statistic= 4.408, P-value = 0.354). There was no statistically significant difference between the “Supplies raw material” in all the categories of primary function within your organization (H(2) = 4.408, P-value = 0.354).

There was no statistically significant difference in “Reducing Job Overlapping” in all the categories of primary function within your organization (chi-square statistic= 4.290, P-value = 0.368). There was no statistically significant difference between the “Reducing Job Overlapping” in all the categories of primary function within your organization (H(2) = 4.290, P-value = 0.368).

NPar Tests

Kruskal-Wallis Test

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
12. Which of the following solutions would improve the reduction of the lead time in your company? [Improve Company Procedures]	Engineer	21	98.90
	Technical	54	79.56
	Manager	11	114.45
	Supervisor	29	78.17
	unspecified job	45	66.24
	Total	160	
12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt One-piece Flow Production]	Engineer	21	89.83
	Technical	54	79.64
	Manager	11	95.59
	Supervisor	29	81.90
	unspecified job	45	72.59
	Total	160	
12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Working stations Capacity]	Engineer	21	96.69
	Technical	54	79.03
	Manager	11	80.91
	Supervisor	29	81.81
	unspecified job	45	73.77
	Total	160	
12. Which of the following 12. Which of the following	Engineer	21	87.67
	Technical	54	81.43

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
solutions would improve the reduction of the lead time in your company? [Adopt group Technology]	Manager	11	75.50
	Supervisor	29	79.16
	unspecified job	45	78.13
	Total	160	
12. Which of the following solutions would improve the reduction of the lead time in your company? [Optimization of the Current Factory Layout & Strategy]	Engineer	21	88.50
	Technical	54	81.09
	Manager	11	88.50
	Supervisor	29	80.22
	unspecified job	45	74.28
	Total	160	
12. Which of the following solutions would improve the reduction of the lead time in your company? [Justified Batch Sizes]	Engineer	21	77.10
	Technical	54	85.66
	Manager	11	85.59
	Supervisor	29	82.64
	unspecified job	45	73.28
	Total	160	
12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Production Control, Scheduling]	Engineer	21	92.81
	Technical	54	73.80
	Manager	11	72.68
	Supervisor	29	94.05
	unspecified job	45	75.98
	Total	160	
12. Which of the following solutions would improve the reduction of the lead time in your company? [Purchase Equipment with Shorter Setup Time]	Engineer	21	83.29
	Technical	54	93.15
	Manager	11	81.23
	Supervisor	29	69.24
	unspecified job	45	71.10
	Total	160	

Test Statistics[a,b]

	12. Which of the following solutions would improve the reduction of the lead time in your company? [Improve Company Procedures]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt One-piece Flow Production]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Working stations Capacity]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt group Technology]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Optimization of the Current Factory Layout & Strategy]
Chi-Square	15.921	5.190	4.687	1.110	6.576
df	4	4	4	4	4
Asymp. Sig.	.003	.268	.321	.893	.160

There was statistically significant difference in “Improve Company Procedures” in all the categories of primary function within your organization (chi-square statistic= 15.921, P-value = 0.003). There was statistically significant difference between the “Improve Company Procedures” in all the categories of primary function within your organization (H(2) = 15.921, P-value = 0.003).

There was no statistically significant difference in “Adopt One-piece Flow Production” in all the categories of primary function within your organization (chi-square statistic= 5.190, P-value = 0.268). There was no statistically significant difference between the “Adopt One-piece Flow Production” in all the categories of primary function within your organization (H(2) = 5.190, P-value = 0.268).

There was no statistically significant difference in “Increase Working stations Capacity” in all the categories of primary function within your organization (chi-square statistic= 4.687, P-value = 0.321).

There was no statistically significant difference between the “Increase Working stations Capacity” in all the categories of primary function within your organization (H(2) = 4.687, P-value = 0.321).

There was no statistically significant difference in “Adopt group Technology” in all the categories of primary function within your organization (chi-square statistic= 1.110, P-value = 0.893). There was no statistically significant difference between the “Adopt group Technology” in all the categories of primary function within your organization (H(2) = 1.110, P-value = 0.893).

There was no statistically significant difference in “Optimization of the Current Factory Layout & Strategy” in all the categories of primary function within your organization (chi-square statistic= 6.576, P-value = 0.160). There was no statistically significant difference between the “Optimization of the Current Factory Layout & Strategy” in all the categories of primary function within your organization (H(2) = 6.576, P-value = 0.160).

Test Statistics[a,b]

	12. Which of the following solutions would improve the reduction of the lead time in your company? [Justified Batch Sizes]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Production Control, Scheduling]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Purchase Equipment with Shorter Setup Time]
Chi-Square	3.088	11.726	8.736
df	4	4	4
Asymp. Sig.	.543	.020	.068

a. Kruskal Wallis Test

b. Grouping Variable: 2. What is your primary function within your organization?

There was no statistically significant difference in "Justified Batch Sizes" in all the categories of primary function within your organization (chi-square statistic= 3.088, P-value = 0.543). There was no statistically significant difference between the "Justified Batch Sizes" in all the categories of primary function within your organization (H(2) = 3.088, P-value = 0.543).

There was statistically significant difference in "Increase Production Control, Scheduling" in all the categories of primary function within your organization (chi-square statistic= 11.726, P-value = 0.020). There was statistically significant difference between the "Increase Production Control, Scheduling" in all the categories of primary function within your organization (H(2) = 11.726, P-value = 0.020).

There was no statistically significant difference in "Purchase Equipment with Shorter Setup Time" in all the categories of primary function within your organization (chi-square statistic= 8.736, P-value = 0.068). There was no statistically significant difference between the "Purchase Equipment with Shorter Setup Time" in all the categories of primary function within your organization (H(2) = 8.736, P-value = 0.068).

Kruskal-Wallis Test

Ranks

	2. What is your primary function within your organization?	N	Mean Rank
16. How, overall, would you rate your company for the job organisation?	Engineer	21	77.71
	Technical	54	81.42
	Manager	11	74.91
	Supervisor	29	67.72
	unspecified job	45	90.30
	Total	160	

Test Statistics[a,b]

	16. How, overall, would you rate your company for the job organisation?
Chi-Square	5.396
df	4
Asymp. Sig.	.249

a. Kruskal Wallis Test

b. Grouping Variable: 2. What is your primary function within your organization?

There was no statistically significant difference in "How, overall, would you rate your company for the job organisation" in all the categories of primary function within your organization (chi-square statistic= 5.396, P-value = 0.249). There was no statistically significant difference between the "How, overall, would you rate your company for the job organisation" in all the categories of primary function within your organization (H(2) = 5.396, P-value = 0.249).

Appendix5: Mann-Whitney Test of survey MLT

Mann-Whitney Test

NPar Tests

The **Ranks** table provides information regarding the output of the actual Mann-Whitney U test. It shows mean rank and sum of ranks for the two categories of how long you have been working within your organization (i.e., Between 1 to 3 years and More than 3 years) for "Do you inform your customers when orders are expected to be late":

Mann-Whitney Test

Ranks

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
3. Do you inform your customers when orders are expected to be late? [Customer / Contractor]	Between 1 To 3 years	122	81.12	9896.50
	More than 3 years	38	78.51	2983.50
	Total	160		

The above table is very useful because it indicates which group can be considered as having the higher categories of how long you have been working within your organization, overall; namely, the group with the highest mean rank.

Test Statistics Table

This table shows the actual significance value of the test. Specifically, the **Test Statistics** table provides the test statistic, *U* value, as well as the asymptotic significance (2-tailed) *p*-value.

Test Statistics[a]

	3. Do you inform your customers when orders are expected to be late? [Customer / Contractor]
Mann-Whitney U	2242.500
Wilcoxon W	2983.500
Z	-.339
Asymp. Sig. (2-tailed)	.735

a. Grouping Variable: 1. How long you have been working within your organization?

From this data on “Do you inform your customers when orders are expected to be late”, the results suggest that there is no statistically significant difference between the underlying distributions of “Do you inform your customers when orders are expected to be late” scores of Between 1 to 3 years and “Do you inform your customers when orders are expected to be late” scores of More than 3 years. It can be concluded that Between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2242.500, p = .735).

NPar Tests

Mann-Whitney Test

Ranks

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
6. Which of the following shortages are likely to limit your ability to work? [Skilled labour & Technical staff]	Between 1 To 3 years	121	82.09	9932.50
	More than 3 years	38	73.36	2787.50
	Total	159		
6. Which of the following shortages are likely to limit your ability to work? [Quality management]	Between 1 To 3 years	120	83.44	10012.50
	More than 3 years	38	67.07	2548.50
	Total	158		
6. Which of the following shortages are likely to limit your ability to work? [Planning for (Lot or Batch) sizes Policy]	Between 1 To 3 years	122	81.22	9909.00
	More than 3 years	38	78.18	2971.00
	Total	160		
6. Which of the following shortages are likely to limit your ability to work? [Equipment, Machine & Technology]	Between 1 To 3 years	122	79.57	9707.00
	More than 3 years	38	83.50	3173.00
	Total	160		
6. Which of the following shortages are likely to limit your ability to work? [Layout Strategy for Operation Management]	Between 1 To 3 years	122	80.44	9814.00
	More than 3 years	38	80.68	3066.00
	Total	160		

Test Statistics[a,b]

	6. Which of the following shortages are likely to limit your ability to work? [Skilled labour & Technical staff]	6. Which of the following shortages are likely to limit your ability to work? [Quality management]	6. Which of the following shortages are likely to limit your ability to work? [Planning for (Lot or Batch) sizes Policy]	6. Which of the following shortages are likely to limit your ability to work? [Equipment, Machine & Technology]	6. Which of the following shortages are likely to limit your ability to work? [Layout Strategy for Operation Management]
Mann-Whitney U	2046.500	1807.500	2230.000	2204.000	2311.000
Wilcoxon W	2787.500	2548.500	2971.000	9707.000	9814.000
Z	-1.261	-2.464	-.409	-.550	-.074
Asymp. Sig. (2-tailed)	.207	.014	.682	.582	.941

a. Grouping Variable: 1. How long you have been working within your organization?

From this data on “Skilled labour & Technical staff”, the results suggest that there is no statistically significant difference between the underlying distributions of “Skilled labour & Technical staff” scores of Between 1 to 3 years and “Skilled labour & Technical staff” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2046.500, p = .207).

From this data on “Quality management”, the results suggest that there is statistically significant difference between the underlying distributions of “Quality management” scores of Between 1 to 3 years and “Quality management” scores of More than 3 years. It can be concluded that between 1 to 3 years are statistically significantly higher than the More than 3 years (U = 1807.500, p = .014).

From this data on “Planning for (Lot or Batch) sizes Policy”, the results suggest that there is no statistically significant difference between the underlying distributions of “Planning for (Lot or Batch) sizes Policy” scores of Between 1 to 3 years and “Planning for (Lot or Batch) sizes Policy” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2230.000, p = .682).

From this data on “Equipment, Machine & Technology”, the results suggest that there is no statistically significant difference between the underlying distributions of “Equipment, Machine & Technology” scores of Between 1 to 3 years and “Equipment, Machine & Technology” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2204.000, p = .582).

From this data on “Layout Strategy for Operation Management”, the results suggest that there is no statistically significant difference between the underlying distributions of “Layout Strategy for Operation Management” scores of Between 1 to 3 years and “Layout Strategy for Operation Management” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (*U* = 2311.000, *p* = .941).

NPar Tests

Mann-Whitney Test

Ranks

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	Between 1 To 3 years	122	81.39	9930.00
	More than 3 years	38	77.63	2950.00
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	Between 1 To 3 years	122	79.33	9678.50
	More than 3 years	38	84.25	3201.50
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	Between 1 To 3 years	122	81.51	9944.50
	More than 3 years	38	77.25	2935.50
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]	Between 1 To 3 years	122	79.83	9739.00
	More than 3 years	38	82.66	3141.00
	Total	160		
9. Which of the following factors, in your opinion, have great impact on	Between 1 To 3 years	122	79.96	9755.50
	More than 3 years	38	82.22	3124.50

Ranks

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	Between 1 To 3 years	122	81.18	9903.50
	More than 3 years	38	78.33	2976.50
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	Between 1 To 3 years	122	80.90	9870.00
	More than 3 years	38	79.21	3010.00
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	Between 1 To 3 years	122	82.69	10088.50
	More than 3 years	38	73.46	2791.50
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	Between 1 To 3 years	122	81.72	9970.00
	More than 3 years	38	76.58	2910.00
	Total	160		
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]	Between 1 To 3 years	122	82.74	10094.00
	More than 3 years	38	73.32	2786.00
	Total	160		

Test Statistics[a]

	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]
Mann-Whitney U	2209.000	2175.500	2194.500	2236.000
Wilcoxon W	2950.000	9678.500	2935.500	9739.000
Z	-.547	-.632	-.541	-.347
Asymp. Sig. (2-tailed)	.584	.527	.588	.728

Test Statisticsa

	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]
Mann-Whitney U	2252.500	2235.500	2269.000	2050.500
Wilcoxon W	9755.500	2976.500	3010.000	2791.500
Z	-.272	-.351	-.217	-1.195
Asymp. Sig. (2-tailed)	.785	.726	.828	.232

Test Statistics[a]

	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]
Mann-Whitney U	2169.000	2045.000
Wilcoxon W	2910.000	2786.000
Z	-.632	-1.211
Asymp. Sig. (2-tailed)	.527	.226

a. Grouping Variable: 1. How long you have been working within your organization?

From this data on “Process Time (Run time)”, the results suggest that there is no statistically significant difference between the underlying distributions of “Process Time (Run time)” scores of Between 1 to 3 years and “Process Time (Run time)” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2209.000, p = .584).

From this data on “Setup Time”, the results suggest that there is no statistically significant difference between the underlying distributions of “Setup Time” scores of Between 1 to 3 years and “Setup Time” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2175.500, p = .527).

From this data on “Batch Sizes”, the results suggest that there is no statistically significant difference between the underlying distributions of “Batch Sizes” scores of Between 1 to 3 years and “Batch Sizes” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2194.500, p = .588).

From this data on “Time Utilisation”, the results suggest that there is no statistically significant difference between the underlying distributions of “Time Utilisation” scores of Between 1 to 3 years and “Time Utilisation” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2236.000, p = .728).

From this data on “Waiting Time”, the results suggest that there is no statistically significant difference between the underlying distributions of “Waiting Time” scores of Between 1 to 3 years and “Waiting Time” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2252.500, p = .785).

From this data on “Less Machine downtime”, the results suggest that there is no statistically significant difference between the underlying distributions of “Less Machine downtime” scores of Between 1 to 3 years and “Less Machine downtime” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2235.500, p = .726).

From this data on “Move Time”, the results suggest that there is no statistically significant difference between the underlying distributions of “Move Time” scores of Between 1 to 3 years and “Move Time” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2269.000, p = .828).

From this data on “Maintenance”, the results suggest that there is no statistically significant difference between the underlying distributions of “Maintenance” scores of Between 1 to 3 years and “Maintenance” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2050.500, p = .232).

From this data on “Supplies raw material”, the results suggest that there is no statistically significant difference between the underlying distributions of “Supplies raw material” scores of Between 1 to 3 years and “Supplies raw material” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2169.000, p = .527).

From this data on “Reducing Job Overlapping”, the results suggest that there is no statistically significant difference between the underlying distributions of “Reducing Job Overlapping” scores of Between 1 to 3 years and “Reducing Job Overlapping” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2045.000, p = .226).

Mann-Whitney Test

Ranks

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
12. Which of the following solutions would improve the reduction of the lead time in your company? [Improve Company Procedures]	Between 1 To 3 years	122	76.43	9324.00
	More than 3 years	38	93.58	3556.00
	Total	160		
12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt One-piece Flow Production]	Between 1 To 3 years	122	77.68	9477.50
	More than 3 years	38	89.54	3402.50
	Total	160		
12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Working stations Capacity]	Between 1 To 3 years	122	77.60	9467.00
	More than 3 years	38	89.82	3413.00
	Total	160		
12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt group Technology]	Between 1 To 3 years	122	80.21	9785.50
	More than 3 years	38	81.43	3094.50
	Total	160		
12. Which of the following solutions would improve the reduction of the lead time in your company? [Optimization of the Current Factory Layout & Strategy]	Between 1 To 3 years	122	78.66	9597.00
	More than 3 years	38	86.39	3283.00
	Total	160		
12. Which of the following solutions would improve the reduction of the lead time in your company? [Justified Batch Sizes]	Between 1 To 3 years	122	80.61	9834.50
	More than 3 years	38	80.14	3045.50
	Total	160		
12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Production Control, Scheduling]	Between 1 To 3 years	122	79.17	9659.00
	More than 3 years	38	84.76	3221.00
	Total	160		

Ranks

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
12. Which of the following solutions would improve the reduction of the lead time in your company? [Purchase Equipment with Shorter Setup Time]	Between 1 To 3 years	122	80.58	9830.50
	More than 3 years	38	80.25	3049.50
	Total	160		

Test Statistics[a]

	12. Which of the following solutions would improve the reduction of the lead time in your company? [Improve Company Procedures]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt One-piece Flow Production]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Working stations Capacity]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Adopt group Technology]
Mann-Whitney U	1821.000	1974.500	1964.000	2282.500
Wilcoxon W	9324.000	9477.500	9467.000	9785.500
Z	-2.158	-1.708	-1.621	-.168
Asymp. Sig. (2-tailed)	.031	.088	.105	.866

Test Statistics[a,b]

	12. Which of the following solutions would improve the reduction of the lead time in your company? [Optimization of the Current Factory Layout & Strategy]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Justified Batch Sizes]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Increase Production Control, Scheduling]	12. Which of the following solutions would improve the reduction of the lead time in your company? [Purchase Equipment with Shorter Setup Time]
Mann-Whitney U	2094.000	2304.500	2156.000	2308.500
Wilcoxon W	9597.000	3045.500	9659.000	3049.500
Z	-1.728	-.066	-.921	-.041
Asymp. Sig. (2-tailed)	.084	.947	.357	.968

a. Grouping Variable: 1. How long you have been working within your organization?

From this data on “Improve Company Procedures”, the results suggest that there is statistically significant difference between the underlying distributions of “Improve Company Procedures” scores of Between 1 to 3 years and “Improve Company Procedures” scores of More than 3 years. It can be concluded that between 1 to 3 years are statistically significantly higher than the More than 3 years (U = 1821.000, p = .031).

From this data on “Adopt One-piece Flow Production”, the results suggest that there is no statistically significant difference between the underlying distributions of “Adopt One-piece Flow Production” scores of Between 1 to 3 years and “Adopt One-piece Flow Production” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 1974.500, p = .088).

From this data on “Increase Working stations Capacity”, the results suggest that there is no statistically significant difference between the underlying distributions of “Increase Working stations Capacity” scores of Between 1 to 3 years and “Increase Working stations Capacity” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 1964.000, p = .105).

From this data on “Adopt group Technology”, the results suggest that there is no statistically significant difference between the underlying distributions of “Adopt group Technology” scores of Between 1 to 3 years and “Adopt group Technology” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2282.500, p = .866).

From this data on “Optimization of the Current Factory Layout & Strategy”, the results suggest that there is no statistically significant difference between the underlying distributions of “Optimization of the Current Factory Layout & Strategy” scores of Between 1 to 3 years and “Optimization of the Current Factory Layout & Strategy” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2094.000, p = .084).

From this data on “Justified Batch Sizes”, the results suggest that there is no statistically significant difference between the underlying distributions of “Justified Batch Sizes” scores of Between 1 to 3 years and “Justified Batch Sizes” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2304.500, p = .947).

From this data on “Increase Production Control, Scheduling”, the results suggest that there is no statistically significant difference between the underlying distributions of “Increase Production Control, Scheduling” scores of Between 1 to 3 years and “Increase Production Control, Scheduling” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2156.000, p = .357).

From this data on “Purchase Equipment with Shorter Setup Time”, the results suggest that there is no statistically significant difference between the underlying distributions of “Purchase Equipment with Shorter Setup Time” scores of Between 1 to 3 years and “Purchase Equipment with Shorter Setup Time” scores of More than 3 years. It can be concluded that between 1 to 3 years are not statistically significantly higher than the More than 3 years (U = 2308.500, p = .968).

NPar Tests

Mann-Whitney Test

	1. How long you have been working within your organization?	N	Mean Rank	Sum of Ranks
16. How, overall, would you rate your company for the job organisation?	Between 1 To 3 years	122	87.99	10734.50
	More than 3 years	38	56.46	2145.50
	Total	160		

Test Statistics[a]

	16. How, overall, would you rate your company for the job organisation?
Mann-Whitney U	1404.500
Wilcoxon W	2145.500
Z	-4.022
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: 1. How long you have been working within your organization?

From this data on “How, overall, would you rate your company for the job organisation”, the results suggest that there is statistically significant difference between the underlying distributions of “How, overall, would you rate your company for the job organisation” scores of Between 1 to 3 years and “How, overall, would you rate your company for the job organisation” scores of More than 3 years. It can be concluded that between 1 to 3 years are statistically significantly higher than the More than 3 years (U = 1404.500, p = .000).

Appendix6: Crosstabs (Chi-Square Tests) of survey MLT

Crosstabs (Chi-Square Tests)

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]		Total
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	10	3	13
		% of Total	6.3%	1.9%	8.1%
	3	Count	28	44	72
		% of Total	17.5%	27.5%	45.0%
	4	Count	11	61	72
		% of Total	6.9%	38.1%	45.0%
	Great impact	Count	0	3	3
		% of Total	0.0%	1.9%	1.9%
Total		Count	49	111	160
		% of Total	30.6%	69.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.736[a]	3	.000
Likelihood Ratio	25.309	3	.000
Linear-by-Linear Association	23.683	1	.000
N of Valid Cases	160		

a. 3 cells (37.5%) have expected count less than 5. The minimum count is.

Null hypothesis (H0): There is no association between Setup Time and Process Time (Run time). Alternative hypothesis (H1): There is an association between Setup Time and Process Time (Run time). The cross-tabulation indicate that there is statistically significant association between Setup Time and Process Time (Run time) (Pearson chi-square with 3 degree of freedom = 24.736, p = 0.000). This result indicates that there is statistically significant association between Setup Time and Process Time (Run time); that is, all the Setup Time do not equally have same Process Time (Run time). We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	1	2
		% of Total	0.6%	1.3%
	4	Count	0	0
		% of Total	0.0%	0.0%
	Great impact	Count	0	0
		% of Total	0.0%	0.0%
Total		Count	1	3
		% of Total	0.6%	1.9%

Crosstab

			[Batch Sizes]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	10	2
		% of Total	6.3%	1.3%
	3	Count	29	34
		% of Total	18.1%	21.3%

	4	Count	13	42
		% of Total	8.1%	26.3%
	Great impact	Count	0	2
		% of Total	0.0%	1.3%
Total		Count	52	80
		% of Total	32.5%	50.0%

Crosstab

			[Batch Sizes]	Total
			Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	13
		% of Total	0.0%	8.1%
	3	Count	6	72
		% of Total	3.8%	45.0%
	4	Count	17	72
		% of Total	10.6%	45.0%
	Great impact	Count	1	3
		% of Total	0.6%	1.9%
Total		Count	24	160
		% of Total	15.0%	100.0%

Chi-Square Tests

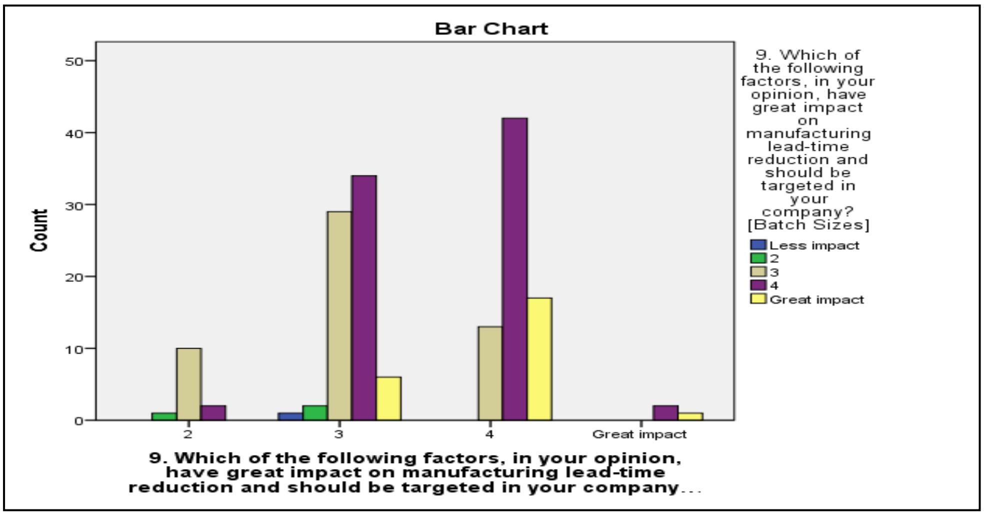
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	32.827[a]	12	.001
Likelihood Ratio	35.852	12	.000
Linear-by-Linear Association	27.785	1	.000
N of Valid Cases	160		

a. 13 cells (65.0%) have expected count less than 5. The minimum expected count is .02.

Null hypothesis (H0): There is no association between Setup Time and Batch Sizes.

Alternative hypothesis (H1): There is an association between Setup Time and Batch Sizes.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Batch Sizes (Pearson chi-square with 12 degree of freedom = 32.827, p = 0.001). This result indicates that there is statistically significant association between Setup Time and Batch Sizes; that is, all the Setup Time do not equally have same Batch Sizes. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	6	7
		% of Total	3.8%	4.4%
	3	Count	21	34
		% of Total	13.1%	21.3%
	4	Count	3	25
		% of Total	1.9%	15.6%
	Great impact	Count	0	1
		% of Total	0.0%	0.6%
Total		Count	30	67
		% of Total	18.8%	41.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	0	13
		% of Total	0.0%	0.0%	8.1%
	3	Count	13	4	72
		% of Total	8.1%	2.5%	45.0%
	4	Count	31	13	72
		% of Total	19.4%	8.1%	45.0%
	Great impact	Count	1	1	3
		% of Total	0.6%	0.6%	1.9%
Total		Count	45	18	160
		% of Total	28.1%	11.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	39.761[a]	9	.000
Likelihood Ratio	46.258	9	.000
Linear-by-Linear Association	35.322	1	.000
N of Valid Cases	160		

a. 7 cells (43.8%) have expected count less than 5. The minimum expected count is .34.

Null hypothesis (H0): There is no association between Setup Time and Time Utilisation.

Alternative hypothesis (H1): There is an association between Setup Time and Time Utilisation.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Time Utilisation (Pearson chi-square with 9 degree of freedom = 39.761, p = 0.000). This result indicates that there is statistically significant association between Setup Time and Time Utilisation; that is, all the Setup Time do not equally have same Time Utilisation. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.] 2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	12	1
		% of Total	7.5%	0.6%
	3	Count	29	23
		% of Total	18.1%	14.4%
	4	Count	2	11
		% of Total	1.3%	6.9%
	Great impact	Count	0	0
		% of Total	0.0%	0.0%
Total		Count	43	35
		% of Total	26.9%	21.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.] 4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	0	13
		% of Total	0.0%	0.0%	8.1%
	3	Count	12	8	72
		% of Total	7.5%	5.0%	45.0%
	4	Count	38	21	72
		% of Total	23.8%	13.1%	45.0%
	Great impact	Count	2	1	3
		% of Total	1.3%	0.6%	1.9%
Total		Count	52	30	160
		% of Total	32.5%	18.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	77.658[a]	9	.000
Likelihood Ratio	86.464	9	.000
Linear-by-Linear Association	59.524	1	.000
N of Valid Cases	160		

a. 8 cells (50.0%) have expected count less than 5. The minimum expected count is .56.

Null hypothesis (H0): There is no association between Setup Time and Waiting Time.

Alternative hypothesis (H1): There is an association between Setup Time and Waiting Time.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Waiting Time (Pearson chi-square with 9 degree of freedom = 77.658, p = 0.000). This result indicates that there is statistically significant association between Setup Time and Waiting Time; that is, all the Setup Time do not equally have same Waiting Time. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	11
		% of Total	0.0%	6.9%
	3	Count	2	38
		% of Total	1.3%	23.8%
	4	Count	12	16
		% of Total	7.5%	10.0%
	Great impact	Count	2	0
		% of Total	1.3%	0.0%
Total		Count	16	65
		% of Total	10.0%	40.6%

Crosstab

			[Less Machine downtime]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	2	0
		% of Total	1.3%	0.0%
	3	Count	21	10
		% of Total	13.1%	6.3%
	4	Count	31	12
		% of Total	19.4%	7.5%
	Great impact	Count	1	0
		% of Total	0.6%	0.0%
Total		Count	55	22
		% of Total	34.4%	13.8%

Crosstab

			[Less Machine downtime]	
			Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	13
		% of Total	0.0%	8.1%
	3	Count	1	72
		% of Total	0.6%	45.0%
	4	Count	1	72
		% of Total	0.6%	45.0%
	Great impact	Count	0	3
		% of Total	0.0%	1.9%
Total		Count	2	160
		% of Total	1.3%	100.0%

Chi-Square Tests

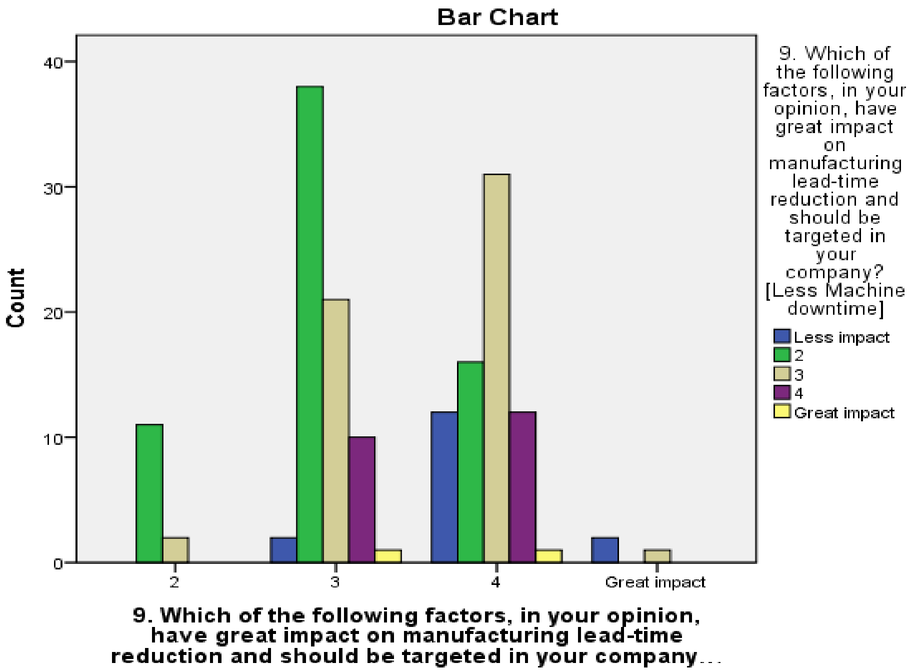
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	40.300[a]	12	.000
Likelihood Ratio	40.472	12	.000
Linear-by-Linear Association	.603	1	.437
N of Valid Cases	160		

a. 11 cells (55.0%) have expected count less than 5. The minimum expected count is .04.

Null hypothesis (H0): There is no association between Setup Time and Less Machine downtime.

Alternative hypothesis (H1): There is an association between Setup Time and Less Machine downtime.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Less Machine downtime (Pearson chi-square with 12 degree of freedom = 40.300, p = 0.000). This result indicates that there is statistically significant association between Setup Time and Less Machine downtime; that is, all the Setup Time do not equally have same Less Machine downtime. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	
			2	3
9. Which of the following factors, in your opinion, have great impact on	2	Count	1	0
		% of Total	0.6%	0.0%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	
			2	3
manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	3	Count	0	9
		% of Total	0.0%	5.6%
	4	Count	1	6
		% of Total	0.6%	3.8%
	Great impact	Count	0	0
		% of Total	0.0%	0.0%
Total		Count	2	15
		% of Total	1.3%	9.4%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	10	2	13
		% of Total	6.3%	1.3%	8.1%
	3	Count	32	31	72
		% of Total	20.0%	19.4%	45.0%
	4	Count	23	42	72
		% of Total	14.4%	26.3%	45.0%
	Great impact	Count	0	3	3
		% of Total	0.0%	1.9%	1.9%
Total		Count	65	78	160
		% of Total	40.6%	48.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.048[a]	9	.012
Likelihood Ratio	22.143	9	.008
Linear-by-Linear Association	7.305	1	.007
N of Valid Cases	160		

a. 8 cells (50.0%) have expected count less than 5. The minimum expected count is .04.

Null hypothesis (H0): There is no association between Setup Time and Move Time.

Alternative hypothesis (H1): There is an association between Setup Time and Move Time.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Move Time (Pearson chi-square with 12 degree of freedom = 21.048, p = 0.012). This result indicates that there is statistically significant association between Setup Time and Move Time; that is, all the Setup Time do not equally have same Move Time. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	12
		% of Total	0.0%	7.5%
	3	Count	6	35
		% of Total	3.8%	21.9%
	4	Count	18	42
		% of Total	11.3%	26.3%
	Great impact	Count	1	2
		% of Total	0.6%	1.3%
Total		Count	25	91
		% of Total	15.6%	56.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	21	9
		% of Total	13.1%	5.6%
	4	Count	8	4
		% of Total	5.0%	2.5%
	Great impact	Count	0	0
		% of Total	0.0%	0.0%
Total		Count	29	14
		% of Total	18.1%	8.8%

Crosstab

			[Maintenance]	
			Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	13
		% of Total	0.0%	8.1%
	3	Count	1	72
		% of Total	0.6%	45.0%
	4	Count	0	72
		% of Total	0.0%	45.0%
	Great impact	Count	0	3
		% of Total	0.0%	1.9%
Total		Count	1	160
		% of Total	0.6%	100.0%

Chi-Square Tests

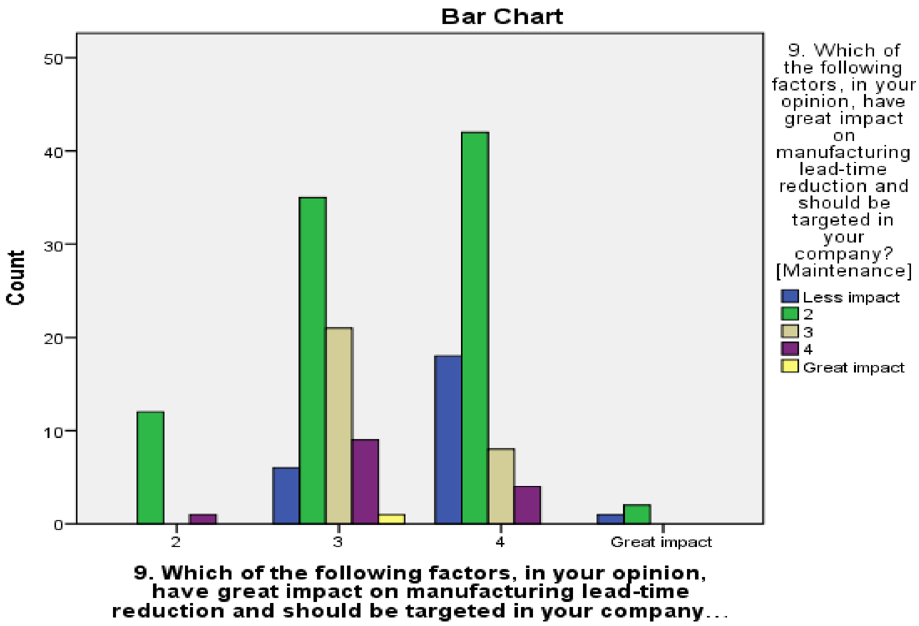
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	26.141[a]	12	.010
Likelihood Ratio	30.563	12	.002
Linear-by-Linear Association	8.269	1	.004
N of Valid Cases	160		

a. 11 cells (55.0%) have expected count less than 5. The minimum expected count is .02.

Null hypothesis (H0): There is no association between Setup Time and Maintenance.

Alternative hypothesis (H1): There is an association between Setup Time and Maintenance.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Maintenance (Pearson chi-square with 12 degree of freedom = 26.141, p = 0.010). This result indicates that there is statistically significant association between Setup Time and Maintenance; that is, all the Setup Time do not equally have same Maintenance. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	1	10
		% of Total	0.6%	6.3%
	3	Count	25	20
		% of Total	15.6%	12.5%
	4	Count	33	27
		% of Total	20.6%	16.9%
	Great impact	Count	3	0
		% of Total	1.9%	0.0%
Total		Count	62	57
		% of Total	38.8%	35.6%

Crosstab

			[Supplies raw material]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	15	10
		% of Total	9.4%	6.3%
	4	Count	8	2
		% of Total	5.0%	1.3%
	Great impact	Count	0	0
		% of Total	0.0%	0.0%
Total		Count	23	13
		% of Total	14.4%	8.1%

Crosstab

			[Supplies raw material] Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	1	13
		% of Total	0.6%	8.1%
	3	Count	2	72
		% of Total	1.3%	45.0%
	4	Count	2	72
		% of Total	1.3%	45.0%
	Great impact	Count	0	3
		% of Total	0.0%	1.9%
Total		Count	5	160
		% of Total	3.1%	100.0%

Chi-Square Tests

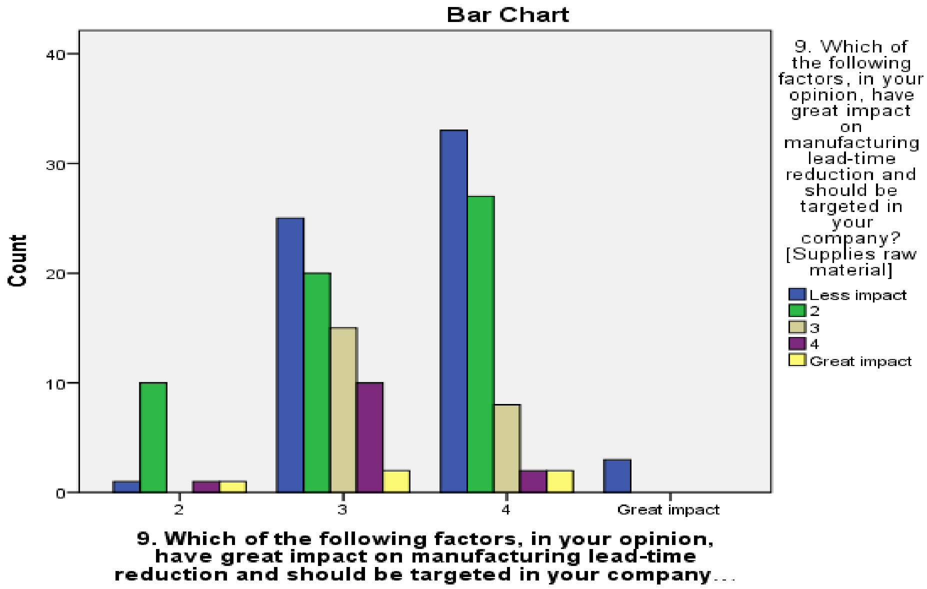
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.646[a]	12	.006
Likelihood Ratio	30.450	12	.002
Linear-by-Linear Association	8.247	1	.004
N of Valid Cases	160		

a. 11 cells (55.0%) have expected count less than 5. The minimum expected count is .09.

Null hypothesis (H0): There is no association between Setup Time and Supplies raw material.

Alternative hypothesis (H1): There is an association between Setup Time and Supplies raw material.

The cross-tabulation indicate that there is statistically significant association between Setup Time and Supplies raw material (Pearson chi-square with 12 degree of freedom = 27.646, p = 0.006). This result indicates that there is statistically significant association between Setup Time and Supplies raw material; that is, all the Setup Time do not equally have same Supplies raw material. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	0	9
		% of Total	0.0%	5.6%
	3	Count	6	30
		% of Total	3.8%	18.8%
	4	Count	5	39
		% of Total	3.1%	24.4%
	Great impact	Count	0	3
		% of Total	0.0%	1.9%
Total		Count	11	81
		% of Total	6.9%	50.6%

Crosstab

			? [Reducing Job Overlapping]		
			3	4	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	2	Count	4	0	13
		% of Total	2.5%	0.0%	8.1%
	3	Count	32	4	72
		% of Total	20.0%	2.5%	45.0%
	4	Count	24	4	72
		% of Total	15.0%	2.5%	45.0%
	Great impact	Count	0	0	3
		% of Total	0.0%	0.0%	1.9%
Total		Count	60	8	160
		% of Total	37.5%	5.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	8.407[a]	9	.494
Likelihood Ratio	11.040	9	.273
Linear-by-Linear Association	.341	1	.559

Null hypothesis (H0): There is no association between Setup Time and Reducing Job Overlapping.

Alternative hypothesis (H1): There is an association between Setup Time and Reducing Job Overlapping.

The cross-tabulation indicate that there is no statistically significant association between Setup Time and Reducing Job Overlapping (Pearson chi-square with 9 degree of freedom = 8.407, p = 0.494). This result indicates that there is no statistically significant association between Setup Time and Reducing Job Overlapping; that is, all the Setup Time do equally have same Reducing Job Overlapping. We accept null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	0	3
		% of Total	0.0%	1.9%
	Great impact	Count	1	0
		% of Total	0.6%	0.0%
Total		Count	1	3
		% of Total	0.6%	1.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	28	17
		% of Total	17.5%	10.6%
	Great impact	Count	24	63
		% of Total	15.0%	39.4%
Total		Count	52	80
		% of Total	32.5%	50.0%

Crosstab

			[Batch Sizes] Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	1	49
		% of Total	0.6%	30.6%
	Great impact	Count	23	111
		% of Total	14.4%	69.4%
Total		Count	24	160
		% of Total	15.0%	100.0%

Chi-Square Tests

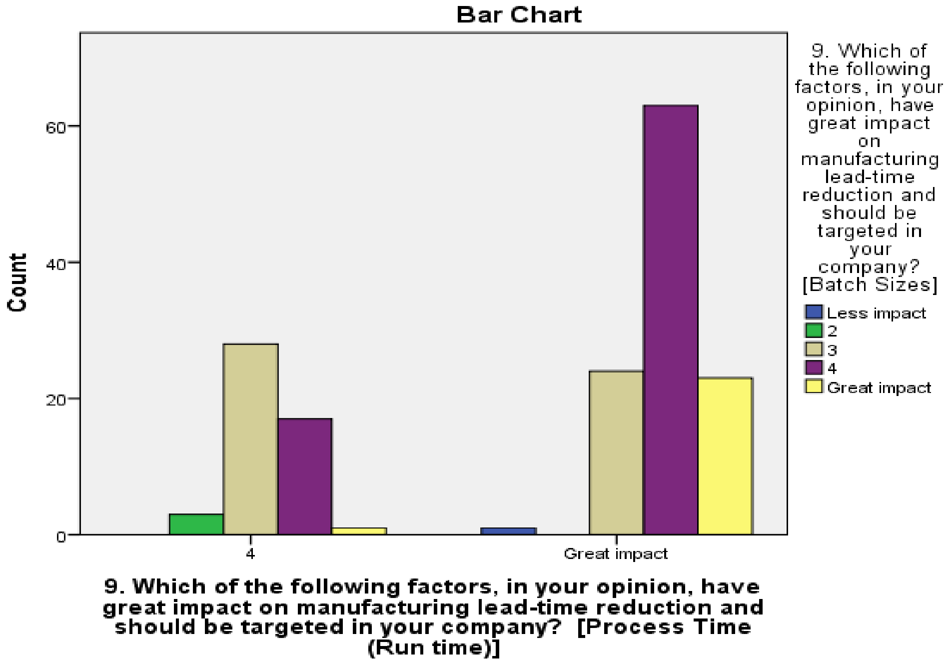
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	31.652[a]	4	.000
Likelihood Ratio	34.288	4	.000
Linear-by-Linear Association	24.831	1	.000
N of Valid Cases	160		

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is .31.

Null hypothesis (H0): There is no association between Process Time (Run time) and Batch Sizes.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Batch Sizes.

The cross-tabulation indicate that there is statistically significant association between Process Time (Run time) and Batch Sizes (Pearson chi-square with 4 degree of freedom = 31.652, p = 0.000). This result indicates that there is statistically significant association between Process Time (Run time) and Batch Sizes; that is, all the Process Time (Run time) do not equally have same Batch Sizes. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	18	23
		% of Total	11.3%	14.4%
	Great impact	Count	12	44
		% of Total	7.5%	27.5%
Total		Count	30	67
		% of Total	18.8%	41.9%

Crosstab

			[Time Utilisation]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	8	0	49
		% of Total	5.0%	0.0%	30.6%
	Great impact	Count	37	18	111
		% of Total	23.1%	11.3%	69.4%
Total		Count	45	18	160
		% of Total	28.1%	11.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.059[a]	3	.000
Likelihood Ratio	28.453	3	.000
Linear-by-Linear Association	23.480	1	.000
N of Valid Cases	160		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.51

Null hypothesis (H0): There is no association between Process Time (Run time) and Time Utilisation.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Time Utilisation.

The cross-tabulation indicate that there is statistically significant association between Process Time (Run time) and Time Utilisation (Pearson chi-square with 3 degree of freedom = 24.059, p = 0.000). This result indicates that there is statistically significant association between Process Time (Run time) and Time Utilisation; that is, all the Process Time (Run time) do not equally have same Time Utilisation. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	25	13
		% of Total	15.6%	8.1%
	Great impact	Count	18	22
		% of Total	11.3%	13.8%
Total		Count	43	35
		% of Total	26.9%	21.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	8	3	49
		% of Total	5.0%	1.9%	30.6%
	Great impact	Count	44	27	111
		% of Total	27.5%	16.9%	69.4%
Total		Count	52	30	160
		% of Total	32.5%	18.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	27.713[a]	3	.000
Likelihood Ratio	28.341	3	.000
Linear-by-Linear Association	26.068	1	.000
N of Valid Cases	160		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 9.19.

Null hypothesis (H0): There is no association between Process Time (Run time) and Waiting Time.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Waiting Time.

The cross-tabulation indicate that there is statistically significant association between Process Time (Run time) and Waiting Time (Pearson chi-square with 3 degree of freedom = 27.713, p = 0.000). This result indicates that there is statistically significant association between Process Time (Run time) and Waiting Time; that is, all the Process Time (Run time) do not equally have same Waiting Time. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	6	27
		% of Total	3.8%	16.9%
	Great impact	Count	10	38
		% of Total	6.3%	23.8%
Total		Count	16	65
		% of Total	10.0%	40.6%

Crosstab

			? [Less Machine downtime]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	15	1
		% of Total	9.4%	0.6%
	Great impact	Count	40	21
		% of Total	25.0%	13.1%
Total		Count	55	22
		% of Total	34.4%	13.8%

Crosstab

			[Less Machine downtime]	Total
			Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	0	49
		% of Total	0.0%	30.6%
	Great impact	Count	2	111
		% of Total	1.3%	69.4%
Total		Count	2	160
		% of Total	1.3%	100.0%

Chi-Square Tests

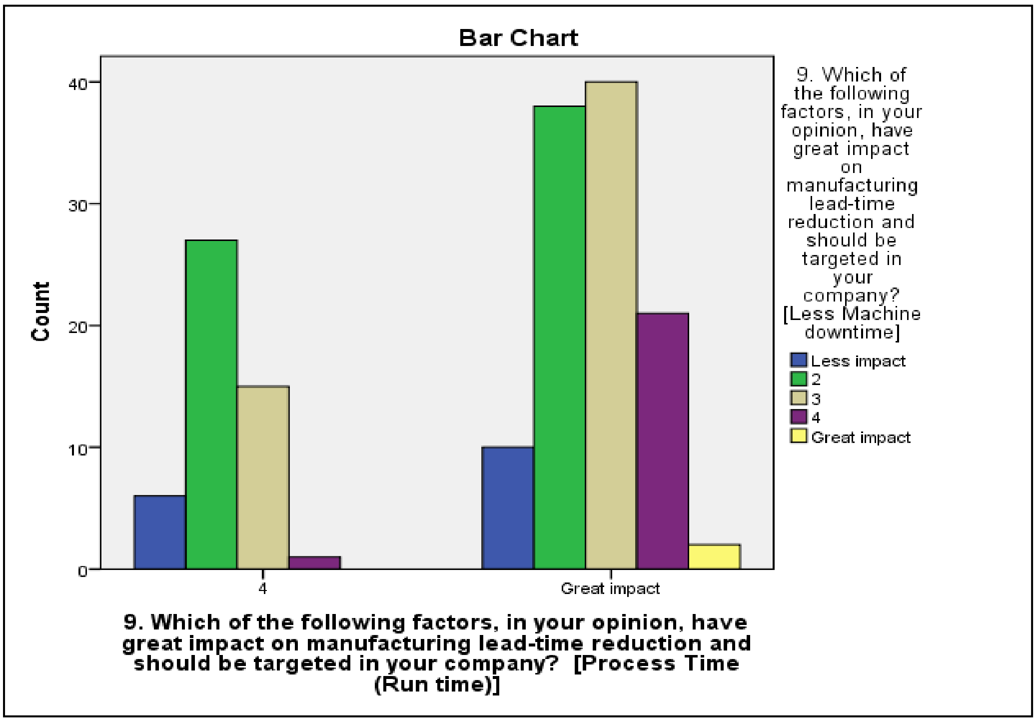
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.216[a]	4	.016
Likelihood Ratio	15.142	4	.004
Linear-by-Linear Association	9.695	1	.002
N of Valid Cases	160		

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is .61.

Null hypothesis (H0): There is no association between Process Time (Run time) and Less Machine downtime.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Less Machine downtime.

The cross-tabulation indicate that there is statistically significant association between Process Time (Run time) and Less Machine downtime (Pearson chi-square with 3 degree of freedom = 12.216, p = 0.016). This result indicates that there is statistically significant association between Process Time (Run time) and Less Machine downtime; that is, all the Process Time (Run time) do not equally have same Less Machine downtime. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	0	11
		% of Total	0.0%	6.9%
	Great impact	Count	2	4
		% of Total	1.3%	2.5%
Total		Count	2	15
		% of Total	1.3%	9.4%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	20	18	49
		% of Total	12.5%	11.3%	30.6%
	Great impact	Count	45	60	111
		% of Total	28.1%	37.5%	69.4%
Total		Count	65	78	160
		% of Total	40.6%	48.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.853[a]	3	.001
Likelihood Ratio	15.231	3	.002
Linear-by-Linear Association	7.232	1	.007
N of Valid Cases	160		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is .61.

Null hypothesis (H0): There is no association between Process Time (Run time) and Move Time.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Move Time.

The cross-tabulation indicate that there is statistically significant association between Process Time (Run time) and Move Time (Pearson chi-square with 3 degree of freedom = 15.853, p = 0.001). This result indicates that there is statistically significant association between Process Time (Run time) and Move Time; that is, all the Process Time (Run time) do not equally have same Move Time. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	6	24
		% of Total	3.8%	15.0%
	Great impact	Count	19	67
		% of Total	11.9%	41.9%
Total		Count	25	91
		% of Total	15.6%	56.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	15	4
		% of Total	9.4%	2.5%
	Great impact	Count	14	10
		% of Total	8.8%	6.3%
Total		Count	29	14
		% of Total	18.1%	8.8%

Crosstab

			[Maintenance]	
			Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	0	49
		% of Total	0.0%	30.6%
	Great impact	Count	1	111
		% of Total	0.6%	69.4%
Total		Count	1	160
		% of Total	0.6%	100.0%

Chi-Square Tests

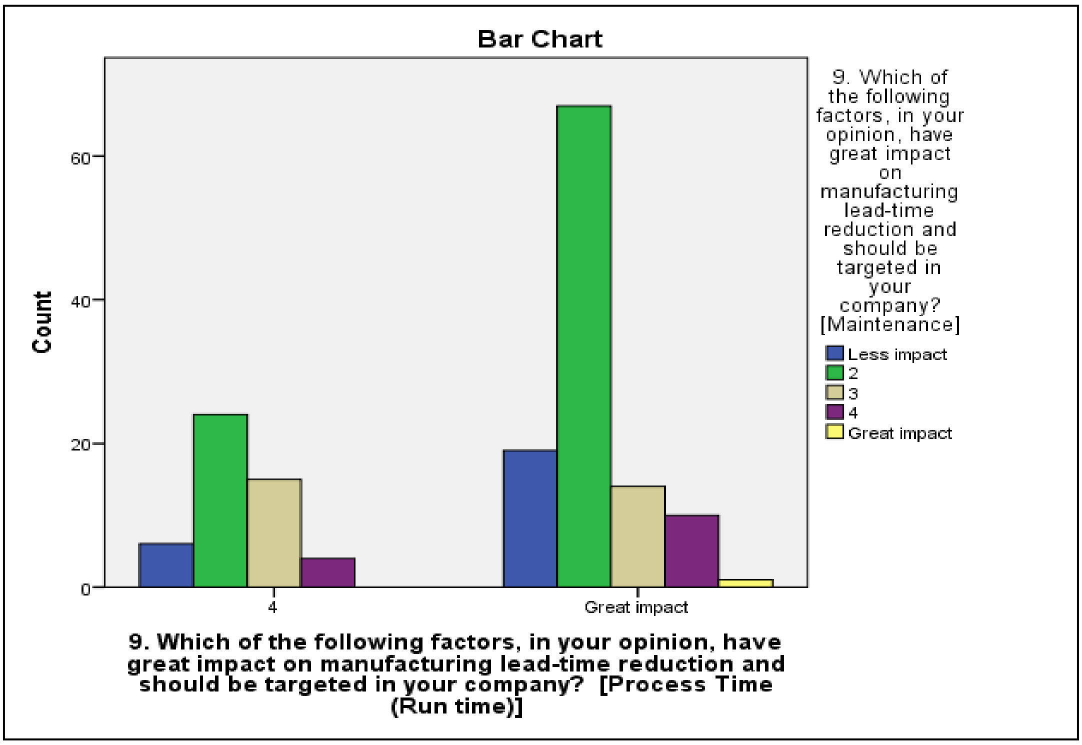
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.836[a]	4	.098
Likelihood Ratio	7.667	4	.105
Linear-by-Linear Association	1.657	1	.198
N of Valid Cases	160		

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is .31.

Null hypothesis (H0): There is no association between Process Time (Run time) and Maintenance.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Maintenance.

The cross-tabulation indicate that there is no statistically significant association between Process Time (Run time) and Maintenance (Pearson chi-square with 4 degree of freedom = 7.836, p = 0.098). This result indicates that there is no statistically significant association between Process Time (Run time) and Maintenance; that is, all the Process Time (Run time) do equally have same Maintenance. We accept null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	15	18
		% of Total	9.4%	11.3%
	Great impact	Count	47	39
		% of Total	29.4%	24.4%
Total		Count	62	57
		% of Total	38.8%	35.6%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	11	4
		% of Total	6.9%	2.5%
	Great impact	Count	12	9
		% of Total	7.5%	5.6%
Total		Count	23	13
		% of Total	14.4%	8.1%

Crosstab

			[Supplies raw material]	Total
			Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	1	49
		% of Total	0.6%	30.6%
	Great impact	Count	4	111
		% of Total	2.5%	69.4%
Total		Count	5	160
		% of Total	3.1%	100.0%

Chi-Square Tests

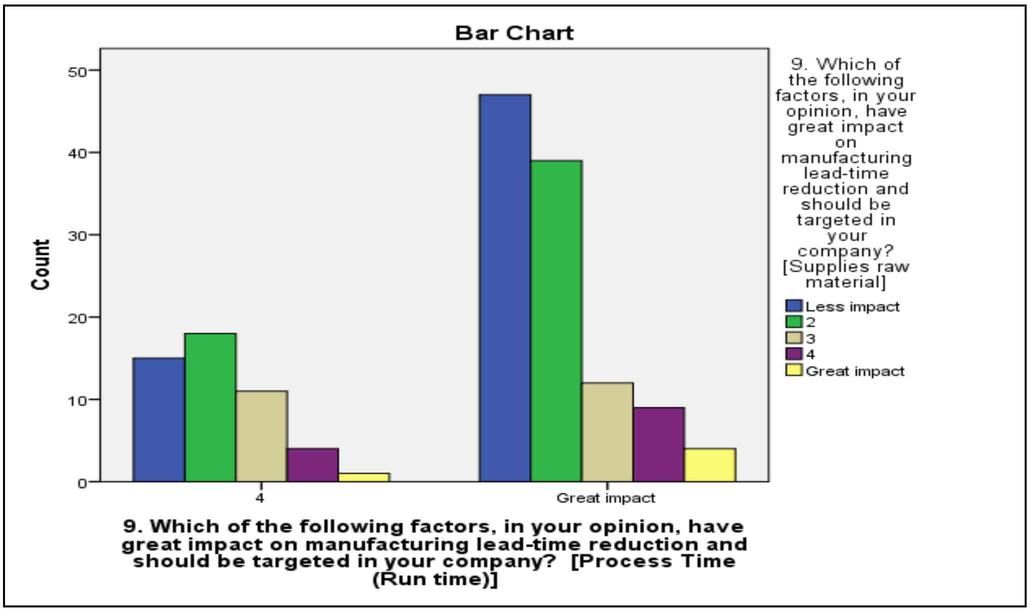
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.700[a]	4	.319
Likelihood Ratio	4.542	4	.338
Linear-by-Linear Association	1.049	1	.306
N of Valid Cases	160		

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is 1.53.

Null hypothesis (H0): There is no association between Process Time (Run time) and Supplies raw material.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Supplies raw material.

The cross-tabulation indicate that there is no statistically significant association between Process Time (Run time) and Supplies raw material (Pearson chi-square with 4 degree of freedom = 4.700, p = 0.319). This result indicates that there is no statistically significant association between Process Time (Run time) and Supplies raw material; that is, all the Process Time (Run time) do equally have same Supplies raw material. We accept null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	3	24
		% of Total	1.9%	15.0%
	Great impact	Count	8	57
		% of Total	5.0%	35.6%
Total		Count	11	81
		% of Total	6.9%	50.6%

Crosstab

			[Reducing Job Overlapping]		
			3	4	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	19	3	49
		% of Total	11.9%	1.9%	30.6%
	Great impact	Count	41	5	111
		% of Total	25.6%	3.1%	69.4%
Total		Count	60	8	160
		% of Total	37.5%	5.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	.305[a]	3	.959
Likelihood Ratio	.299	3	.960
Linear-by-Linear Association	.268	1	.605
N of Valid Cases	160		

a. 2 cells (25.0%) have expected count less than 5. The minimum expected count is 2.45.

Null hypothesis (H0): There is no association between Process Time (Run time) and Reducing Job Overlapping.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Reducing Job Overlapping.

The cross-tabulation indicate that there is no statistically significant association between Process Time (Run time) and Reducing Job Overlapping (Pearson chi-square with 3 degree of freedom = 0.305, p = 0.959). This result indicates that there is no statistically significant association between Process Time (Run time) and Reducing Job Overlapping; that is, all the Process Time (Run time) do equally have same Reducing Job Overlapping. We accept null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]	4	Count	10	28
		% of Total	6.3%	17.5%
	Great impact	Count	3	44
		% of Total	1.9%	27.5%
Total		Count	13	72
		% of Total	8.1%	45.0%

Crosstab

			[Setup Time.]		
			4	Great impact	
(Run time)]	4	Count	11	0	49
		% of Total	6.9%	0.0%	30.6%
	Great impact	Count	61	3	111
		% of Total	38.1%	1.9%	69.4%
Total		Count	72	3	160
		% of Total	45.0%	1.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.736[a]	3	.000
Likelihood Ratio	25.309	3	.000
Linear-by-Linear Association	23.683	1	.000
N of Valid Cases	160		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is .92.
Null hypothesis (H0): There is no association between Process Time (Run time) and Setup Time.

Alternative hypothesis (H1): There is an association between Process Time (Run time) and Setup Time.

The cross-tabulation indicate that there is statistically significant association between Process Time (Run time) and Setup Time (Pearson chi-square with 3 degree of freedom = 24.736, p = 0.000). This result indicates that there is statistically significant association between Process Time (Run time) and Setup Time; that is, all the Process Time (Run time) do not equally have same Setup Time. We reject null hypothesis.

Crosstabs

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Batch Sizes]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	0
		% of Total	0.0%	0.0%
	3	Count	0	2
		% of Total	0.0%	1.3%
	4	Count	1	1
		% of Total	0.6%	0.6%
	Great impact	Count	0	0
		% of Total	0.0%	0.0%
Total		Count	1	3
		% of Total	0.6%	1.9%

Crosstab

			[Batch Sizes] 3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	8	4
		% of Total	5.0%	2.5%
	4	Count	28	29
		% of Total	17.5%	18.1%
	Great impact	Count	16	45
		% of Total	10.0%	28.1%
Total		Count	52	80
		% of Total	32.5%	50.0%

Crosstab

			[Batch Sizes] Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	1	15
		% of Total	0.6%	9.4%
	4	Count	6	65
		% of Total	3.8%	40.6%
	Great impact	Count	17	78
		% of Total	10.6%	48.8%
Total		Count	24	160
		% of Total	15.0%	100.0%

Chi-Square Tests

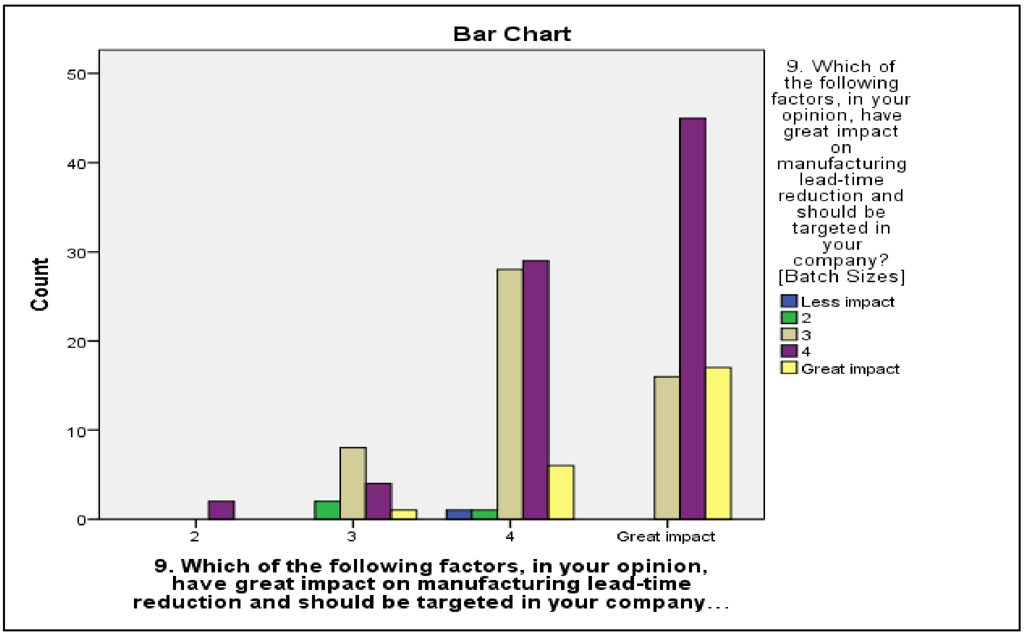
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	30.614[a]	12	.002
Likelihood Ratio	27.499	12	.007
Linear-by-Linear Association	14.919	1	.000
N of Valid Cases	160		

a. 13 cells (65.0%) have expected count less than 5. The minimum expected count is .01.

Null hypothesis (H0): There is no association between Move Time and Batch Sizes.

Alternative hypothesis (H1): There is an association between Move Time and Batch Sizes.

The cross-tabulation indicate that there is statistically significant association between Move Time and Batch Sizes (Pearson chi-square with 12 degree of freedom = 30.614, p = 0.002). This result indicates that there is statistically significant association between Move Time and Batch Sizes; that is, all the Move Time do not equally have same Batch Sizes. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	6	9
		% of Total	3.8%	5.6%
	4	Count	14	30
		% of Total	8.8%	18.8%
	Great impact	Count	10	27

your company? [Move Time]		% of Total	6.3%	16.9%
Total		Count	30	67
		% of Total	18.8%	41.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Time Utilisation]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	1	0	2
		% of Total	0.6%	0.0%	1.3%
	3	Count	0	0	15
		% of Total	0.0%	0.0%	9.4%
	4	Count	20	1	65
		% of Total	12.5%	0.6%	40.6%
	Great impact	Count	24	17	78
		% of Total	15.0%	10.6%	48.8%
Total		Count	45	18	160
		% of Total	28.1%	11.3%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	28.180[a]	9	.001
Likelihood Ratio	35.320	9	.000
Linear-by-Linear Association	16.909	1	.000
N of Valid Cases	160		

a. 7 cells (43.8%) have expected count less than 5. The minimum expected count is .23.

Null hypothesis (H0): There is no association between Move Time and Time Utilisation.

Alternative hypothesis (H1): There is an association between Move Time and Time Utilisation.

The cross-tabulation indicate that there is statistically significant association between Move Time and Time Utilisation (Pearson chi-square with 12 degree of freedom = 28.180, p = 0.001). This result indicates that there is statistically significant association between Move Time and Time Utilisation;

that is, all the Move Time do not equally have same Time Utilisation. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Waiting Time.]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	1	0
		% of Total	0.6%	0.0%
	3	Count	7	7
		% of Total	4.4%	4.4%
	4	Count	22	15
		% of Total	13.8%	9.4%
	Great impact	Count	13	13
		% of Total	8.1%	8.1%
Total		Count	43	35
		% of Total	26.9%	21.9%

Crosstab

			[Waiting Time.]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	1	0	2
		% of Total	0.6%	0.0%	1.3%
	3	Count	1	0	15
		% of Total	0.6%	0.0%	9.4%
	4	Count	23	5	65
		% of Total	14.4%	3.1%	40.6%
	Great impact	Count	27	25	78
		% of Total	16.9%	15.6%	48.8%
Total		Count	52	30	160
		% of Total	32.5%	18.8%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	30.775[a]	9	.000
Likelihood Ratio	34.742	9	.000
Linear-by-Linear Association	21.503	1	.000
N of Valid Cases	160		

a. 8 cells (50.0%) have expected count less than 5. The minimum expected count is .38.

Null hypothesis (H0): There is no association between Move Time and Waiting Time.

Alternative hypothesis (H1): There is an association between Move Time and Waiting Time.

The cross-tabulation indicate that there is statistically significant association between Move Time and Waiting Time (Pearson chi-square with 9 degree of freedom = 30.775, p = 0.000). This result indicates that there is statistically significant association between Move Time and Waiting Time; that is, all the Move Time do not equally have same Waiting Time. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	0	8
		% of Total	0.0%	5.0%
	4	Count	4	35
		% of Total	2.5%	21.9%
	Great impact	Count	12	20
		% of Total	7.5%	12.5%
Total		Count	16	65
		% of Total	10.0%	40.6%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]	
			[Less Machine downtime]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	0
		% of Total	0.0%	0.0%
	3	Count	5	2
		% of Total	3.1%	1.3%
	4	Count	21	3
		% of Total	13.1%	1.9%
	Great impact	Count	29	17
		% of Total	18.1%	10.6%
Total		Count	55	22
		% of Total	34.4%	13.8%

Crosstab

			[Less Machine downtime]	
			Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	0	15
		% of Total	0.0%	9.4%
	4	Count	2	65
		% of Total	1.3%	40.6%
	Great impact	Count	0	78
		% of Total	0.0%	48.8%
Total		Count	2	160
		% of Total	1.3%	100.0%

Crosstab

	9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Less Machine downtime]

Chi-Square Tests

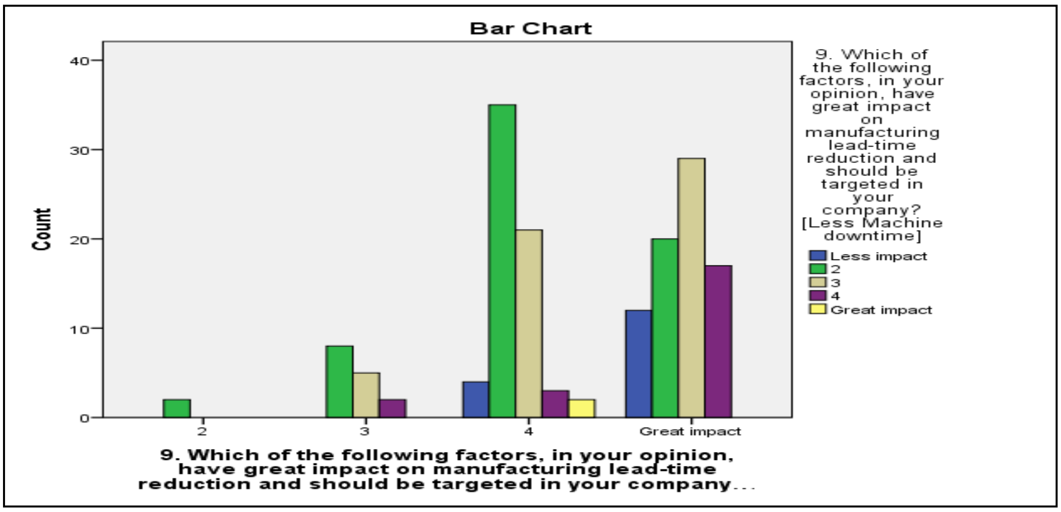
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	26.130[a]	12	.010
Likelihood Ratio	29.955	12	.003
Linear-by-Linear Association	1.327	1	.249
N of Valid Cases	160		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .03.

Null hypothesis (H0): There is no association between Move Time and Less Machine downtime.

Alternative hypothesis (H1): There is an association between Move Time and Less Machine downtime.

The cross-tabulation indicate that there is statistically significant association between Move Time and Less Machine downtime (Pearson chi-square with 12 degree of freedom = 26.130, p = 0.010). This result indicates that there is statistically significant association between Move Time and Less Machine downtime; that is, all the Move Time do not equally have same Less Machine downtime. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	0	3
		% of Total	0.0%	1.9%
	4	Count	8	36
		% of Total	5.0%	22.5%
	Great impact	Count	17	50
		% of Total	10.6%	31.3%
Total		Count	25	91
		% of Total	15.6%	56.9%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Maintenance]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	0
		% of Total	0.0%	0.0%
	3	Count	11	1
		% of Total	6.9%	0.6%
	4	Count	12	8
		% of Total	7.5%	5.0%
	Great impact	Count	6	5
		% of Total	3.8%	3.1%
Total		Count	29	14
		% of Total	18.1%	8.8%

Crosstab

			[Maintenance] Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	0	15
		% of Total	0.0%	9.4%
	4	Count	1	65
		% of Total	0.6%	40.6%
	Great impact	Count	0	78
		% of Total	0.0%	48.8%
Total		Count	1	160
		% of Total	0.6%	100.0%

Chi-Square Tests

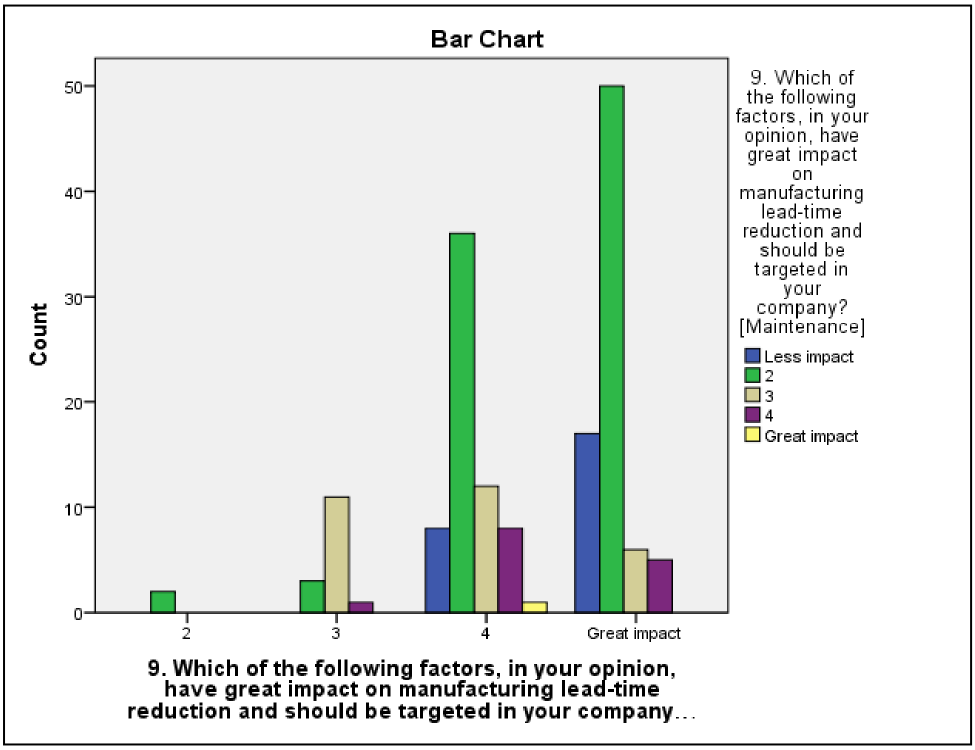
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	43.410[a]	12	.000
Likelihood Ratio	38.046	12	.000
Linear-by-Linear Association	13.046	1	.000
N of Valid Cases	160		

a. 11 cells (55.0%) have expected count less than 5. The minimum expected count is .01.

Null hypothesis (H0): There is no association between Move Time and Maintenance.

Alternative hypothesis (H1): There is an association between Move Time and Maintenance.

The cross-tabulation indicate that there is statistically significant association between Move Time and Maintenance (Pearson chi-square with 12 degree of freedom = 43.410, p = 0.000). This result indicates that there is statistically significant association between Move Time and Maintenance; that is, all the Move Time do not equally have same Maintenance. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	1	4
		% of Total	0.6%	2.5%
	4	Count	17	28
		% of Total	10.6%	17.5%
	Great impact	Count	44	24
		% of Total	27.5%	15.0%
Total		Count	62	57
		% of Total	38.8%	35.6%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Supplies raw material]	
			3	4
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	9	1
		% of Total	5.6%	0.6%
	4	Count	11	5
		% of Total	6.9%	3.1%
	Great impact	Count	3	6
		% of Total	1.9%	3.8%
Total		Count	23	13
		% of Total	14.4%	8.1%

			[Supplies raw material]	
			Great impact	Total
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2
		% of Total	0.0%	1.3%
	3	Count	0	15
		% of Total	0.0%	9.4%
	4	Count	4	65
		% of Total	2.5%	40.6%
	Great impact	Count	1	78
		% of Total	0.6%	48.8%
Total		Count	5	160
		% of Total	3.1%	100.0%

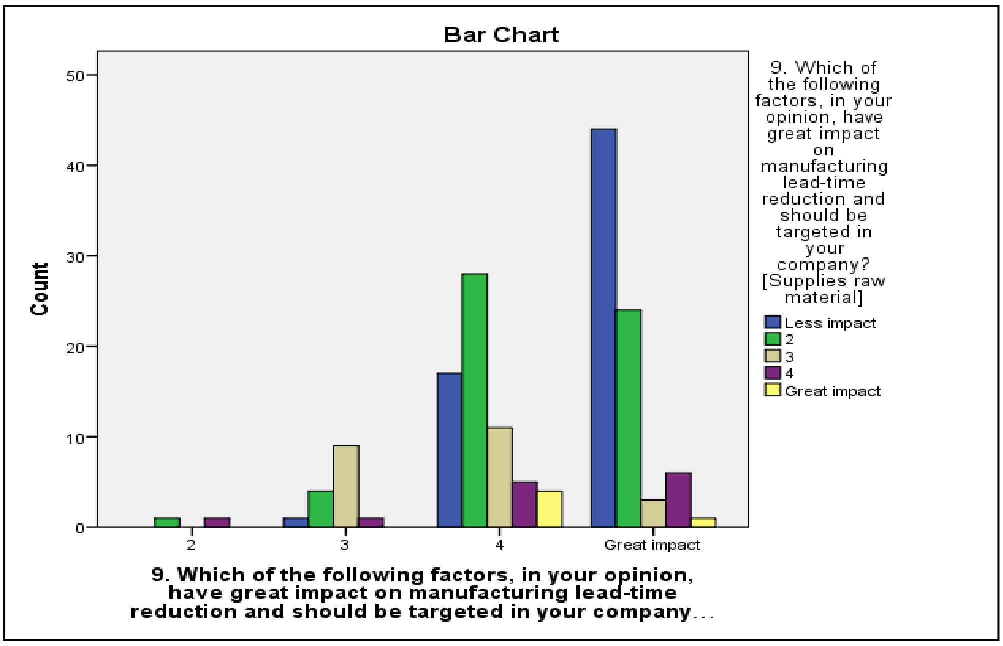
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	51.676[a]	12	.000
Likelihood Ratio	45.196	12	.000
Linear-by-Linear Association	18.298	1	.000
N of Valid Cases	160		

a. 10 cells (50.0%) have expected count less than 5. The minimum expected count is .06.
Null hypothesis (H0): There is no association between Move Time and Supplies raw material.

Alternative hypothesis (H1): There is an association between Move Time and Supplies raw material.

The cross-tabulation indicate that there is statistically significant association between Move Time and Supplies raw material (Pearson chi-square with 12 degree of freedom = 51.676, p = 0.000). This result indicates that there is statistically significant association between Move Time and Supplies raw material; that is, all the Move Time do not equally have same Supplies raw material. We reject null hypothesis.



9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]	
			Less impact	2
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	1
		% of Total	0.0%	0.6%
	3	Count	0	7
		% of Total	0.0%	4.4%
	4	Count	3	33
		% of Total	1.9%	20.6%
	Great impact	Count	8	40
		% of Total	5.0%	25.0%
Total		Count	11	81
		% of Total	6.9%	50.6%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Reducing Job Overlapping]		
			3	4	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	1	0	2
		% of Total	0.6%	0.0%	1.3%
	3	Count	6	2	15
		% of Total	3.8%	1.3%	9.4%
	4	Count	25	4	65
		% of Total	15.6%	2.5%	40.6%
	Great impact	Count	28	2	78
		% of Total	17.5%	1.3%	48.8%
Total		Count	60	8	160
		% of Total	37.5%	5.0%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.462[a]	9	.693
Likelihood Ratio	7.147	9	.622
Linear-by-Linear Association	3.753	1	.053
N of Valid Cases	160		

a. 9 cells (56.3%) have expected count less than 5. The minimum expected count is .10.

Null hypothesis (H0): There is no association between Move Time and Reducing Job Overlapping.

Alternative hypothesis (H1): There is an association between Move Time and Reducing Job Overlapping.

The cross-tabulation indicate that there is no statistically significant association between Move Time and Reducing Job Overlapping (Pearson chi-square with 9 degree of freedom = 6.462, p = 0.693). This result indicates that there is no statistically significant association between Move Time and Reducing Job Overlapping; that is, all the Move Time do equally have same Reducing Job Overlapping. We accept null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] *

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]	
			2	3
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	1	0
		% of Total	0.6%	0.0%
	3	Count	0	9
		% of Total	0.0%	5.6%
	4	Count	10	32
		% of Total	6.3%	20.0%
	Great impact	Count	2	31
		% of Total	1.3%	19.4%
Total		Count	13	72
		% of Total	8.1%	45.0%

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Setup Time.]		
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	1	0	2
		% of Total	0.6%	0.0%	1.3%
	3	Count	6	0	15
		% of Total	3.8%	0.0%	9.4%
	4	Count	23	0	65
		% of Total	14.4%	0.0%	40.6%
	Great impact	Count	42	3	78
		% of Total	26.3%	1.9%	48.8%
Total		Count	72	3	160
		% of Total	45.0%	1.9%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	21.048[a]	9	.012
Likelihood Ratio	22.143	9	.008
Linear-by-Linear Association	7.305	1	.007
N of Valid Cases	160		

a. 8 cells (50.0%) have expected count less than 5. The minimum expected count is .04.

Null hypothesis (H0): There is no association between Move Time and Setup Time.

Alternative hypothesis (H1): There is an association between Move Time and Setup Time.

The cross-tabulation indicate that there is statistically significant association between Move Time and Setup Time (Pearson chi-square with 9 degree of freedom = 21.048, p = 0.012). This result indicates that there is statistically significant association between Move Time and Setup Time; that is, all the Move Time do not equally have same Setup Time. We reject null hypothesis.

9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time] * 9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]

Crosstab

			9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Process Time (Run time)]		Total
			4	Great impact	
9. Which of the following factors, in your opinion, have great impact on manufacturing lead-time reduction and should be targeted in your company? [Move Time]	2	Count	0	2	2
		% of Total	0.0%	1.3%	1.3%
	3	Count	11	4	15
		% of Total	6.9%	2.5%	9.4%
	4	Count	20	45	65
		% of Total	12.5%	28.1%	40.6%
	Great impact	Count	18	60	78
		% of Total	11.3%	37.5%	48.8%
Total		Count	49	111	160
		% of Total	30.6%	69.4%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	15.853[a]	3	.001
Likelihood Ratio	15.231	3	.002
Linear-by-Linear Association	7.232	1	.007
N of Valid Cases	160		

a. 3 cells (37.5%) have expected count less than 5. The minimum expected count is .61.

Null hypothesis (H0): There is no association between Move Time and Process Time (Run time)].

Alternative hypothesis (H1): There is an association between Move Time and Process Time (Run time)].

The cross-tabulation indicate that there is statistically significant association between Move Time and Process Time (Run time)] (Pearson chi-square with 9 degree of freedom = 15.853, p = 0.001). This result indicates that there is statistically significant association between Move Time and Process Time (Run time)]; that is, all the Move Time do not equally have same Process Time (Run time)]. We reject null hypothesis.