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SUPPLY CHAIN LEAD TIME ANALYSIS FOR POSSIBLE REDUCTION: CASE STUDY IN AN OIL AND GAS COMPANY IN INDONESIA

Nurbani Hasan
09211150018005

Advisor:
Prof. Ir. I Nyoman Pujawan, M.Eng, Ph.D
196912311994121076

TECHNOLOGY MANAGEMENT DEPARTMENT
INDUSTRIAL MANAGEMENT PROGRAM
FACULTY OF BUSINESS AND TECHNOLOGY MANAGEMENT
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
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APPROVAL SHEET

This Thesis is written as one of the requirement to entitlement of Master of Management of Technology (M.MT)
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by:

NURBANI HASAN
09211150018005

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Approved by:

1. **Prof. Ir. I Nyoman Pujawan, M.Eng, Ph.D** **(Advisor)**
NIP : 196912311994121076

2. **Prof. Dr. Ir. Budisantoso Wirjodirdjo, M.E** **(Examiner)**
NIP : 195503081979031001

3. **Dr. Ir. Mokh. Suef, M.Sc(Eng)** **(Examiner)**
NIP : 196506301990031002

Dean of Faculty of Business and Technology Management,

Prof. Dr. Ir. Udisubakti Ciptomulyono, M.Eng.Sc.
NIP. 195903181987011001

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ANALISA DAN UPAYA PENURUNAN *LEAD TIME* RANTAI SUPLAI: STUDI KASUS DI PERUSAHAAN MINYAK DAN GAS BUMI DI INDONESIA

Nama Mahasiswa : Nurbani Hasan
NRP : 09211150018005
Dosen Pembimbing : Prof. Ir. I Nyoman Pujawan, M.Eng, Ph.D

ABSTRAK

Dukungan rantai suplai pada kegiatan operasi di bidang perminyakan dan gas bumi adalah sangat penting. Keterlambatan dalam menyediakan barang yang diperlukan dapat mengakibatkan kerugian bagi perusahaan, tertundanya pekerjaan, serta dapat meningkatkan resiko terkait aspek keselamatan dan keamanan lingkungan. Untuk memastikan kegiatan operasi berjalan dengan baik, khususnya pada perusahaan yang memiliki resiko operasi tinggi seperti PT.X, dukungan fungsi rantai suplai dalam memastikan ketersediaan dan kelayakgunaan barang yang diperlukan (kuantitas, kualitas dan biaya yang optimal) adalah sangat penting. PT.X adalah perusahaan dibidang minyak dan gas bumi yang memiliki Kontrak Kerjasama dengan Republik Indonesia. Salah satu permasalahan yang dihadapi PT.X adalah *lead time* dalam proses rantai suplai barang yang masih sangat panjang dan memiliki variabilitas yang cukup besar.

Penelitian ini bertujuan untuk mengidentifikasi faktor yang berkontribusi pada *lead time* penyediaan barang, serta melakukan evaluasi mengenai strategi perbaikan yang perlu dilakukan agar dicapai performa rantai suplai yang lebih baik. Data historis *lead time* penyediaan barang dievaluasi, *Current State Map* dari proses rantai suplai selanjutnya dibuat, serta pendapat para ahli dipertimbangkan sebagai masukan dalam proses analisa. Tahapan dengan *lead time* yang panjang atau variabilitas yang tinggi dievaluasi dan dianalisa lebih jauh untuk mencari akar penyebab atas permasalahan *lead time*. Selanjutnya strategi perbaikan disusun dan *Future State Map* rantai suplai dibangun. Simulasi dengan metode *Monte Carlo* dilakukan untuk memperkirakan dampak perbaikan *lead time* dengan menerapkan rekomendasi yang diajukan.

Sirkulasi dan persetujuan dokumen yang panjang, proses manual atas persetujuan dokumen, tingginya jumlah permintaan pembelian serta kurangnya dukungan terkait basis data penyedia barang yang komprehensif adalah beberapa akar penyebab permasalahan *lead time*. Rata-rata *lead time* dapat diturunkan hingga 85% dengan mengimplementasikan kontrak jangka panjang dibandingkan pembelian terputus. Perubahan periode *MRP Run* dari setiap bulan menjadi setiap dua bulan sekali juga akan memberikan dampak penurunan *lead time* yang cukup berarti (23.57%). *Key Performance Indicator* (KPI) serta sistem pengawasan atas kegiatan pembelian perlu diperbaiki, serta perlu dibuat KPI dan sistem pengawasan untuk kegiatan pengiriman barang ke pengguna akhir.

Kata Kunci: Lead Time, Pendapat Ahli, Peta Aliran Nilai, Rantai Suplai, Simulasi Monte Carlo.

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SUPPLY CHAIN LEAD TIME ANALYSIS FOR POSSIBLE REDUCTION: CASE STUDY IN AN OIL AND GAS COMPANY IN INDONESIA

Student Name	: Nurbani Hasan
NRP	: 09211150018005
Advisor	: Prof. Ir. I Nyoman Pujawan, M.Eng, Ph.D

ABSTRACT

Supply Chain activity is critical in supporting the operational process of Oil and Gas business. Delay in providing the right material at the right time might lead to potential profit lost for the Company, delay in job execution, and possible increase in risks related to safety and environmental aspects. To ensure the smooth process in operational side, especially for a company which conducting a high risk operational activity like PT.X, it is important to be supported by a good Supply Chain process to assure deliverability and serviceability of material as per requirement (optimum amount, time, and quality). PT.X is one of the Oil and Gas Companies which form a Production Sharing Contract (PSC) with the government of the Republic of Indonesia. One of the current issues in PT.X is the lead time of material supply which is considered still too long and has a big variability.

This research aim is to identify the lead time contributors in material supply chain process, and evaluating the improvement strategy to be taken to have a better performance in overall material supply chain process. Historical material lead time data are evaluated, Current State Map of supply chain process then developed, and expert opinions are taken into account in the evaluation process. Stage(s) of supply chain process with long lead time or big lead time variability then further evaluated and analyzed with Root Cause Analysis process, to further develop the improvement recommendations and develop the Future State Map of supply chain process. At the end of the research, Monte Carlo Simulation used to simulate the possible impact of the recommendation(s) for improvement.

Long chain of approval and document circulation, paper based approval, high number of purchase requisition and inadequate support system of comprehensive vendor database are some main root causes of the lead time issue. Maximizing utilization of the blanket contract could significantly reduce the average lead time up to 85% reduction from Spot Order PO average lead time. Reducing MRP Run frequency from monthly basis to be bi-monthly basis also has a significant impact in lead time reduction (23.57%). Existing Key Performance Indicator (KPI) and lead time monitoring tools for purchasing activity need to be improved; KPI is to be set-up and monitoring tools proposed to be developed for goods issuance process from warehouse to requester.

Key Words: Expert Opinion, Lead Time, Monte Carlo Simulation, Supply Chain, Value Stream Mapping.

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PREFACE

Alhamdulillah. Praise to Allah SWT for His blessings and guidance that allow this research to be carried out and finally completed. This thesis is submitted as one of the requirement to complete the Magister of Management Technology Program in Institut Teknologi Sepuluh Nopember. During my study in MMT, there are a lot of knowledge and experiences that I got, which I believe will be a great advantage for my future career and life. I finally reach this end part of the MMT program is not solely by my own, but of course with a lot of help and support from everyone that I could not mention one by one. However, please allow me to express my utmost gratitude to:

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I believe this thesis research is still far from perfect. Any constructive feedbacks and remarks are very welcome and will be a valuable input for future research study related with this research topic or for writer’s personal improvement in the future. Hopefully this research can contribute benefit and positive contribution for PT.X particularly, and broaden the academic knowledge in general.

Balikpapan, August 2018

Nurbani Hasan

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CHAPTER 1
INTRODUCTION

1.1. Background

In the more competitive business nowadays, a good supply chain function that has capability to give added value to the company is a more crucial issue. Supply chain is no longer as an administrative matters only but more than that, nowadays supply chain already became one of important functions to support the successfulness of a business.

More challenges are faced by supply chain function to stay competitive in the more complex market. Globalization and more advance technology have push all supply chain players to adapt and improve their business process to be able to stay flexible in a fluctuated and uncertain condition, where in the same time still need to maintain efficiency on their business process. Distribution channel and management, centralization or decentralization of the business, implementation of electronic procurement system, implementation of lean supply chain system, outsourcing strategy, etc., are some of the issues that exist in supply chain management nowadays.

Company needs to be flexible and responsive to customer's changes on requirements and also market condition. Some terminologies are used related to this increase in supply chain responsiveness such as Just in Time, agile manufacturing, lean manufacturing, quick response, and more. Lean concept is became more popular in supply chain world, where more and more company are thinking towards this approach and try to implement tools or method that available to achieve a lean system. It is expected that with lean supply chain system the company could minimize or even eliminate non-added value activities, have a more efficient value added and necessary activities, also could maximize output with optimized resources in the system. Despite most of supply chain management approaches, methods or concepts are originated or developed initially in manufacturing industry, does not mean that those approaches, methods or concepts cannot be implemented or adapted in oil and gas business. Some adjustments and modifications on those approaches could be made to adapt with different supply chain concept in oil and gas.

PT.X is an oil and gas company that has a Production Sharing Contract (PSC) with the government of Indonesia. This company's activities are in exploration and production area for oil and natural gas in some blocks or areas in Indonesia. Major activity of this company is on their block in East Kalimantan area.

PT.X is the main operator of the activities on their block in East Kalimantan, where PT.X officially appointed as the new operator for that block as per January 2018. In term of organization and business process, PT.X is mostly continuing previous operator's organization and business process which already established and operated for more than 40 years. PT.X have more than 3,500 employees working on several divisions and departement, both in office based in Balikpapan, East Kalimantan, also on fields. They has six fields that located in Mahakam Delta of East Kalimantan provence. Daily production of those fields together could reach more than 1,000 MMscf/d of gas, and more than 40,000 bbl/d of oil and condensate. With this level of production, PT.X is one of the main contributors of Government of Indonesia's earning from oil and gas sector.

In their business, with targeted production level and commitment to customers that need to be fulfilled, production loss is a case that need to be avoided as much as possible. One of production loss contributors is material unavailability by the time it is required on site. The longer the delay on material availability, the more loss will occure which could lead to profit loss, safety or environmental issue, also could impating performance of the well it self once it's back into production.

There are more than 50,000 material numbers (Stock Keeping Unit / SKU) that maintained on stock system of PT.X, with total value more than 300 Million USD. Those materials are belong to several divisions such as Drilling, Well Service, Field Operation, Engineering and Construction, also several support divisions such as General Services, Logistics, Health Safety & Environment, etc. From those 50,000 material numbers, around 70% is belongs to Field Operation Division, where the scope covering maintenance materials, production chemicals, laboratory consumables, pigging materials, inspections and floating hose materials, sand and corrossion monitoring materials, and production choke valves.

Field operation materials relate directly with operation and production activities of PT.X. Unavailability of critical equipment or spare part could directly impact the production level of the company. To assure continuous support to operation, some critical and routine consumable materials need to be maintained as stock items that kept at company's warehouse. Level of the stock shall consider some aspects such as the required quantity or unit all over fields, mean time between failure data, lead time of material supply, also the type of material it self whether able to be kept in long period or not. Other materials which considered not critical (to safety or operation) or not routinely consumed are not maintained as safety stock at PT.X warehouse. Those materials will be purchased only once there is a requirement.

As one of consideration in determining the stocking strategy of certain material, lead time of material supply is considered as one of the main focus in Key Performance Indicator (KPI) of Contract and Procurement Division of PT.X. Long lead time on material procurement process had been a long time issue that faced by PT.X, which in some cases not only impacting the operational activity, but could also financially impact the company by having too high stock level to be maintained to coupe with the long lead time of material supply, or causing the company to pay higher for shorter lead time to expedite the material availability. This requirement to maintain a high stock parameter is contradictive with PT.X's objective to optimize the stock level, to ensure the financial risk related with stock level is as minimize as possible. Considering the significant impact of this procurement lead time to the stock level requirement and to operational activities, certain actions needs to be taken to improve the lead time which considered still too long for PT.X.

It is expected that by reducing the material procurement lead time, PT.X could re-evaluate its stock parameter setting which then could be set lower compare to current stock level. Lower stock level will impact also the holding and maintenance cost of on hand stock, so at the end could reduce overall cost. By having a shorter procurement lead time, PT.X could also avoid or minimize occurrences of any additional unnecessary expediting cost. Ultimately, reducing the lead time will give more flexibility and adaptability in PT.X Supply Chain, to better support the operation by avoiding or minimizing disruption to operation due to material unavailability.

Based on the main actors involving on the process, lead time in PT.X's procurement process could be divided into two main categories, i.e. internal lead time and external lead time. Internal lead time is lead time that the main actors and lead time contributors are entities inside the company. On the other hand, external lead time is mainly contributed by external parties outside the company. Figure 1.1 shows simplified business process flow related with material procurement process in PT.X, which indicate also the internal and external lead time along the process flow.

Table 1.1 shows historical data of overall internal procurement lead time that recorded by Contract and Procurement Division of PT.X from 2012 until 2016 for material purchase, when the block was still operated under the previous operator/company. This internal procurement lead time figure is for the tendering process only, which is started from the initial Purchase Requisition (PR) issuance until Purchase Order (PO) award. The lead time not yet including initial requirement identification and PR preparation, lead time of supply from external parties (vendors), also lead time for material issuance from warehouse to end user. This data is based on procurement lead time per issued PO (one lead time data for one PO), not based on lead time per material number/stock keeping unit (SKU).

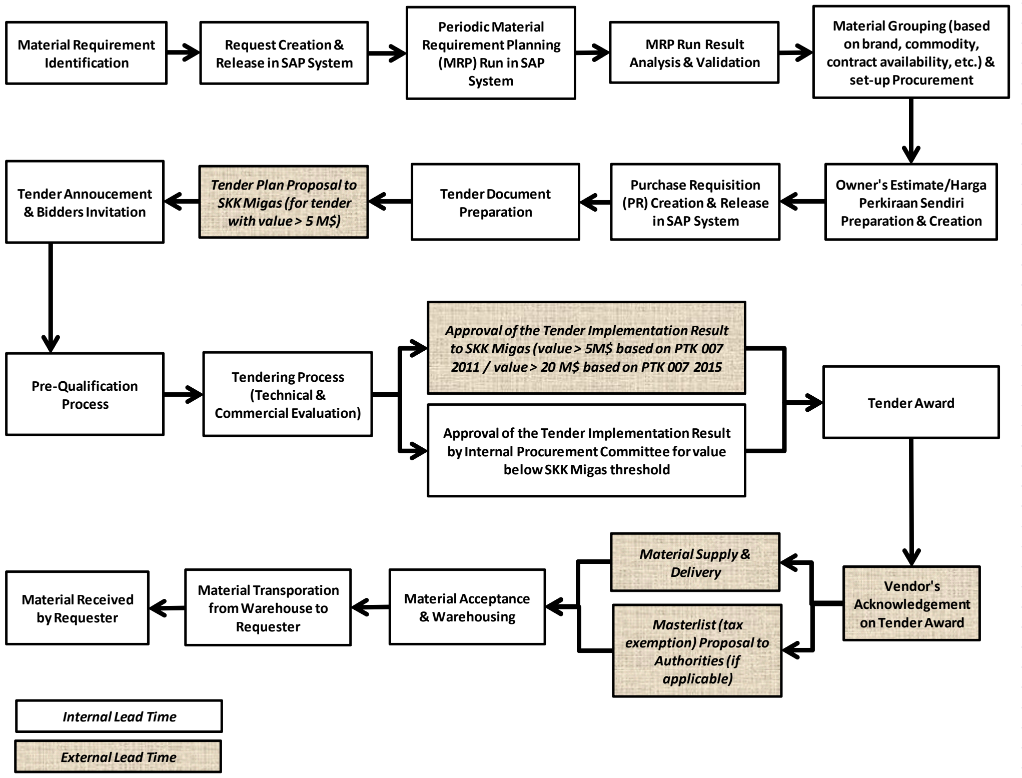

Figure 1.1. Simplified Business Process Flow of PT.X's Material Supply Chain

Table 1.1. Average Internal Material Procurement Process Lead Time of PT.X's Procurement Department (2012-2016)

Year	Procurement Method	Target Average Procurement Lead Time (days)	Actual Average Procurement Lead Time (days)
2012	All type of method, all value range, non-call out	85	102.31
2013	All type of method, all value range, non-call out	85	130.49
2014	All type of method, all value range, non-call out	85	156.49
2015	All type of method, all value range, non-call out	85	155.89
2016	All type of method, all value range, non-call out	85	129.32

Source: PT.X's supply chain reporting platform

Table 1.2. shows the historical internal procurement lead time data (2012-2016 average) for material purchase, based on type of procurement method used (Direct Appointment (DA), Direct Selection (DS), Call for Tender (CFT)). This data is also based on procurement lead time per issued PO (one lead time data for one PO), not based on lead time per material number/stock keeping unit (SKU). Figure 1.2 shows the same data but in yearly average procurement lead time from 2012 until 2016, differentiated by the procurement method (CFT/DS/DA).

Table 1.2. Average Internal Procurement Process Lead Time of PT.X's Procurement Department during 2012-2016 based on Type of Procurement Method

Year	Procurement Method	Actual Average Procurement Lead Time (days)
2012-2016	Direct Appointment (DA)	112
2012-2016	Direct Selection (DS)	126
2012-2016	Call for Tender (CFT)	276

Source: PT.X's supply chain reporting platform

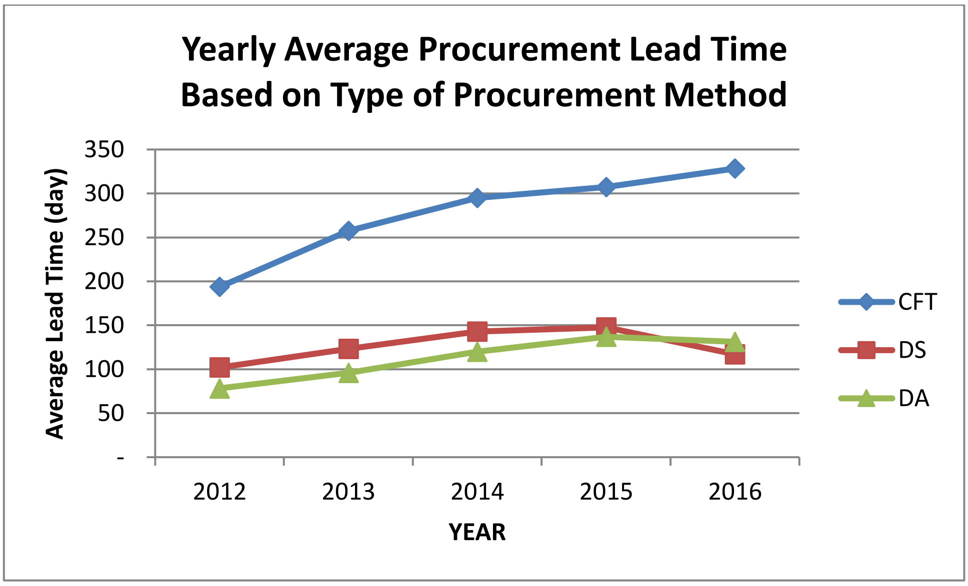

Figure 1.2. Yearly Average Procurement Lead Time Based on Type of Procurement Method

Different procurement methods as shown on above figure are also resulting on the different average procurement lead time. This is due to different procurement method has its specific stages, and some stages might not be mandatory in all procurement method. Call for Tender (CFT) method is the most complete and ideal procurement method, which also is most competitive method among those methods. However, longer lead time is required as the consequences of this competitive procurement process. Direct Selection (DS) is the next procurement method which still has competitive aspect on the process but could be conducted in a shorter duration because some stages that exist in CFT process might not be mandatory in DS process. Direct Appointment (DA) process is the least competitive method because the procurement process conducted directly to only one supplier, and could be conducted in a shorter duration.

Selection of which procurement method to be used (CFT/DS/DA) for a specific procurement process in oil and gas company in Indonesia is regulated by the government through *Pedoman Tata Kerja (PTK) SKKMIGAS Nomor: PTK-007/SKKO0000/2015/S0 (Revisi-03).* Priority is still to be given to the most competitive method. This prioritization also set as one of Key Performance Indicator (KPI) of PSC's company Supply Chain function which assessed by *Satuan Kerja Khusus Pelaksana Kegiatan Usaha Hulu Minyak dan Gas Bumi (SKK Migas)* in yearly basis to all PSC company in Indonesia.

Looking at above figures in Table 1.1., Table 1.2 and Figure 1.2., it is obvious why PT.X's management expect that there should be some improvements on the lead time of material procurement proccess expecially when it is relates with critical operation materials. Procurement lead time in 2013-2014 is far above the target. In those two years, operational activity under the previous operator in this block in East Kalimantan is quite high with more than 100 wells drilled each year. Material procurement activities for this block operation since 2016 is lower compare with previous years due to decreasing number of drilled wells, no big project activity, and tighter budget allocation for operational activities as part of cost reduction program. Lower load for procurement team following less items that need to be procured is resulting a better overall lead time performance in 2016 compare with other previous years. However, the low level of operational activity in this block with the previous operator around 2016-2017 could be considered as temporer condition, and higher operational activities is expected to occur again in the future under PT.X operation.

Continuous lead time improvement, whether it is internal or external lead time, is essential to support overall operational activities and to achieve the business objective. To allow the improvement to took place, it is important to understand first the overall stages and activities in current condition. Material requisition flow need to be drawned in detail, started from initial requirement identification until the order is fulfilled. All stakeholders that involved in the process and the lead time of each stage also to be identified. Further evaluation on the lead time of each stages and any activities involved in it will then need to be conducted to identify which activities or stages that have a contribution in term of value added, and which are not necessary so could be eliminated, also what can be done to improve the lead time on that stage.

All stages and activities need to be differentiated into several categories which are non-value added activity, necessary but non-value added activity, and value added activity. By knowing the category of each stage, it is expected that further improvement on overall material requisition process in PT.X could be achieved.

1.2. Problem Formulation

In this research, will be reviewed and analyzed some points as follow:

1. What is the current status of lead time on each stage of material supply chain process in PT.X?
2. Which stage(s) of the supply chain process of PT.X is possibly improved in terms of the lead time?
3. What is the root cause(s) of the long lead time in material supply chain process in PT.X?
4. What can be done to improve the material supply chain lead time in PT.X?
5. How much is the possible impact of the proposed improvement to the material supply chain lead time performance in PT.X?

1.3. Research Objective

Refer to above problem formulation; objective of this research could be described as follow:

1. To know the lead time of each stages of material supply chain process in PT.X.
2. To identify which supply chain stage(s) is the most important to be improved in term of the lead time.
3. To evaluate the root cause(s) of the long lead time issue in PT.X's material supply chain process.
4. To identify and list-up some actions/recommendations that could be done to improve the material supply chain lead time in PT.X.
5. To estimate the possible impact of the proposed actions/recommendation for improvement of the material supply chain lead time performance in PT.X.

1.4. Benefit of Research

Benefits that could be obtained from this research are:

1. For the Company (PT.X), this research will be useful to help them to identify room of improvements related to material supply chain process, which the main objective is to reduce the overall supply chain lead time of material, to better support the operation.
2. For academic's benefit, this research will be useful to broaden the knowledge regarding Supply Chain business particularly in Oil & Gas business, which in some aspects has different approach from Supply Chain in manufacturing sectors. Some local regulation in Oil and Gas business in Indonesia also add more uniqueness to the Supply Chain in this business.

1.5. Research Scope

To be more focus and have a specific object of research, this research's scope will be limited by certain factors and assumption as follow:

1. The research conducted only for the material supply managed by Purchasing Department of Contract and Procurement Division in PT.X, which the purchase requisition is coming from the Material and Inventory Management Service of the organization (procurement for stock materials).
2. Historical data used in this research is from 2012-2016 periods, for materials that are managed under Field Operation Division. Data from 2012-2016 periods are considered representative for current and future operational activities in PT.X.
3. Materials of Field Operation Division that the supply chain process observed in this research is assumed to be homogeny and has a similar supply chain characteristics.
4. Lead time evaluated is for one chain of purchasing process only and not considering yet the retender process due to fail tender (if any).
5. Force majeure or unexpected disruption to the supply chain process is not taken into account. The supply chain activities assumed to be performed under normal operation condition.
6. Costs and external lead time factors are not taken into account in this study.
7. Internal lead time evaluated to be improved in this research is only the lead time from Purchase Requisition released in SAP system until material received by requester (requirement fulfilled). Initial requirement identification process on user’s side, MRP Run analysis, material grouping and Owner’s Estimate preparation and creation are not taken into account in this research.

1.6. Chapter Outline

This research consists of several chapters divided as follows:

CHAPTER I –INTRODUCTION

This chapter covering the background of the research including brief explanation of the company profile, problem formulation, objectives and benefits of the research, scope and also the chapter outline of the thesis.

CHAPTER II - LITERATURE REVIEW

Theories related with the research that taken from several sources such as books, journals and other previous researches are reviewed and described in this chapter.

CHAPTER III - RESEARCH METHODOLOGY

This chapter describes the steps of the research process that presented also in the form of flowchart, also methodology that used in the research. Research position among other previous researches also explained in this chapter.

CHAPTER IV - DATA COLLECTION AND PROCESSING

This chapter consists of data collection process from both primary and secondary sources, also data processing that required in the process of obtaining the objective of the research.

CHAPTER V - DATA ANALYSIS

Data that collected and processed on previous chapter then further analyzed in this chapter, with refer to initially formulized and identified problems to ensure the final conclusions are in line with the research objectives and scope.

CHAPTER VI - CONCLUSIONS AND RECOMMENDATIONS

This last chapter is consist of conclusions of the research and also presenting some recommendations that might help the company to implement some improvement related with the lead time issue as well as for future researches purpose.

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CHAPTER 2
LITERATURE REVIEW

2.1. Operational Definition

2.1.1. Supply Chain and Lean Supply Chain Concept

Refer to several sources; supply chain could be described as follow:

1. A series (or network) of companies who work collectively to make and deliver products and services to the end customers. Those companies are including suppliers, factories, distributors, shops or retailers, also other supporting companies such as logistic service providers (Pujawan and Mahendrawathi, 2010).
2. The series of companies eventually making products and services available to consumers – including all of the functions enabling the production, delivery and recycling of materials, components, end products and services (Wisner, et al., 2012).
3. Supply Chain is activities of supplying and utilizing material and service that covering some stages such as planning, execution and controlling of material/service procurement process, asset management, customs and project management, including material/service supplier management, local product and competencies empowerment and also management of conflict/arbitrage (*Pedoman Tata Kerja (PTK) SKKMIGAS Nomor: PTK-007/SKKO0000/2015/S0 (Revisi-03)*).

Leenders et al. (2006) mention that the use of the concept of purchasing, procurement, supply, and supply chain management will vary from organization to organization. It will depend on their stage of development and/or sophistication, the industry in which they operate, and their competitive position.

Related with oil & gas business in Indonesia, supply chain in an exploration and production company could be described as process of delivering material or service to the end user/customer at the right time, quality, quantity and price, which involved a series or several entities that work collectively in an integrated network, where the process are including but not limited to planning, purchasing, manufacturing, distribution, inspection, and warehousing. The supply chain process of oil and gas company in Indonesia is unique due to related regulation issued by government (*Pedoman Tata Kerja (PTK) SKKMIGAS Nomor: PTK-007/SKKO0000/2015/S0 (Revisi-03)*), where in some aspects add more challenges in the supply chain management. Any incompliance to the regulation in supply chain area may lead to non-cost recovery risk, potential legal dispute, and disrupt company image.

In managing supply chain business, there are some challenges that need to be managed and usually become the root causes of problem in supply chain. Complexity on supply chain structure and uncertainty are highlighted by Pujawan and Mahendrawathi (2010) as two main challenges in managing supply chain. Complexity could vary from number of parties involved in supply chain, internal and external conflict of interest or objective, different time zone and culture, etc. Uncertainty on several aspects also adds more issues and most of the time are the main problem in managing supply chain process. Pujawan and Mahendrawathi classify the uncertainty in supply chain into three points depend on the sources, i.e. demand uncertainty, uncertainty from supplier side (e.g. delivery lead time uncertainty, price, quality and quantity of delivered materials), and internal uncertainty (e.g. engine/equipment performance, man power availability, time and quality of production).

Lean purchasing or *lean supply management* refers primarily to a manufacturing context and the implementation of just-in-time (JIT) tools and the techniques to ensure every step in the supply process adds value, that inventories are kept at minimum level, and that distances and delays between process steps are kept as short as possible (Leenders et al., 2006). Even though the concept was initially developed and applied in manufacturing business, lean concept has widely implemented in many fields and organizations, not only limited to the manufacturing business. Lean approached mentioned by Pujawan and Mahendrawathi as an approach which based on empowerment and involvement of all employees within the organization, the nature is more to bottom-up, and need no significant investment cost.

Lean thinking is broader, although closely related to JIT, and describes a philosophy incorporating tools that seek to economically optimize time, human resources, assets and productivity while improving product and service quality (Wisner et al., 2012). The basic idea is about elimination of waste or non-value added (NVA) activities as much as possible to achieve an efficient process flow, and meet the target or objective that expected from the process. Wisner et al. (2012) mention seven major lean elements that most likely considered on lean program in most firms, i.e waste reduction, lean supply chain relationships, lean layouts, inventory and setup time reduction, small batch scheduling, continuous improvement, and workforce empowerment. Below are short descriptions of each element that discussed by Wisner et al (2012):

Table 2.1. The Elements of Lean

Elements	Description
Waste reduction	Eliminating waste is the primary concern of the lean philosophy. Includes reducing excess inventories, material movements, production steps, scrap losses, rejects and rework.
Lean supply chain relationships	Firms work with buyers and customers with the mutual goal of eliminating waste, improving speed and improving quality. Key suppliers are considered partners, and close customer relationships are sought.
Lean layouts	WIP inventories are positioned close to each process, and layouts are designed where possible to reduce movements of people and materials. Processes are positioned to allow smooth flow of work through the facility.
Inventory and setup time reduction	Inventories are reduced by reducing production batch sizes, setup times and safety stocks. Tends to create or uncover processing problems, which are then managed and controlled.

Elements	Description
Small batch scheduling	Firms produce frequent small batches of product, with frequent product changes to enable a level production schedule. Smaller, more frequent purchase orders are communicated to suppliers, and more frequent deliveries are offered to customers. Kanbans are used to pull WIP through the system.
Continuous improvement	As queues and lead times are reduced, problems surface more quickly, causing the need for continual attention to problem solving and process improvement. With lower safety stocks, quality levels must be high to avoid process shutdowns. Attention to supplier quality levels is high.
Workforce empowerment	Employees are cross-trained to add processing flexibility and to increase the workforce's ability to solve problems. Employees are trained to provide quality inspections as parts enter a process area. Employee roles are expanded, and employees are given top management support and resources to identify and fix problems.

(Source: Supply Chain Management: A Balanced Approach by Wisner et al.)

2.1.2. Supply Chain Lead Time

Supply Chain lead time is time that required in fulfilling user/customer's requirement, starting from the initial requirement identification until the requested material/service is received by the requester. In supply chain of oil and gas companies especially those operates in Indonesia, lead time is a long story problem and difficult to be standardized due to a lot of variables that involve in the process. Compliances with related government regulation also become a challenge in achieving the expected supply chain lead time in the complex and uncertain market condition. The regulation itself also very dynamic and updated from time to time, which continuously push company to adapt and adjust with the latest regulations that available.

Long lead time in supply chain process has become a long time problem in PT.X as well. Material unavailability or shortage for some type of materials are unacceptable condition and could cause some problems like process inefficiency, health/safety/environmental issue, downgraded situation, production loss, and even a more catastrophic problem if the missing/fail item is the critical one that related with health/safety/environment.

Poernomo (2014) on the research with title *Single Source Performance Measurement in Supply Chain Division PT. XYZ* (a company that engage with oil and gas business in Indonesia) mention that procurement lead time could be divided into two categories which are internal and external lead time. “Internal lead time is contributed by the process involving only the internal entities in the Company, such as internal document approval, technical evaluation, etc. External lead time is contributed by the process involving external entities, such as the authority’s approval” (Poernomo, 2014).

In oil and gas business, external lead time of procurement process mainly dealing with obtaining authorities approval for some documents such as tender plan document, recommendation to award document and masterlist (tax exemption) proposal. Since external lead time is an uncontrollable variable, then this research will focus only on the internal lead time of the supply chain business in PT.X where a more tangible result could be expected from the improvement that proposed to be implemented.

In order to stay competitive in the business and achieve company’s objectives, lead time of procurement process is expected to be as short as possible to give more flexibility related with changes on requirement from end-user, also to have a more optimum stock level which obviously will be impacted significantly by the performance of procurement lead time. A lot of company has put lead time reduction as one of their main supply chain focus. Several strategies and approaches that commonly implemented in the way to reduce the lead time are including but not limited to:

1. Implementation of Lean Concept to reduce or eliminate waste.
2. Partnership with Supplier, to assure continuous and smooth supply (supply and demand syncronization).
3. Long term relationship with selected suppliers by implementing certain type of contract (e.g. call-off order contract, price agreement, technical frame contract, cost plus fee contract, etc.).
4. Early supplier involvement in initial stage of requirement planning.
5. Supplier Performance Management.
6. Strategic Sourcing.
7. Vendor Managed Inventory / Consignment.
8. Change in decoupling point.
9. Utilization of advance Information Technology System.

2.1.3. Waste and Type of Activity

Activities on the value stream could be differentiated into three main categories, depend on the type of value it contributes to the overall process:

1. Value adding activities
2. Un-necessary activities/non value adding activities (waste)
3. Necessary non value adding activities (waste)

Waste is anything that consumes resources (people, material, time) without creating value (King, 2009). Seven Waste Concept in the Toyota Production System (TPS) which was firstly categorized by Taiichi Ohno are commonly used in manufacturing business as the starting point of the stream evaluation. Those Seven Waste Concept in TPS are as follow:

1. Waste of overproduction
2. Waste of time on hand (waiting)
3. Waste in transporation
4. Waste of processing itself
5. Waste of stock on hand (inventory)
6. Waste of movement
7. Waste of making defective parts

Not all waste are need to be eliminated. In some cases, there could be waste that necessary to exist on the process to guarantee a smooth and continous flow of product along the stream. Requirement to comply with certain standard and regulation could also became the background of those wastes are still need to be exist and could not be eliminated, but might be improved. Distinction need to be made between necessary waste that contribute to the overall process, and unnecessary waste that has no contribution in the process. Necessary waste are also need to be managed so it could be maintained at the optimum condition, if it is really difficult to be avoided or eliminated from the process.

Seven Waste concept in Toyota basically developed under perspective of assembly operation. King (2009) try to compare and extend the root causes of those seven wastes in process operation. Table 2.2. shows comparison expressed by King (2009) regarding the root causes of waste in both assembly operation and process operation. In different type of process or environtment (e.g. parts assembly vs process operation), same waste might be caused by different root causes.

Table 2.2. Root Causes of Waste

Waste Category	**Parts making and assembly**	**Process operations**
Overproduction	Inappropriate productivity measures Long runs due to long setups Scheduling from forecasts ("push")	Large batch mentality "Economic of scale" thinking in equipment design Inappropriate productivity measures Long campaigns due to costly changeover Long campaigns due to incapable processes Unneeded types being produced Scheduling from forecasts ("push")
Waiting	Poor workload balancing	Need for very quick response to process upsets

Waste Category	Parts making and assembly	Process operations
	Late parts arrivals Temporary stockouts	Many taks at starts and end of a batch, but few during the batch
Transportation	Poor factory layouts	Equipment scattered, not co-located Large WIP storage systems located remotely
Processing	Unnecessarily tigh specifications Overspecifying requriements Making defective material	Making defective material Testing for defective material Sorting defective material Reworking defective material Preparing defective material to be recycled (e.g. Chopping, dissolving)
Inventory	Overproduction To buffer againts defects Unsyncronized parts flow	Overproduction Batch size differences Equipment rate differences Unsyncronized material flow Long campaigns Bottleneck protection To buffer against process upsets To buffer against demand variability
Movement	Poor process layouts Inefficient workstation design Searching for tools	Process equipment large and distributed over large areas (horizontally and vertically) Central control rooms located remotely Searching for tools
Defect	Worn tooling Improper setups Incomplete specifications Lack of work standards	Raw material inconsistencies Very sensitive processes Process parameters difficult to control Rushing to market before products are fully developed Lack of work standards

(Source: Lean for The Process Industries (2009))

Different type of business and different environment might has different type of waste. The root causes also will differ from one environment to another. King already shows the example of waste and root cause variety between assembly and proccess operation. Procurement process which the nature also differ from assembly and process operation, might have different type of waste as well. The seven waste concept in TPS might not entirely suitable and exist as it is in procurement process, but the concept can be used as the starting point in evaluating the business process in procurement activity. The main idea is to implement the lean concept through waste identification and continuous improvement in the process that being evaluated.

2.1.4. Value Stream Mapping

Value Stream Mapping described as a paper-and-pencil tool that helps to see and understand the flow of material and information as a product or service makes its way through the value stream (Nash & Poling, 2008). It is usually applied in lean concept approaches in many industries, and could give a more clear big picture of the process or system that being evaluated, to help the identification of areas to be focused on for further improvement.

Value Stream Mapping could give an overview of the overall process and stages that exist in a company or specific section in a company. It shows material/physical and information flow in the system, with detail lead time data for each stage or section. Value stream map are used to document both the *current state* (i.e., reality) and the *future state* (i.e., the goal) (Nash & Poling, 2008):

1. Current state value stream map: It shows the current process map/baseline view of the system or business process from which all improvements are measured.
2. Future state value stream map: It shows the new or proposed process map after review and analysis conducted to seek for possible improvement in the process.

On this research, current state of supply chain mapping will be developed to be further analyzed and improved, which at the end will allow future state supply chain map to be developed. To get the detail information and ensure the big picture map already representing all components of the process, direct observation and interview to related person in charge are required.

As part of the Value Stream Mapping data, Takt and cycle time are two of the most important parameters to be taken into account. King (2009) describe Takt as a measure of total customer demand, expressed as a time factor. It is calculated by taking the time available, the total time the plant/system plans to be operating over some period, and dividing it by the average number of units of product that customers purchase over that time period. Different from Takt, cycle time is a measure of the time required to produce a part or lot. If Takt reflects the customers demand, then cycle time reflects equipment/system capability.

Since the nature or demand in manufacturing/assembly process is different from demand in procurement process context, then cycle time and Takt in procurement process need to be redefined to be suitable with the nature of that specific business process. In procurement process context, cycle time could be measured from time required to perform a certain procurement process from start to end, while Takt will be derived by end-users or management's expectation of the time to perform that process.

2.1.5. Root Cause Analysis

Root Cause Analysis (RCA) is a method that is used to address a problem or non-conformance, in order to get to the "root cause" of the problem (Vorley, 2008). By knowing the causes of the problem or non-conformance that being an issue, it is expected that the identified root cause could be corrected or eliminated to prevent the problem to reoccurring in the future or to reduce the negative impact of the root cause to the main problem.

Several stages or steps that are commonly implemented in RCA process are as follow:

1. Identify the problem
2. Define the problem
3. Understand the problem
4. Identify the root cause

5. Corrective action
6. Monitor the system

There are several commonly used tools and techniques to help identify and evaluate the root cause of a problem or condition, e.g:

1. 5 Why's (Gemba Gembutsu)

   Gemba Gembutsu means Place and Information in Japanese. This technique refers to a practice of asking (for five times), why the failure has occurred. The objective is to identify the root cause(s) of the problem. 5 Why's approach is best used for a simple RCA process.

2. Pareto Analysis

   Pareto technique could help researcher in focusing area for improvement or to choose the most effective changes to be implemented. It uses the Pareto principle, i.e. the idea that by doing 20% of the work you can generate 80% of the advantage of doing the entire job (Vorley, 2008).

3. Cause and Effect Diagrams

   Cause and Effect Diagram which also known as Fishbone Diagrams or Ishikawa Diagrams is a useful technique which could help in performing a more complex RCA. The diagram that developed could shows and identifies all possible/potential processed and/or factors that could contribute to the occurrence of the problem that being analyzed.

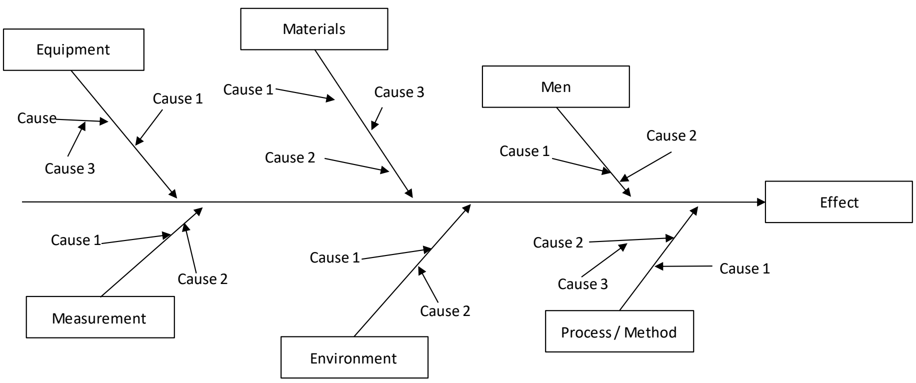


Figure 2.1. Cause and Effect Diagram or Fishbone Diagrams

4. Brainstorming/Interviewing

This is a method that most people are familiar with. Several reminders need to considered as described by Vorley (2008) are:

a. Collect as many ideas as possible from all participants with no criticism or judgments made while ideas are being generated.
b. All ideas are welcome. Be creative. The more ideas the better.
c. No secondary discussion should take place during the brainstorming activities.
d. Do not criticize or judge. All ideas are equally valid at this point.
e. Write all ideas on a flipchart or board so all participants could easily see them. Use Cause and Effect Diagrams and Fault Trees to help capture the information.
f. Set a time limit for the brainstorming.

5. Process Analysis, Mapping and Flowchart

Flowcharts could arrange and organize all related information about a process or system in a graphical manner, so that it could be easier to be understood.

6. Fault Tree

Fault Tree technique is a graphical technique. This technique could help researcher in obtaining a systematic description of the combinations of possible occurrences in a system or process, which can cause an undesirable outcome or cause a problem. The diagram could be presented in the format left-to-right or top-to-bottom.

7. Check Sheet

Check Sheet or Tally Charts is used to collect data of a process of system, which could be in numerical format or other format such as audit questions check list. Check sheet could be used in day-to-day basis to record the data of the process.

8. Sampling

Sampling is the activity of collecting data from a system or process.

9. Control Charts

The control chart is a graph used to study how a process changes over time (Vorley, 2008). Data that collected or obtained from the system is plotted in time order, where a control chart has a central line (representing the average), an upper line as the upper control limit, and also a lower line for the lower control limit. Central, upper and lower lines are determined based on historical data. Process variations could be showed by the chart, by comparing current process data to these defined lines. Control Chart often used to look at points or areas where the performance or result of the process is falling outside the defined limit.

2.1.6. Monte Carlo Simulation

Evaluating a simple business process with clear characteristics and demand condition is not too difficult. Different condition will occure with a system or business process where there is uncertainties in the system characteristics and demand. In such situation, modeling and simulation is really helpfull in quantifying certain variable in the design with probabilistic condition. Modeling and simulation is preferable compare to direct testing on the real system especially in large and complex system, considering some factors such as lower cost in simulation compare to testing on the real system, significant shorther time will be required, and this approach could facilitate quantitative evaluation which could be used to help managerial decision making.

In modeling and simulation process, there could be some uncertainties that involved and occurred which might impacting simulation result and how precise the model in representing the actual system. Uncertainties could arise from several sources, some known sources that mentioned by Chong P. Ken et al. are:

1. Physical uncertainty or inherent variability. This uncertainty relate with asociated variability that occure to demands on engineering system as well as its properties. They represented as random variables, with statistical parameters such as mean values, standard deviations, distribution types, etc.
2. Informational uncertainty. This could be a statistical uncertainty due to small number or samples, imprecise information, etc. The statistical

distribution parameters accuracy is depend on the amount of available data, so the distribution parameters themself is considered as uncertain (random variable)). Information could be imprecise or in qualitative form, which could impact also uncertainty on the data.

3. Modeling Error. Result from approximate mathematical models of the system behaviour, and from numerical approximations during the computational process.

Monte Carlo simulation in its simplest form is a random number generator that is useful for forecasting, estimation, and risk analysis. Monte Carlo simulation is a type of parametric simulation, where specific distributional parameters are required before a simulation can begin. The alternative approach is nonparametric simulation where the raw historical data is used to tell the story and no distributional parameters are required for the simulation to run (Mun, 2010).

There are many studies that already utilized Monte Carlo simulation on the research. The implementation is not limited in certain area or field of study only, but very wide e.g. in chemical engineering area, risk analysis in various fields, nuclear energy business, manufacturing, pharmaceutical production process, and many more.

In some research, Monte Carlo simulation is used to estimate or forecast the possible impact of certain proposed model or solution to the simulated process or system. Prior executing the simulation, initial data or model with certain type of data distribution need to be developed. Then the proposed/improved model/solution is developed. From these two data distribution, then the possible impact or performance of the new proposed model/solution could be estimated by using the Monte Carlo simulation. Basic data that commonly used as parameter to determine the improvement/impact of the new model are including but not limited to Mean and Standard Deviation.

Monte Carlo simulation can be performed by using certain simulation tools (e.g. Risk Simulator) or simply by using Excel. In this research, Excel will be used to perform the simulation process. To generate a random number for the simulation in Excel, "*RAND()*" function will be utilized. This function is simply a random number generator Excel uses to create random number from a uniform distribution between 0 and 1 (Mun, 2010). Random numbers are used, in the simulation context, to generate uncertainty events. In particular, they are used to make random draws from a probability distribution (Eppen et al., 1989).

2.2. Previous Research

Ratnaningtyas (2009) utilize Value Stream Analysis Tools (VALSAT) to identify waste and the root cause of the waste on a shoulder/rail clip housing production in PT. Barata Indonesia (Persero). This company engage in foundry, manufacturing and EPC (Engineering, Procurement and Construction), and the research focusing the analysis and evaluation of lead time on the foundry section of the shoulder production. Big Picture Mapping drawn at the beginning of the research to give understanding of the ongoing process flow, which the data was collected through direct observation and interview. Questionnaire also utilized to identify the waste (based on seven waste concept of Toyota) and gives scoring to each of waste that occurs. The waste then weighted to know which waste that dominant on the value stream. VALSAT used on the research to select which mapping tools that suitable to identify the root cause of waste.

Research at shoulder/rail clip housing production in PT. Barata Indonesia (Persero) above came with result that some dominant wastes are waiting, defect and inappropriate processing. Average score of each waste then multiplied with detail mapping multiplying factor, resulting that Process Activity Mapping and Supply Chain Response Matrix are two dominant mapping tools which then used to further analyze and set recommendation for lead time improvement.

Utilization of value stream mapping could also as a part of other process analysis like what have conducted on a research on PT. Ecco Indonesia by Nuuru (2012) with title "*Penerapan Lean Six Sigma dan Theory of Inventive Problem Solving untuk mengurangi waste dan perbaikan kualitas di PT. ECCO INDONESIA*". The research was try to find some way of improvements that can reduce the waste and solve quality issue that exist by following lean six sigma methodology (Define, Measure, Analyze, Improve, Control). Value stream mapping was used on the Define stage of the research to identify waste, which then followed by waste weighting and tools selection by using Value Stream Analysis Tool (VALSAT).

Another research that also conducted in PT. Ecco was done by Saifuddin (2009) with research title "*Aplikasi Metode Lean Six Sigma untuk Meminimalkan Waste dan Meningkatkan Kualitas Produk dengan Parameter Pengukuran Cost Saving of Implementation*" highlighting quality and lead time some performance indicators that became significant issue on that company at that time. Lead time reduction is one of the research focuses, where Lean Six Sigma is chosen as the method approach. Value stream mapping of current state and future state was used to set a lead time parameter. VALSAT data analysis resulting on the type, frequency and impact of each waste, which then further analyzed to know the root cause of each waste and allowing researcher to propose some way forwards for improvement on lead time issue.

Lean and waste been linked a lot and relate significantly due to waste reduction/elimination is part of important action to achieve lean process/system. Research titled *"Penerapan Metode Lean untuk Mengurangi Pemborosan pada Proses Produksi Corrugated Carton Box PT.SRC"* by Putranto (2007) also focusing on waste identification and reduction by applying Process Activity Mapping (PAM) and Quality Filter Mapping (QFM) as the VALSAT tools that chosen based on AHP calculation matrix.

Different approach in facing delay or lead time issue was introduced by Wangsadiharja (2009) on the research in PT. Burketindo Kontromatik Surabaya. Research with title "*Perbaikan Proses Pemesanan Barang ke Head Office untuk Mengurangi Keterlambatan Pemenuhan Pemesanan dari Pelanggan"* use a simulation of business process to identify potential improvement on the process, especially related with the problem in term of delay of request fulfilment. Several scenario (in addition to current business process) was developed and simulated to find the optimum scenario that could lead to higher service level while still maintaining optimum cost. Software ARENA used to help the simulation process.

In this research, researcher will use Excel and Minitab Software to help in performing Monte Carlo Simulation. As mentioned earlier, Monte Carlo simulation is widely used in various area and business process. Bustamin (2015) use Monte Carlo simulation on the research to simulate the scheduling acceleration based on confidence level of the project completion. The research was conducting on Hull Construction project of Landing Craft Utility (LCU), where network planning of initial schedule was developed, then the schedule acceleration based on critical path conducted to calculate the Earliest Event Time and Latest Event Time. New network planning then developed, and some iteration executed using Monte Carlo simulation to get the estimated confidence level of project completion for each possible accelerated schedule scenario.

Jabbarzadeh, et al. (2016) in research with title "*Designing a supply chain resilient to major disruptions and supply/demand interruptions*" mention that there are two types of risk that facing supply chain, refer to what defined by Tang (2006). Operational risk which normally caused by inherrent interruption to the supply chain process such as undertainty in customer demand, uncertainty in supply/production capacity, and also uncertainty in procurement cost; the other one is disruption risk, which caused by major incident both natural or man-mad disaster. The paper present a hybrid robust optimization model for designing a supply chain resilient to supply/demand variations and major disruptions whose risk of occurence and magnitude of impact can be mitigated through facility fortification investment.

Objective of the research was to minimize the total cost in establishing the network while maximizing the supply chain resilience. Target of the proposed model is to determine the supply chain design decisions (including number, location and type of facilities) in the presence of certain budget constraint. Monte Carlo simulation method is used in the research to examine the performance of the proposed model. A total 9000 random numbers are generated for three datasets with different distribution, i.e. uniform, normal and beta distributions which are used to model the situations in which the uncertain data is unknown (only the range of uncertain parameters is known), normal (value of the random parameters tend to be near the nominal value) and unusual (uncertain parameters are likely to take the highest and lowest possible values). Using the generated random value combined with the obtained optimal solution, then the 'mean total cost', 'standard deviation' and 'percentage of infeasibility' (i.e., the proportion of situations resulting in stockout or product shortage) are calculated to evaluate the quality of the proposed model.

Model and simulation method in the research by Jabbarzadeh, et al. (2016) then firstly implemeted in Sepahan Oil Company (SOC), an oil refinery located in Middle East, to determine optimal locations of facilities with different fortification levels. The model also used to determine the optimal assignment of customers to these facilites at different conservatism degrees. For SOC management, this analysis helps identify the opportunities in which a supply chain can be protected against fire risks and supply/demand uncertainties at a reasonably minor supply chain cost increase (Jabbarzadeh, et al., 2016).

Related with lead time issue, Eberle et al. (2014) in research with title "Improving Lead Time of Pharmaceutical Production Processes using Monte Carlo Simulation" mention that leadtime, i.e. the duration between start and end of an activity, needs to be well managed in any production facility in order to make scheduling predictable, agile and flexible. In many paharmaceutical facilities, the total lead time is known to be vary and causing difficulties in management's side to identify potential improvement and obstruct reasonable allocation of process enhancements. In this research, a data-based method is presented to assess and improve the total lead time of pharmaceutical production, and Monte Carlo simulation is used to quantify the total lead time of batch production (predicting future total lead time) as a probability distribution.

The method consists of five phases: (1) set up lead time model, (2) fit probability distributions, (3) perform Monte Carlo Simulation and sensitivity analysis, (4) perform what-if analysis and (5) derive managerial implications (Eberle et al., 2014). From phase 1 until phase 3, a probability distribution of the total lead time is obtained, based on summation of each individual lead time of the sub-processes which representing also in the form of probability distribution. The next step is to analyze the sub-processes sensitivity to allow identification of improvement opportunities, and then the future situations are simulated by What-if analysis and re-running the Monte Carlo Simulation. From these final simulation, managerial implication can be obtained.

The method presented by Eberle et al. (2014) was applied to an actual pharmaceutical facilities of Roche Parenterals in Switzerland. The Monte Carlo Simulation was performed with 100,000 iterations, using the fitted probability distributions as well as rank order correlation coefficients so that the as-is total lead time was obtained. After the new proposed model developed and new lead time distribution obtained, then the effect to total lead time is estimated by rerunning the Monte Carlo Simulation on the updated distributions. In this research, the presented method does not characterized root causes for unsatisfying lead time, but only identifying the processes that most sensitive to the total lead time and then focusing the possible lead time improvement on those area only (dominant lead time contributors).

Another implementation of Monte Carlo Simulation in procurement process was presented by Hong, Z. And Lee, CKM (2012) in research with title “A Decision Support System for Procurement Risk Management in the Presence of Spot Market”. The idea is to built a robust purchasing plan, including supplier selection and order allocation. Monte Carlo Simulation was used in this research to quantify each supplier’s risk, to help decision maker in making a proper decision by taking into account the trade-off between profit and risk. Main advantages of the result is in helping buyer making optimal and robust procurement decision (e.g. supplier selection, order allocation among multiple sources) in the existence of correlated demand, yield and spot price uncertainties.

On the research, the proposed Procurement Risk Management framework provides a novel procurement risk management solution, which includes four stages as follow: (1) supply risk identification; (2) supply risk assessment based on Monte Carlo simulation and Profit–Supply at Risk (SaR) map; (3) Supply risk mitigation with goal programming model; and (4) supply risk monitoring (Hong, Z. And Lee, CKM, 2012). A profit model is built based on identified risks (such as unpredictable demand, volatile price, uncertain supply yield) and the cost components of the procurement. Final procurement plan was presented at the end of the research with detail risk level and expected profit in selecting certain supplier.

2.3. Research Position

Utilization of Big Picture Mapping or Value Stream Mapping (VSM) is not a new thing in process improvement and already implemented is several fields. Difference of this research with some previous researches are in this research the tool is used on supply chain business in Oil and Gas industry that has a different nature and environment from other fields like manufacturing, service industry, etc..

This research is expected to enrich this VSM tool application in different area and more variance environment, which also open possibility of further modification and enrichment from current method that already commonly used. Specifically this research is try to implement this approach on Oil and Gas Company in Indonesia with its specific local challenges, and will be focused on supply chain process of maintenance and operation material. Monte Carlo simulation at the end of the research also introduced to estimate the improvement impact of the proposed system improvement. This research position to some earlier researches could be seen on table 2.3.

Table 2.3. Research Position to Other Research

No	Title	Author / Year	Tools	Result
1	Penerapan Metode Lean untuk Mengurangi Pemborosan pada Proses Produksi Corrugated Carton Box PT. SRC	Johni Harius Putranto (2007)	- Process Value Analysis - Value Stream Analysis - VALSAT (Process Activity Mapping & Quality Filter Mapping) - AHP for VALSAT method selection - Work Sampling	Dominant waste: defect. Some recommendation for improvemed proposed to reduce waste.
2	Implementasi Lean Manufacturing	Ratnaningtyas (2009)	- VALSAT (Procces Activity	Dominant waste: waiting, defect, unappropriate

No	Title	Author / Year	Tools	Result
	untuk Mengurangi Lead Time Shoulder Studi Kasus PT. Barata Indonesia (Persero)		Mapping & Supply Chain Response Matrix) - Big Picture Mapping - Root cause analysis	processing. Lead time could be reduce after recommendation improvement.
3	Implementasi Lean Service pada Proses Upgrade Layanan dalam Program Apresiasi Pelanggan untuk Mengurangi Lead Time dan Non Value Added Activities di PT. TKM Surabaya	Putri Chairunnisa (2013)	- Big Picture Mapping - Pareto Diagram - VALSAT (Process Activity Mapping) - Root cause analysis (cause & effect diagram) - Pull system	Dominant waste: error, delay, unclear communication. Proposed some improvement that could reduce the lead time process, as shown by future state map.
4	Simulasi Value Stream untuk Perbaikan pada Proses Produksi Pelumas (Studi Kasus LOBP PT. Pertamina UPMS V)	Rika Ajeng Priskandana (2010)	- Big Picture Mapping/Value Stream Mapping - VALSAT (Process Activity Mapping) - Time study - Simulation of current state and future state after improvement.	Total cycle time of the process, which consist of non-value added and value added activities. Alternative improvement could increase the utility of forklift operator and increase product output in one cycle.
5	Perancangan Lean Production System dengan Pendekatan Cost Integrated Value Stream Mapping pada Divisi Kapal Niaga Studi Kasus PT. PAL Indonesia	Farich Firmansyah (2015)	- Value Stream Mapping - Activity Based Costing - Cycle time analysis - Root cause analysis	Dominant waste: inventory, motion. Proposed cost integrated value stream mapping. Future state map shows the design could reduce the production time by eliminating waste.

No	Title	Author / Year	Tools	Result
6	Perbaikan Proses Pemesanan Barang ke Head Office untuk Mengurangi Keterlambatan Pemenuhan Pesanan dari Pelanggan (Studi Kasus: PT. Burkertindo Kontromatik Surabaya)	Darmawan Wangsadiharja (2009)	- Business Process Simulation	Four scenario simulated, where one scenario could lead to higher service level and lower cost. The higher the average of inventory level, then the higher service level.
7	Penerapan Metode Lean Six Sigma dan Theory of Inventive Problem Solving untuk Mengurangi Waste dan Perbaikan Kualitas di PT. Ecco Indonesia	Pricily An Nuuru (2012)	- Big Picture Mapping - VALSAT (Process Activity Mapping) - Pareto Diagram - Failure Mode and Effect Analysis	Proposed improvement to company related with control and monitoring process of production, especially in quality control department. Cost saving calculation with proposed improvement.
8	Aplikasi Metode Lean Six Sigma untuk Meminimalkan Waste dan Meningkatkan Kualitas Produk dengan Parameter Pengukuran Cost Saving of Implementation (Studi Kasus di PT. Ecco Indonesia)	M. Riza Saifuddin (2009)	- Value Stream Mapping - VALSAT	Proposal on lead time reduction strategy.
9	Perbaikan Proses Produksi Blender Menggunakan Pendekatan Lean	Rian Adhi Saputra (2012)	- Value Stream Mapping - VALSAT (Process	Dominant waste: waiting, overproduction, inventory.

No	Title	Author / Year	Tools	Result
	Manufacturing di PT. PMT		Activity Mapping & Supply Chain Response Matrix) - Root cause analysis	Total required time to process was reduced after improvement implemented.
10	Kajian Percepatan Penjadwalan Pembangunan Landing Craft Utility (LCU) dengan Metode Simulasi Monte Carlo	Bustamin (2015)	- Monte Carlo Simulation - Network Planning - Critical Path Method - PERT	Estimated confidence level of project completion for each possible accelerated schedule scenario.
11	Improving Lead Time of Pharmaceutical Production Processes using Monte Carlo Simulation	Eberle, L.G., Sugiyama, H., Schmidt, R. (2014)	- Critical Path Method - Monte Carlo Simulation - Sensitivity Analysis - What-if analysis - Expert information	Proposed scenarios to improve total lead time, prioritizing processes that need further enhancement, 94.9% confidence level in achieving the management goal on the production leadtime.
12	Designing a Supply Chain Resilient to Major Disruptions and Supply/demand Interruptions.	Jabbarzadeh, A., Fahimnia, B., Sheu, J.B., Moghadam, H.S. (2016)	- Monte Carlo Simulation - Supply Chain Network Design	Determine optimal locations of facilities with different fortification levels, optimal assignment of customers to the facilites.
13	A Decision Support System for Procurement Risk Management in the Presence of Spot Market	Hong, Z. and Lee, CKM (2012)	- Monte Carlo Simulation - Supply and Procurement Risk Management	Procurement plan with risk level and expected profit information per supplier (for buyer's consideration in making

No	Title	Author / Year	Tools	Result
				procurement strategy decision), Instead of using single supplier, risk can be hedged against multiple suppliers and multiple periods.
14	Supply Chain Lead Time Analysis for Possible Reduction: Case Study in an Oil and Gas Company in Indonesia	Nurbani Hasan (2018)	- Big Picture Mapping/Value Stream Mapping - Root cause analysis - Expert Opinion - Monte Carlo simulation	Develop current and future state map of supply chain process. The value stream in the current state map is evaluated to identify room for improvement, and root cause analysis conducted to further set up improvement recommendation in order to reduce supply chain lead time in oil and gas business in Indonesia. Monte Carlo simulation to estimate the effect of the proposed recommendation.

CHAPTER 3
RESEARCH METHODOLOGY

3.1. Research Design

This research is a problem solving and survey research, which try to provide some improvement solutions for the problem that presented on this research. As described in Chapter 1 of this research, Contract and Procurement Division of PT.X is has a concern related with procurement process lead time that is still an issue and could impact their operational activities.

At the first stage of the research, current state map of the supply chain process will be developed to show the supply chain process flow from the beginning to the end of the process. Further breakdown then will be conducted on this supply chain mapping, to separate the process flow into several stages. Historical lead time data for each supply chain stages will be collected through recorded data in the system, available historical documentation and direct survey to personnel in charge, to know the previous and current lead time figure of each stage of the supply chain process.

Preliminary data that will be taken into account for research purpose are as follow:

1. Historical data of material requisition and procurement process (2012-2016 period), and other related lead time data in supply chain PT.X.
2. Lead time data for each stage of material requisition and procurement process.
3. Key Performance Indicator (KPI) related with supply chain lead time in PT.X.

Material groups that will be used in this research are materials managed under Field Operation Division of PT.X. This group of materials consists of more than 44,000 material numbers (Stock Keeping Unit) which representing around 70% of overall PT.X's number of materials, with stock value representing 25% of PT.X's total stock value (refer to PT.X stock closing status at end of 2016).

Procurement stage(s) with long internal lead time and/or big variability in the lead time historical data will be the main focus to be further reviewed and analyzed in this research. Some feedbacks from related functions and experts will be collected through direct interview with some experts that hold strategic function or have experience in supply chain area.

Previous studies on related field also will be taken into account, to help researcher on focusing the data collecting and analysis to the area that could lead to a bigger impact on the improvement stage. Some of those literatures that used as supporting references on this research are papers, journals, books and other thesis report. Refer to some other researches and literature review in Chapter 2, several methodologies/approaches then chosen to be used to evaluate and analyze current lead time performance in supply chain process of PT.X which are Value Stream Mapping, Root Cause Analysis by taking into account expert opinion as well, and then enriched with Monte Carlo Simulation and the end of analysis stage to simulate the possible impact of proposed improvement strategy.

3.2. Research Program

Research program is developed to be used as a guideline during the research, to ensure the objective of the research could be achieved in timely manner and with structured stages. Stages of this research are begin with preliminary study, continued with literature study, data collection, developing current state of supply chain map and waste identification, analysis and discussion, and closed with conclusion and recommendation for further research.

Overall stages in this research are as follow:

1. Preliminary Study.
2. Literature Study.
3. Data Collection.
4. Current state supply chain map development and waste identification.
    a. Create the current state of Value Stream Mapping of the supply chain process, showing current steps involved, lead time figure, also physical and information flows.

b. Asses and review the current state of Value Stream Mapping to identify value adding activities, unnecessary activities and necessary NVA activities.
c. Dominant waste identification through data collected from historical data and expert opinion.
d. Select supply chain stage(s) that will be further reviewed and analyzed (long internal lead time and/or big variability on the historical lead time data).

5. Analysis and Discussion.
   a. Root cause analysis of lead time problem.
   b. Develop improvement strategy for Lead Time reduction, taking into account expert opinion and result from literature review.
   c. Develop a future state Value Stream Mapping which accommodates possible lead time improvement.
   d. Simulate the potential lead time improvement from the developed future state Value Stream Mapping, to estimate possible impact of the proposed Value Stream Mapping and recommendation for process improvement. This simulation stage will use the Monte Carlo Simulation method, which the steps are as follow:
      i. Setup the lead time model.

Define the equation of Total Lead Time (TLT) as the sum of duration of each stage of supply chain process. Figure 3.1 shows the illustration of one supply chain process from start to end, that consist of several stages (stage 1, stage 2, continued until stage *n*) with different lead time on each stage. Any stage *i* is framed by two time stamps, marked with x_i and x_{i+1}, which indicate the starting and end point of that particular stage.

Previously developed Current State Map of the supply chain process is used as the initial guideline in developing and set up the lead time model. In the case that there are any parallel sub-processes or stages (not sequential one into another), then Critical Path Method might be required to identify the most relevant and time critical stage among those stages that run in parallel mode.

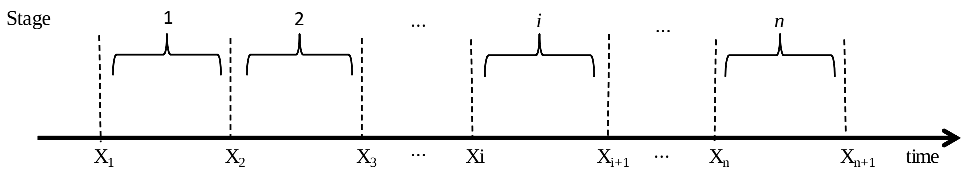


Figure 3.1. Illustration of one process flow lead time which consists of several stages from start to end (adopted from Eberle et al.)

ii. Fit probability distribution.

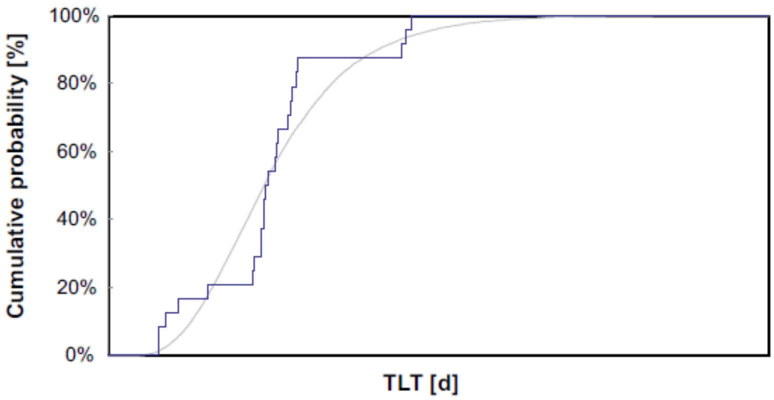
In this step, a probability distribution for each stage of supply chain process is defined, based on collected historical data. Different supply chain process stage might have a different type of data distribution, whether it has a Normal distribution, Uniform, Exponential, and so on. By having specific data for each stage of the process, the Mean, Standard Deviation, Minimum value, Maximum value and other specific parameter for each stage of those processes with its specific type of data distribution then could be obtained.

In this step, the Spearman rank order correlation coefficient *(R)* will also be determined. This coefficient could be used to evaluate the correlation between one stage to another in the process flow. The coefficient has a figure range from -1 to 1. Zero value indicates that there is no correlation of lead time between those stages.

iii. Perform Monte Carlo Simulation and Sensitivity Analysis.

In this third step, TLT is calculated and impact of each supply chain stage to TLT is quantified. Sensitivity Analysis conducted to identify any sensitive stage to overall lead time performance.

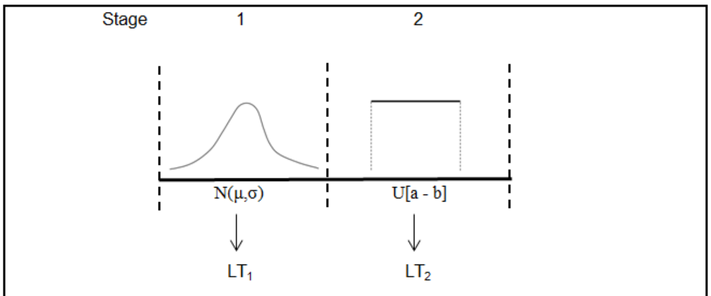
In the beginning, current TLT is calculated by running the Monte Carlo Simulation. To verify the reproducibility of the model, distribution as result of the simulation is to be compared with the actual TLT value (historical data). It is expected that there is no significant differences between the actual value and the simulation result. Graphically, comparing these both data could be done by overlaying cumulative graphs as shown in Figure 3.2. Statistically, the reproducibility of the model could also be evaluated. A calculative approach is conducting statistical tests such as equal variance test by F-test or mean value comparison by *t*-test, with an aim not to find any significant difference between calculated and actual TLT (Eberle et al., 2014).



Source: Eberle et al. (2014)

Figure 3.2. Overlaying Cumulative Graphs of Calculated (smooth line) and Actual (step-wise line) TLT to Assess the Validity of the Model

Excel and Minitab Software are used in this research to help in performing data analysis and Monte Carlo Simulation. Random variation from each stage of supply chain process will be modeled based on its type of distribution. Figure 3.3 shows the illustration of modeling the random variations for data which has a Normal and Uniform distribution, for 5000 times iteration.



Iteration #	LT_1	LT_2	Total LT
1	$LT_{1,1}$	$LT_{2,1}$	$= LT_{1,1} + LT_{2,1}$
2	$LT_{1,2}$	$LT_{2,2}$	$= LT_{1,2} + LT_{2,2}$
3	$LT_{1,3}$	$LT_{2,3}$	$= LT_{1,3} + LT_{2,3}$
…	…	…	…
j	$LT_{1,j}$	$LT_{2,j}$	$= LT_{1,j} + LT_{2,j}$
…	…	…	…
5000	$LT_{1,5000}$	$LT_{2,5000}$	$= LT_{1,5000} + LT_{2,5000}$

$LT_{1,j}$ =NORMINV(probability,mean,standard_dev)
=NORMINV(RAND(),μ,σ)

$LT2_{,j}$ =Rand()*(Max-Min)+Min
=Rand()*(b-a)+a

**LT = Lead Time*

Figure 3.3. Illustration of Modeling and Run Monte Carlo Simulation for Data with Normal and Uniform Distribution

iv. Perform what-if analysis.

Potential improvement(s) to the system is assessed by introducing the improved scenario to the model, and re-run the Monte Carlo Simulation. New lead time distribution that introduced to the model will be generated by adjusting the parameter (such as Mean and/or Standard Deviation) of the initial distribution (current state of supply chain process lead time). This adjustment will be based on input and analysis conducted previously while conducting analysis of lead time improvement with some experts.

v. Simulation result analysis.

Estimate the potential impact of the proposed improvement scenario, to support managerial decision making.

6. Conclusion and future research suggestion.

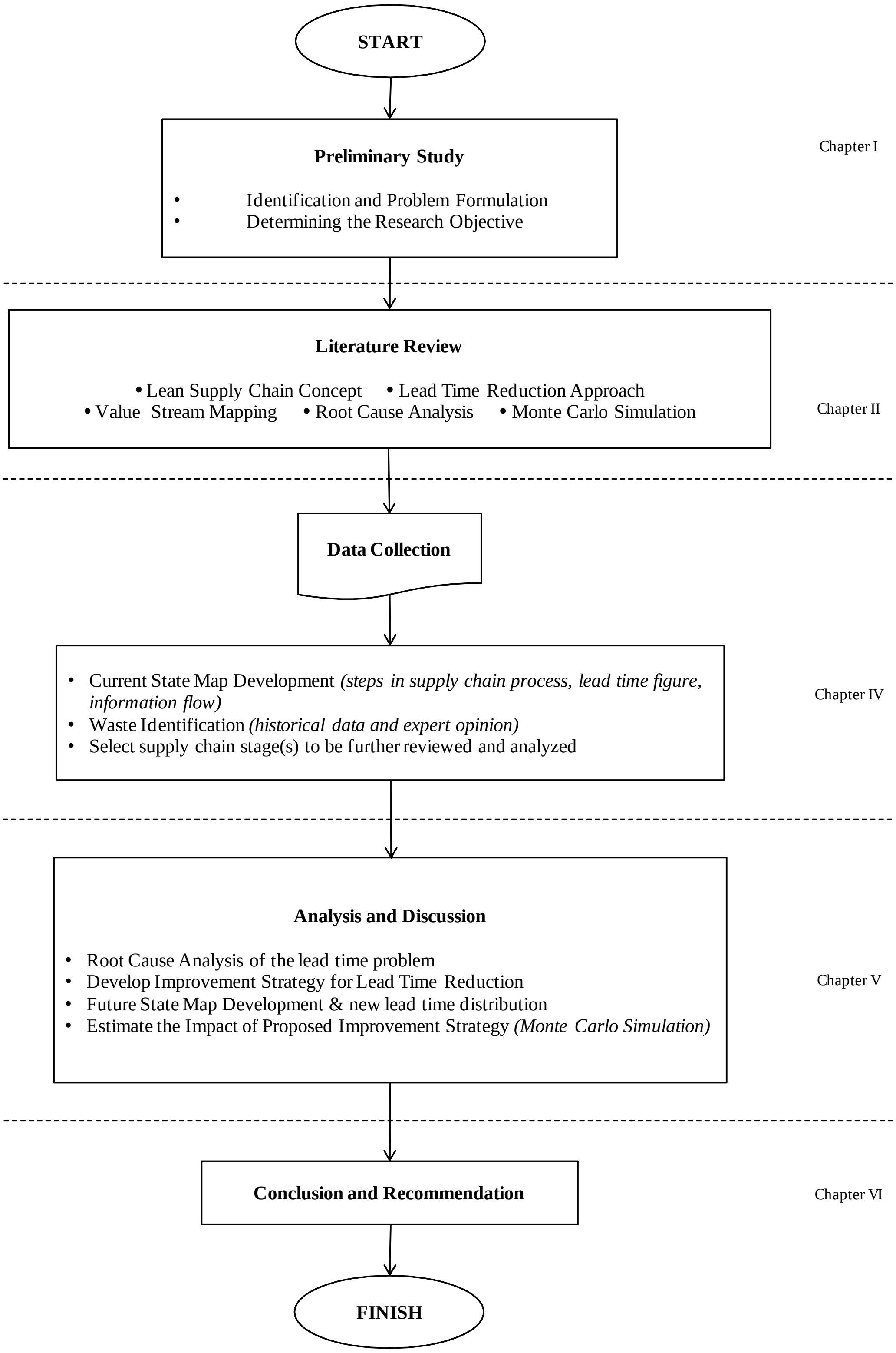


Figure 3.4. Research Flow Diagrams

CHAPTER 4
DATA COLLECTION AND PROCESSING

4.1. Data Collection

Primary and secondary data to support the research are collected at this stage. Primary data are collected through direct interview with several key persons involved in the supply chain process in PT.X such as Material and Inventory Coordinator, Procurement Officer (Senior Buyer) and Material Acceptance Supervisor.

Several employees within PT.X are involved in this research to give feedback and suggestion regarding the research process and analysis. These experts are considered and chosen as expert parties in this research based on their experience in supply chain business and their current position. Experts involved in this research are as follow:

1. Head of Purchasing Department
2. Head of Material and Inventory Management Service
3. Head of Warehouse Service

Secondary data are collected from available database in the company's system (SAP system), documented purchasing document data, and documented historical report of Key Performance Indicator (KPI) available in the system that used by PT.X.

4.1.1. Detail of Material Supply Chain Process Flow

As previously mentioned in Chapter 1 of this research, there are two types of lead time in the supply chain process of PT.X i.e. internal lead time and external lead time. Focus of this research is on the stage(s) categorized as internal lead time contributor. Simplified business process flow related with material procurement and supply in PT.X already presented earlier in Figure 1.1., which showing also which stages that considered as internal and external lead time contributors. Further breakdown with a more detailed process flow of material supply chain in PT.X is presented in this chapter as showed on Figure 4.1, Figure

4.2 and Figure 4.3, where the initial simplified business process flow from Figure 1.1 is divided into 3 main supply chain phases with detail as follow:

1. Preparation Phase

   This stage of supply chain process is started from initial material requirement identification by end-user, until Purchase Requisition (PR) creation and issuance. Issued PR will then further processed/followed-up on the Purchase Phase.

   a. Material Requirement Identification
   b. Request Creation and Release in SAP System
   c. Periodic Material Requirement Planning (MRP Run) in SAP System
   d. MRP Run Result Analysis and Validation
   e. Material Grouping and Set-up Procurement Strategy
   f. Owner's Estimate (*Harga Perkiraan Sendiri*/HPS) Preparation and Creation
   g. Purchase Requisition (PR) Creation and Release in SAP System

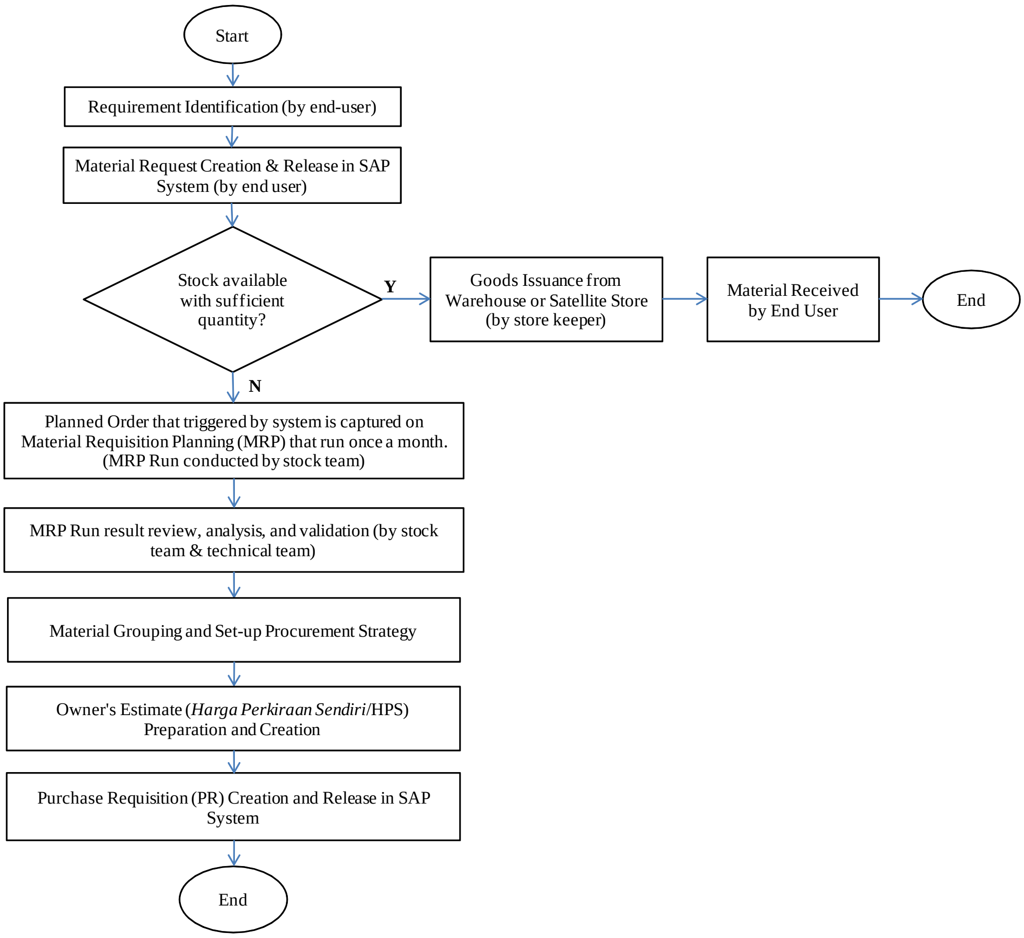


Figure 4.1. Detail Process Flow of Preparation Phase on Material Supply Chain

2. Purchase Phase

In this phase, procurement/tendering process is conducting which at the end resulting in a Tender Award or issuance of Purchase Order (PO) to Vendor. There are 3 types of procurement method used in PT.X, i.e. Call for Tender (CFT), Direct Selection (DS) and Direct Appointment (DA). Different procurement method has its own stages which at the end could lead into different procurement lead time. Differences between CFT, DS and DA process are described in Table 4.1. In general, stages in purchase phase are as follow:

a. Tender Document Preparation

b. Tender Plan Proposal to SKK Migas (for tender with value greater than 5 Million USD)
c. Tender Announcement and Potential Bidders Invitation for qualification
d. Pre-Qualification Process
e. Invitation to Bidders
f. Tendering Process (Pre Bid Meeting, Technical and Commercial Evaluation)
g. Approval of Tender Implementation Result (internal & external)
h. Tender Award

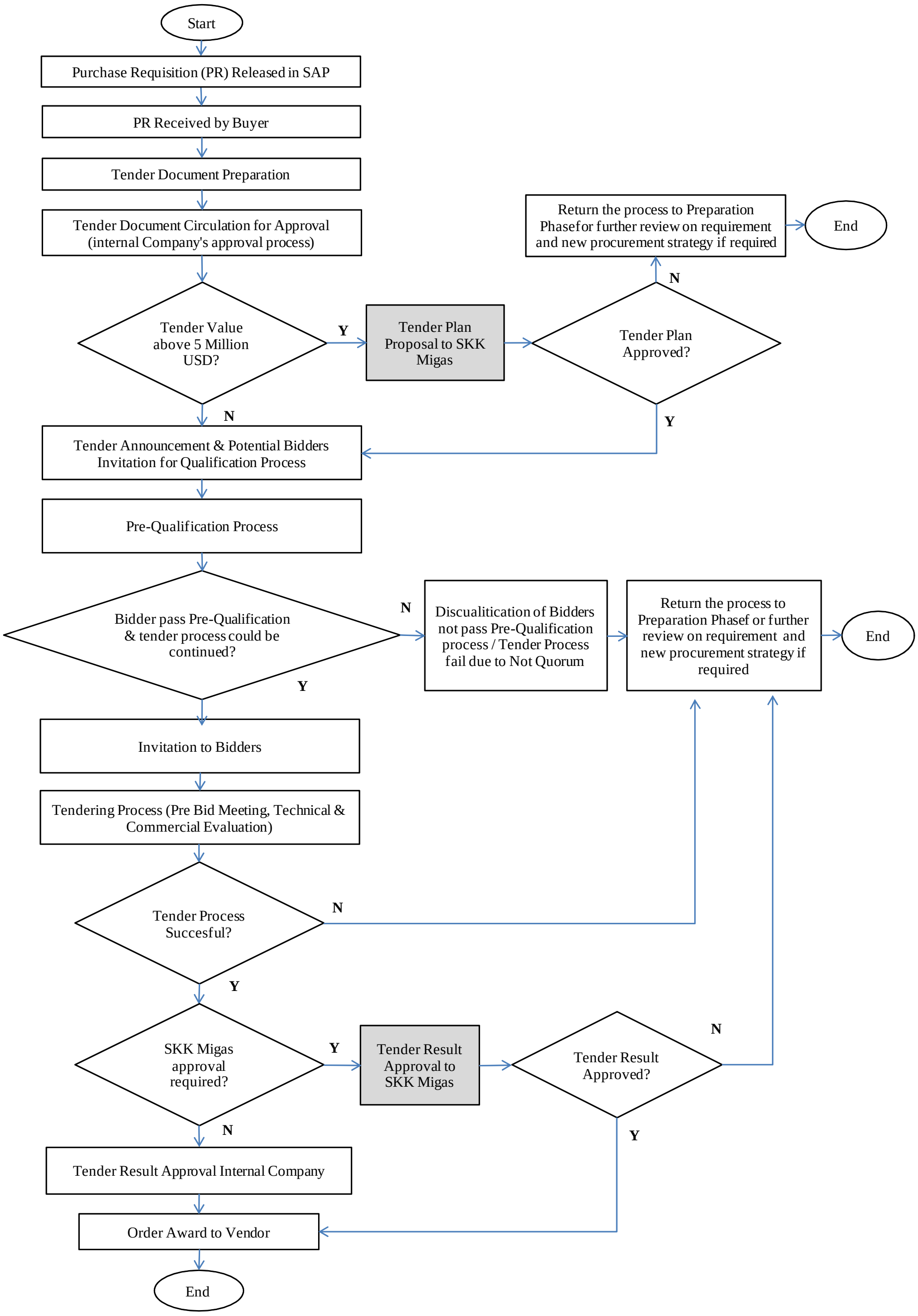


Figure 4.2. Detail Process Flow of Purchase Phase on Material Supply Chain

Table 4.1. General Differences between Call for Tender, Direct Selection and Direct Appointment Process

	Call for Tender (CFT)	**Direct Selection (DS)**	**Direct Appointment (DA)**
Tender Announcement	Yes	No	No
Pre-Qualification	Yes	Not Mandatory (Pre-Qualification simplified by using *Sertifikat Pengganti Dokumen Administrasi (SPDA)* or similar administrative acknowledgement document (before SPDA implemented by SKK Migas))	Not Mandatory (Pre-Qualification simplified by using *Sertifikat Pengganti Dokumen Administrasi (SPDA)* or similar administrative acknowledgement document (before SPDA implemented by SKK Migas))
Number of Bidders Invited *(PTK-007/SKKO0000/2015/S0 issued 2015)*	>= 3	Minimum 3 Bidders (tender value up to US$ 500,000); Minimum 2 Bidders (DS as continuation of fail limited Call for Tender or if only 2 supplier could provide the material)	1
Number of Bidders pass Pre-Qualification *(PTK-007/SKKMA0000/2017/S0 (Revisi 04) issued 2017)*	>= 3	Minimum 3 Bidders (tender value up to US$ 500,000); Minimum 2 Bidders (DS as continuation of fail re-tender process)	1
Invitation to Bidder	Yes	Yes	Yes
Pre-Bid Meeting	Yes if required	Yes if required	Yes if required
Protest by Bidder regarding content of tender document	Yes	Yes	No
Bid Submission	Yes	Yes	Yes
Bid Opening Attended by Bidder	Yes	Yes	No
Technical Evaluation	Yes	Yes	Yes
Commercial Evaluation	Yes	Yes	Yes
Approval of Tender Implementation Result	Yes	Yes	Yes

	Call for Tender (CFT)	Direct Selection (DS)	Direct Appointment (DA)
Tender Award	Yes	Yes	Yes
Objection Period	Yes	Yes	No

3. Commitment Follow-up Phase

This phase consist of several post-award activities started from tender award acknowledgement by the vendor, until the requested material is received by the requester.

a. Tender Award Acknowledgement by Vendor
b. Material Supply by Vendor
c. Masterlist (tax exemption) Proposal to Authorities (if applicable)
d. Material Acceptance and Warehousing
e. Material Transportation from Warehouse to Requester
f. Material Reception by Requester

Material issuance process from Warehouse to Requester is involving several functions as follow:

1. Warehouse Team (Store Keeper): initiate the picking list items, prepare and packing the material. Perform Goods Issuance posting in SAP System.
2. Logistic Team: perform shipment/delivery process for issued material, to be delivered to User's location. Some User are located on the same Site with Warehouse location, while some other locations are need a land or even sea transportation process. Logistic team create the Shipment Document in SAP system, and post the Shipment End in SAP system once the material arrive on the target location. Material then handed over to receiver (Store Keeper on Site or User requesting the material).
3. Sites Store Keeper: receive material from Logistic team, perform material checking and then post Good Receipt in SAP system.

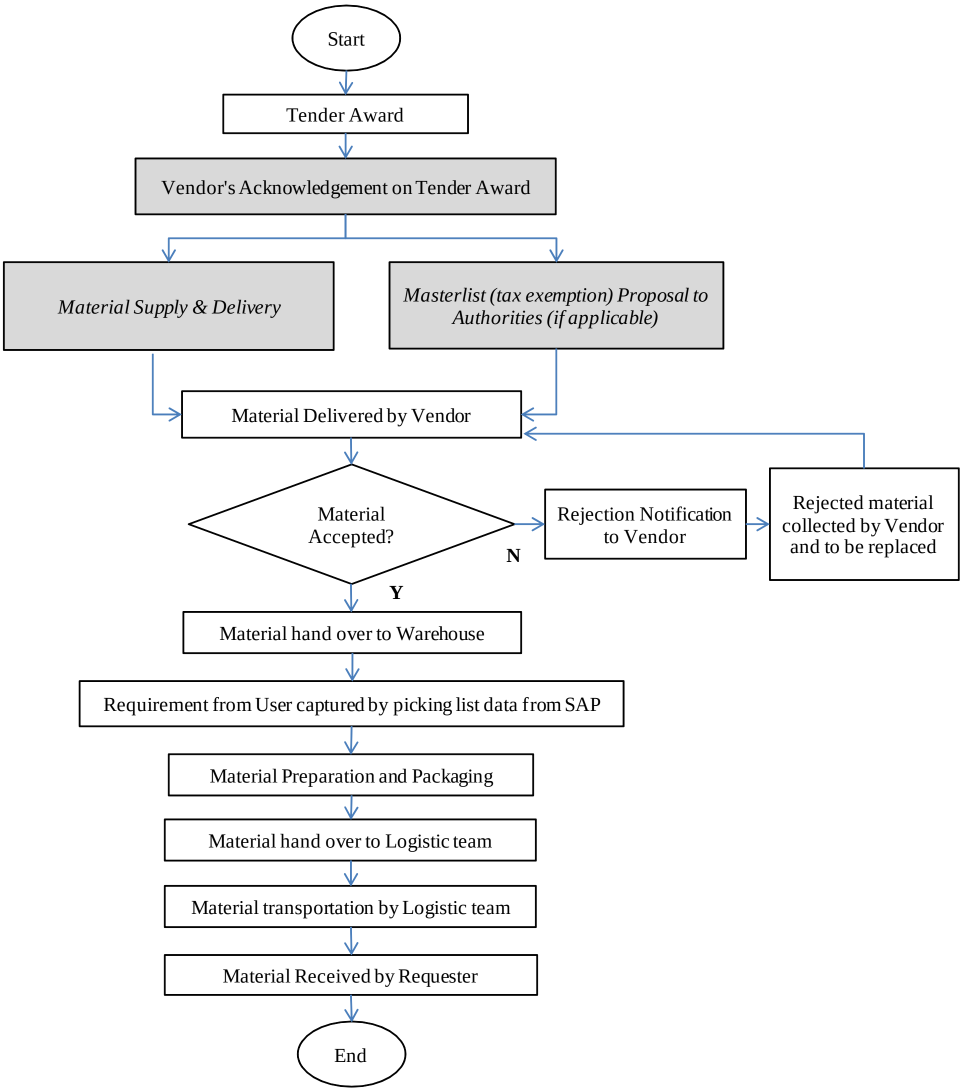


Figure 4.3. Detail Process Flow of Commitment Follow-up Phase on Material Supply Chain

4.1.2. Historical Lead Time and Key Performance Indicator

Internal lead time that to be further evaluated and analyzed in this research is lead time of supply chain process which started from Purchase Requisition (PR) creation and release in SAP system until requirement fulfillment which indicated by material received by requester. Lead time information of those several stages of material supply chain process are collected from data recorded in SAP system, documented purchasing document (paper/hardcopy document) and/or historical data report, while for some other stages the lead time data are need to be collected from other sources such as direct interview with key person(s) for those specific supply chain stage(s).

Preliminary data collected for this research purpose are as follow:

1. Historical data of material procurement process (2012-2016 period).

   As previously mentioned in Chapter 1 of this research, procurement process data that will be taken into account in this research is procurement data for Field Operation Division of PT.X, which the requisition is coming from Material and Inventory Management Service (procurement for stock material). Based on recorded historical data in PT.X's SAP system, there are 7,521 Purchase Orders (PO) for stock materials issued during 2012-2016 periods, where 4,374 among them are for Field Operation materials. Table 4.2 shows number of total PO issued per year during 2012-2016 period for stock materials.

Table 4.2. Total Number of Issued Purchased Order for Stock Items on 2012-2016 Period

Year	Total Number of Issued Purchase Order of Stock Items	
	All Commodities	Field Operation Materials PO
2012	2,180	1,365
2013	1,841	1,012
2014	1,533	810
2015	1,126	669
2016	841	518
TOTAL	**7,521**	**4,374**

Source: Historical Data Record in SAP System

   Issued PO could be divided into 2 main categories, i.e. Spot Purchase PO and Call-Out Order PO. Spot Purchase PO is PO that issued as a result of tender process, while Call-Out Order PO is PO that created directly with reference to the blanket contract or agreement (e.g. Outline Agreement or Price Agreement). In the case of Call-Out Order PO, after Purchase Requisition (PR) issued in the SAP system by Material and Inventory Management team and received by Buyer in

Purchasing Department, then the PR could be directly converted into PO in the system. Tender process only conducted once at the beginning to create the blanket contract, and no tender process required to issue PO based on the blanket contract. After Call-Out Order PO draft created in the system, then the PO draft circulated for approval and signature with approval flow similar with Spot Purchase PO approval flow. No Owner's Estimate need to be prepared for each Call-Out Order, due the price of material(s) in the PO already have a price reference as agreed on the blanket contract. Figure 4.4 shows simplified flow of the purchase phase to shows differences between Spot Purchase PO and Call-Out Order PO.

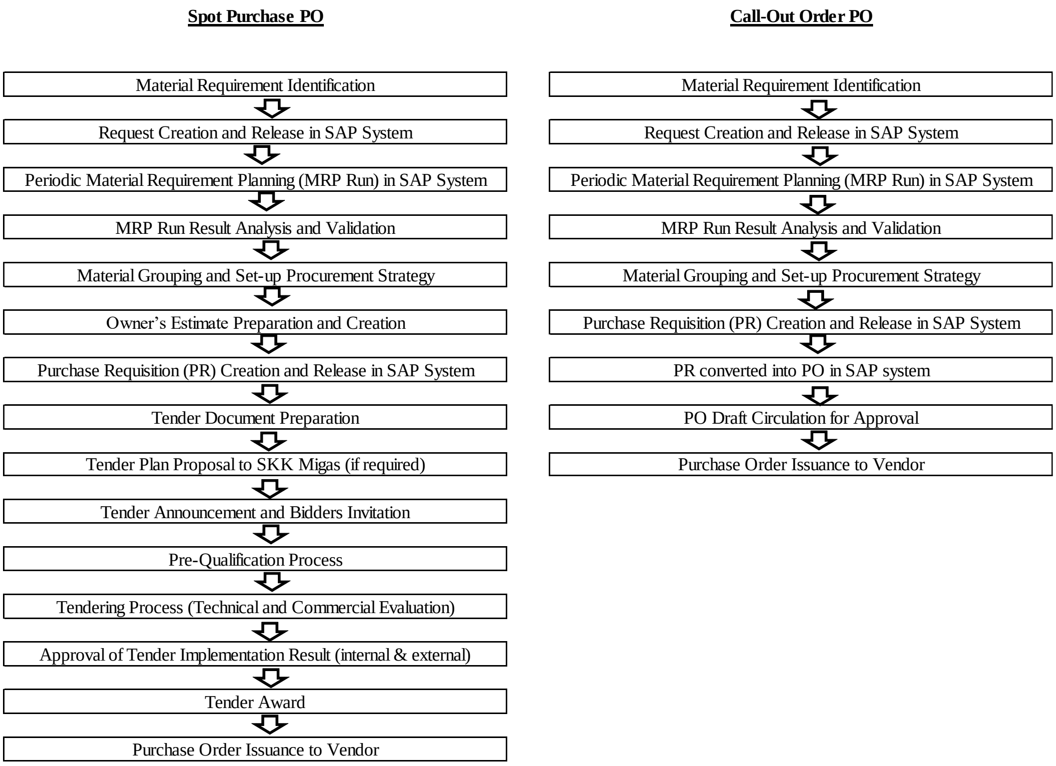


Figure 4.4. Different Process Flow between Spot Order PO and Call-Out Order PO

As per end of 2016 status, from 43,780 registered Stock Keeping Unit (SKU) for Field Operation, there are 7,681 SKU that already covered with blanket contract (69 Outline Agreement/Price Agreement). In term of number of SKU, mostly those contracts are for materials that has a sole agent available in Indonesia, but not all materials with sole agency has a blanket contract yet. Other contracts are non-sole agency materials but considered critical and requiring a continuous supply to support company's operational activities such as chemicals materials, mechanical seal, pigging materials, etc., or for materials with certain expiry date but need to be maintained in stock such as paint.

Since the nature of those 2 categories is different as shown on Figure 4.4 above, then lead time review for those categories shall also be segregated. Table 4.3 below shows the average and standard deviation of historical lead time, for Field Operation materials PO both for Spot Order and Call-Out Order types. Lead time presented in Table 4.3 is based on the duration from first PR issuance date until first PO released date in the SAP system. This data also show different PR-to-PO lead time figure based on different procurement method (CFT/DS/DA) for Spot Order PO.

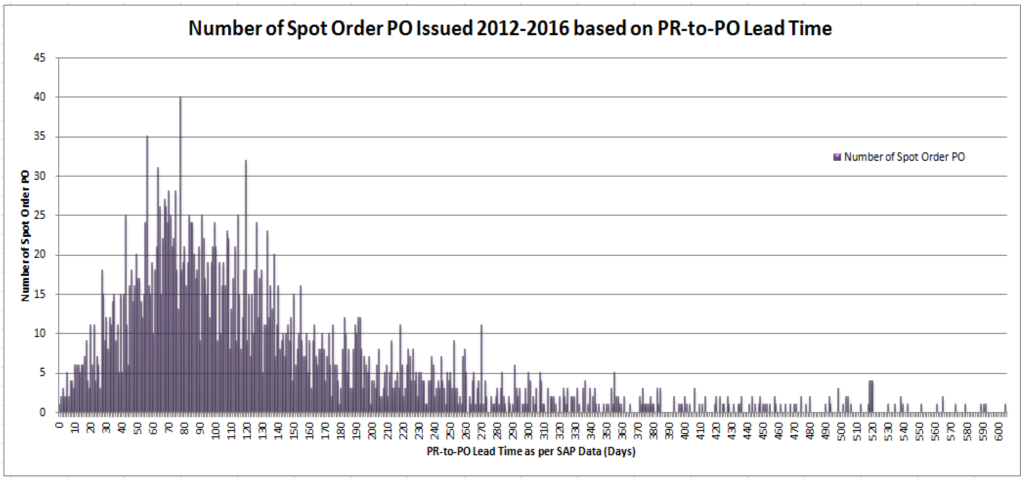


Figure 4.5. Number of Spot Order PO Issued 2012-2016 based on PR-to-PO Lead Time

Table 4.3. Historical Average and Standard Deviation Data of PR-to-PO Lead Time for Field Operation Materials PO

Category / Proc. Method	Average of Lead Time (days)					Standard Deviation of Lead Time (days)					Average of Lead Time (days) 2012-2016 Period	Standard Deviation of Lead Time (days) 2012-2016 Period
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016		
Spot Oder PO / CFT	168.5	300.5	362.2	332.3	263.2	76.11	126.5	149.1	188.3	108.2	299.18	150.37
Spot Oder PO / DS	141.6	166.9	171	135.5	120.1	100.6	116.8	112.2	91.0	53.7	148.47	102.40
Spot Oder PO / DA	93.2	114.8	126	119.1	111.4	66.9	88.9	105.8	76.5	76.8	109.69	84.01
Call-Out Order PO	8.31	8.85	20.4	26.6	20.9	17.1	14.7	35.7	47.3	37.3	16.10	32.35

2. Detail lead time data for each stage of material supply chain process
   a. PR-to-PO Detail Lead Time (in Purchase Phase)

To allow researcher to develop a detail current state of supply chain map and to have a more detail lead time data for each stage of procurement process to be further evaluated and analyzed on the next chapter, above presented PR-to-PO lead time data for Spot Order PO then need to be further breakdown into several smaller stages. Focus of further lead time data breakdown is on the Spot Order PO category, since the proportion of this category representing around 70% of total population of issued PO during 2012-2016 PO for Field Operation Material, and based on historical lead time figure presented on Table 4.3 above this category has a longer average lead time and bigger variability.

Different procurement method could lead to different lead time. Based on historical data, around 52% of Spot Order PO issued for Field Operation Material was procured through Direct Appointment method, 47% with Direct Selection method and 1% with Call for Tender method. This research will focus the lead time reduction analysis to the Spot Order PO which procured with Direct Selection (DS) method, with consideration that this category representing almost 50% of the overall executed tender process, current average lead time is considered still too high, and the tender process complexity is higher compare with Direct Appointment method (which mainly the Direct Appointment is triggered by sole agency status of the purchased material).

Based on available data and information that able to be collected, the PR-to-PO lead time in purchase phase for Direct Selection method then divided into 4 main stages as follow:

i. Initial Stage of Purchase

This stage is started from PR released in SAP system until Bid Submission by Bidder(s), which covering some activities e.g. PR assignment (in the SAP system) to Buyer, tender document preparation, pre-qualification process and Bidder selection, invitation to Bidder and pre bid meeting (if required).

ii. Evaluation Stage of Purchase

This stage is started from Bid Submission by Bidder, until result of commercial evaluation obtained. Some activities covered by this stage are technical evaluation, technical clarification (if any), commercial evaluation and negotiation process.

iii. Finalization Stage of Purchase

This stage is covering some activities such as PO draft creation in SAP system, approval of tender implementation result document preparation, circulation for approval of tender implementation result, PO release in SAP system by related authorized person, until PO final release in SAP system.

iv. Tender Award Stage of Purchase

This stage consist of tender winner announcement process, objection period for the tender result, objection response by tender committee for objection issued by Bidders (if any) and tender winner appointment.

Data for above detailed procurement stages of purchase phase are collected manually from available purchasing document data documented in PT.X system and data warehouse (for initial, evaluation, and finalization stage), also from direct interview with related key persons in PT.X supply chain function (for tender award stage). List of PO for sampling purpose prepared for data collection purpose, where 289 Spot Order PO are selected to be used for sample in this research from 1,423 Spot Order PO with Direct Selection procurement method that issued in the 2012-2016 period for Field Operation Materials. Based on data collected from those PO samples, Average, Standard Deviation, Minimum Value, Maximum Value and lead time (LT) Range for PR-to-PO DS procurement process then obtained and summarized as presented in Table 4.4. Data presented in this Table 4.4. is based on collected sample data for Spot Order PO with DS procurement method for one cycle of tender process (not taken into account lead time required for retender process if any).

Average of lead time used in this evaluation is to give a quick and representative interpretation regarding the performance of the supply chain function to the management. Average is commonly used as the value set in Key Performance Indicator (KPI) of lead time monitoring system. Standard deviation will give information regarding how the lead time performance is varied compare to the average lead time; whether the lead time is quite stable and close to the average lead time value or the lead time performance is vary significantly (spread in a wider range) from the average value.

Minimum and maximum value of the lead time also presented in this data evaluation. Minimum lead time figure could be an indicator of how far the lead time could be decreased/reduced, while maximum lead time figure will give an information regarding the worst possible situation related with lead time process that need to be anticipated by supply chain management and related parties such as end-user of the materials. This longest lead time figure (maximum value) could be used as one of consideration for end-user to planning their works that requiring the materials, to ensure that the material will be available to be used as per scheduled activities.

Table 4.4. Descriptive Statistics Figures of Sample Data for Direct Selection Procurement Method on Purchase Phase

	Stages in Purchase Phase			
	Initial Stage LT	**Evaluation Stage LT**	**Finalization Stage LT**	**Tender Award Stage LT**
Average	33.03	54.21	18.02	7
Standard Deviation	22.97	41.71	17.59	2
Min Value	5	1	1	
Max Value	144	278	111	

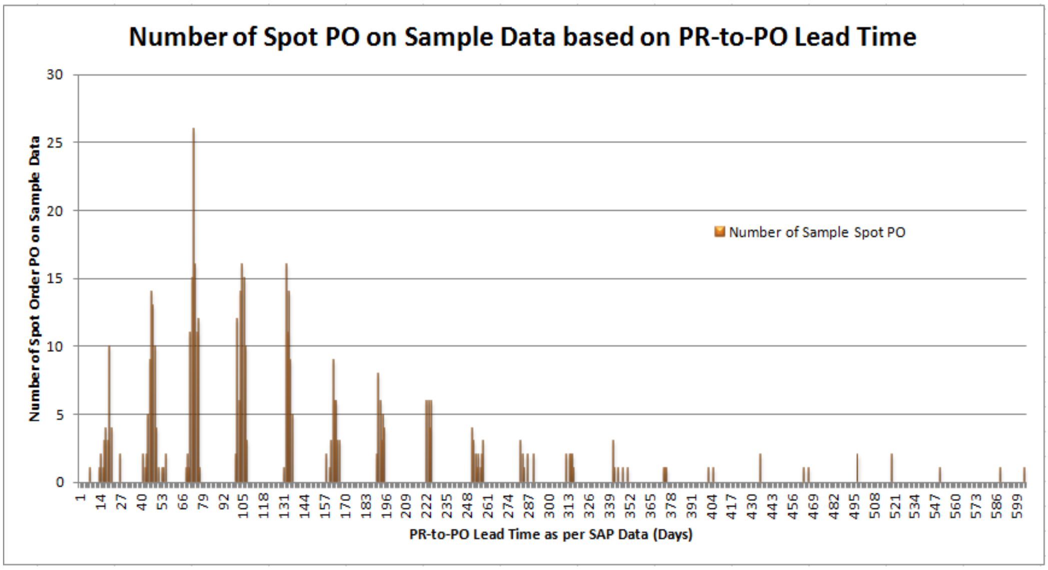


Figure 4.6. Number of Spot Order PO Sample based on PR-to-PO Lead Time

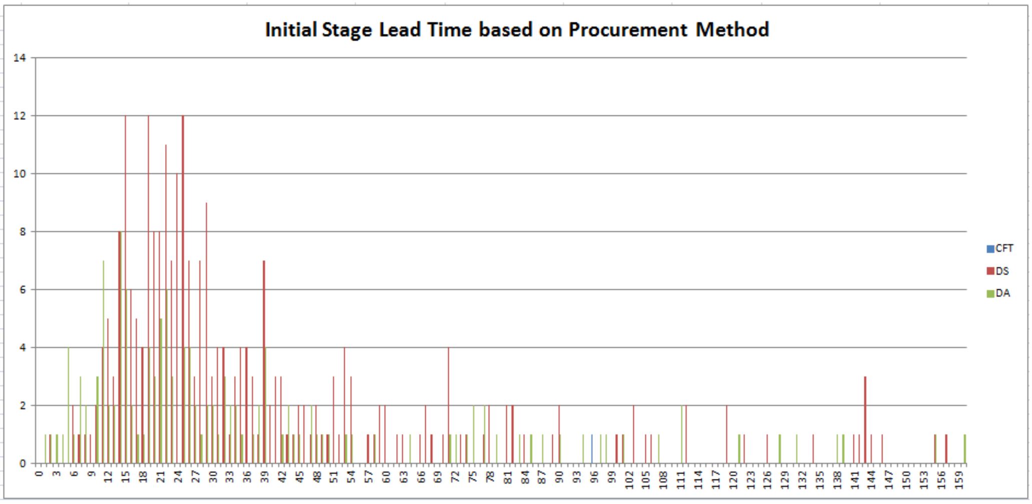


Figure 4.7. Sample Data Distribution for Initial Stage Lead Time based on Procurement Method

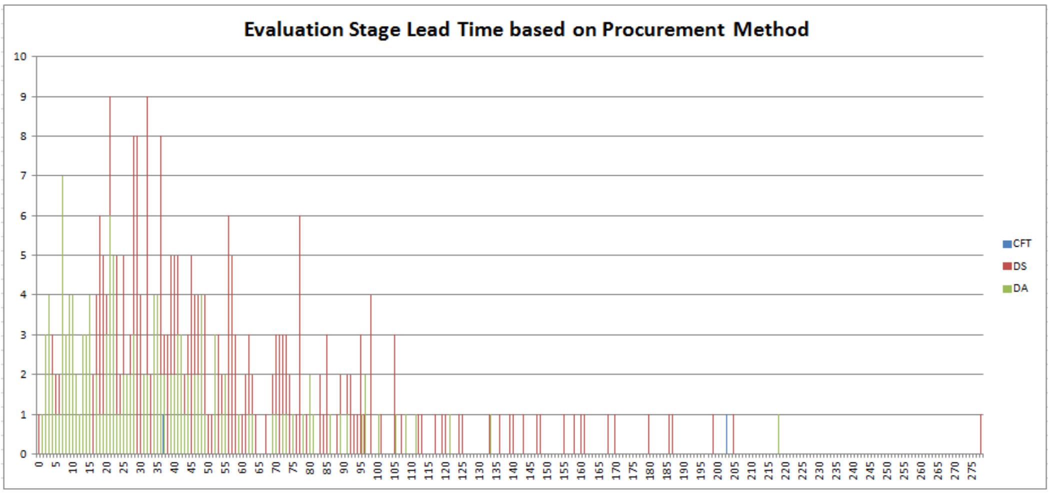


Figure 4.8. Sample Data Distribution for Evaluation Stage Lead Time based on Procurement Method

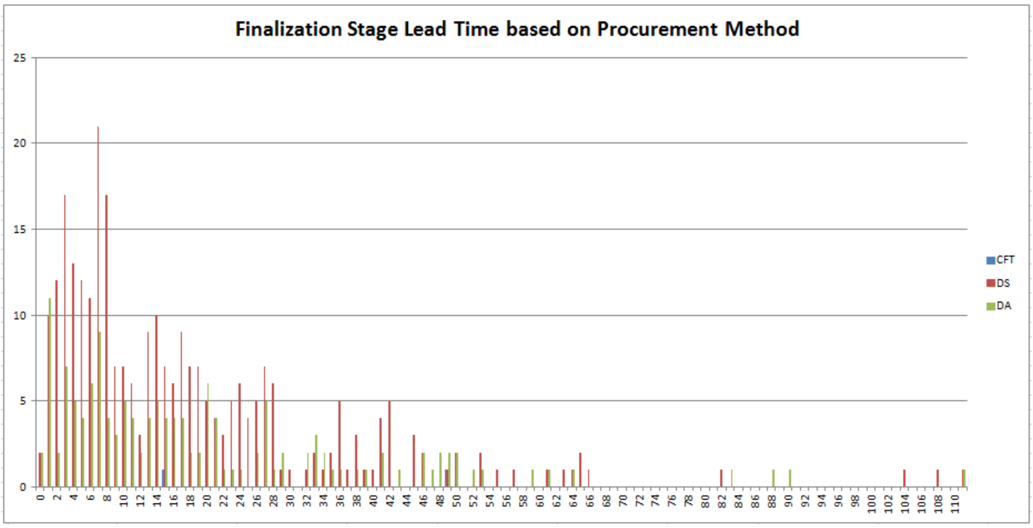


Figure 4.9. Sample Data Distribution for Finalization Stage Lead Time based on Procurement Method

As can be seen on Figure 4.6., 4.7., 4.8. and 4.9., data distribution of lead time in Purchase Phase are tend have a long tail on the right side. Most of the processes are fall on the area around the mean, but some processes are fall quite far from the mean (heavy long tail). This figure presentation could indicate that there are some uncontrollable processes in this supply chain phase, which could be triggered by missing control and monitoring of the process it self or by external uncontrollable factors (e.g. unexpected disruption, force majeure).

b. PO Issuance to Requirement Fulfillment Detail Lead Time (Commitment Follow-up Phase)

Since not all lead time information for each stage of material supply chain process could be directly retrieved from available documentation or system, then some data are need to be collected through direct interview to several key persons in the supply chain process in PT.X. Some lead time data in Commitment Follow-up Phase are taken from direct interview with related key persons within the company's supply chain related functions, while some other data could be retrieved from SAP system. Table 4.5 below shows average lead time for each stage in Commitment Follow-up Phase collected from available sources within PT.X's supply chain related functions.

Table 4.5. Historical Lead Time for Commitment Follow-up Phase

<table>
<tr><th>Activities</th><th>Average Lead Time</th><th>Data/Information Source</th></tr>
<tr><td>Tender Award Acknowledgement by Vendor</td><td>7 - 10 Days
(including document (hardcopy) circulation from PO final releaser to administration team who shall follow-up the award acknowledgment to vendor and waiting for vendor's confirmation on the award)</td><td>Direct Interview</td></tr>
<tr><td>Material Supply by Vendor</td><td colspan="2">Not taken into account in this research (external lead time)</td></tr>
<tr><td>Masterlist (tax exemption) Proposal to Authorities (if applicable)</td><td colspan="2">Not taken into account in this research (external lead time)</td></tr>
<tr><td rowspan="2">Material Acceptance and Warehousing</td><td>Material Acceptance:
1 - 2 Days for inspection process in average. Could take longer if certain inspection procedure need to be implemented (e.g. laboratory test for chemical materials where sample of material need to be sent to laboratory first for testing).</td><td>Direct Interview</td></tr>
<tr><td>Warehousing: Not further detailed, due to Warehousing duration shall depend on material requirement date from requester which could be vary from one case to another.</td><td>-</td></tr>
<tr><td>Material Transportation from Warehouse to Requester</td><td rowspan="2">Goods Issuance Material until Material Reception by Requester for 2012-2016 period:
- Average Lead Time = 22.06 Days
- Standard Deviation = 55.66 Days

Preparation time prior Goods Issuance = ± 7 days</td><td rowspan="2">SAP Historical Data & Direct Interview</td></tr>
<tr><td>Material Reception by Requester</td></tr>
</table>

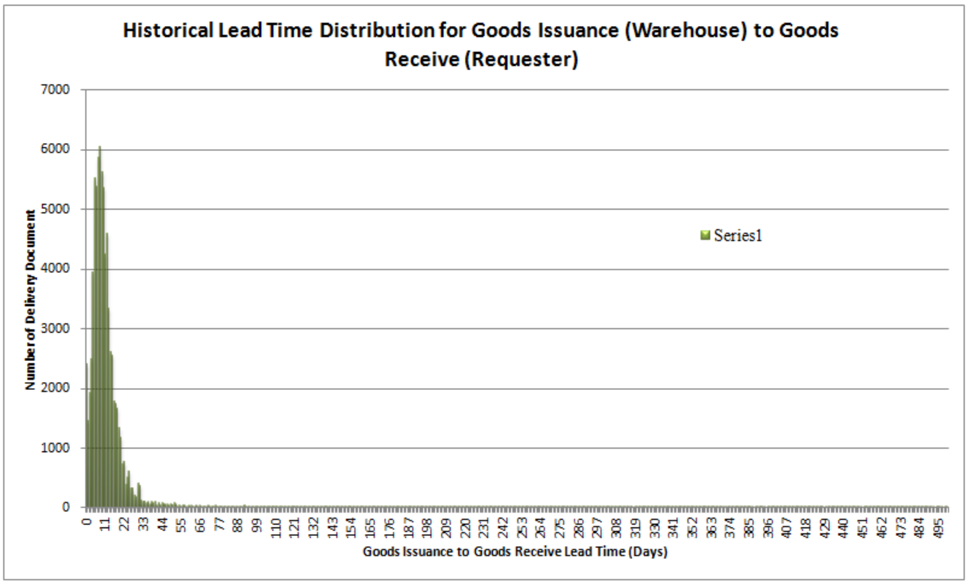


Figure 4.10. Historical Lead Time Distribution for Goods Issuance (by Warehouse) to Goods Received (by Requester) posted in SAP System

3. Key Performance Indicator (KPI) related with supply chain lead time

Key Performance Indicator (KPI) in PT.X which related with material supply chain is presented in Table 4.6 below. This information is gathered as additional input to this research and as a comparison between company's target and actual condition.

Table 4.6. Several Supply Chain Key Performance Indicator (KPI) in PT.X

KPI	KPI Objective	Report Frequency	Calculation	Unit	Target
Goods Procurement Lead Time	To measure the average Lead Time to carry out Goods Procurement process	Weekly & Monthly	Date of first PO released - Date of last PR released	Days	85 Days
Goods Procurement Backlog	To measure the number of Goods Procurement that already exceed the lead time target	Weekly & Monthly	Number of backlog ----------------------------- Number of total active procurement	%	Good < 25% Weak > 30%
Goods Inspection (Material Acceptance Process)	To measure the percentage of goods inspected	Weekly & Monthly	Number of Inspected Goods ----------------------------- Number of Inspected Goods + Number of Goods Awaiting Inspection	%	Good > 97% Weak < 80%

4.2. Current State Supply Chain Map Development and Waste Identification

4.2.1. Current State of Value Stream Mapping

Current state of Value Stream Mapping of material supply chain process presented in this part, which showing all main activities involved in the process, lead time figure (for several stages where the lead time data available), also information and physical flow along the process. Developed current state value stream map for material supply chain process of Field Operation materials in PT.X which processed using Direct Selection procurement method is presented in Attachment A, Figure A.1., A.2., A.3., A.4. A.5. and A.6.

4.2.2. Value Adding Activities, Non Value Adding (NVA) Activities and Necessary NVA Activities

The process of identifying the Value Adding (VA), Non Value Adding (NVA) and Necessary Non Value Adding (NNVA) activities is performed through evaluation on the current state map of business process and discussion with several experts in supply chain function. Several questions raise to help researcher and experts to define the category of certain activity whether it categorized as VA, NVA or NNVA activity; such as whether the activity contribute positively to the result of the process or not (e.g. in purchase phase: the activity is required to be performed and add value to the process of processing the PR into PO), if not contribute positively then whether the activity is still mandatory to be performed or not (can be removed/deleted from the process or not), and so on. The review conducted for each stage in the purchase phase and commitment follow-up phase (on material issuance process) by running through all activities involved/conducted on that stage.

Refer to developed current state map of material supply chain process for Spot Order PO with Direct Selection method in PT.X, most of activities involved in the process are categorized as Value Adding (VA) Activities or Necessary Non Value Adding (NNVA) Activities (necessary waste). Some Non Value Adding

(NVA) Activities also identified, which are clarification regarding un-clear requirement/specification/scope of order, protest by Bidders related with tender evaluation result (technical or commercial evaluation result) and waiting activity between two process/stage where no value added resulted from that waiting status.

Waiting activities identified in several stages along the process flow. These activities are considered as unnecessary waste and could contribute negative impact to overall supply chain performance in term of lead time. This kind of waste need to be eliminated whenever possible, or maintained as low as possible to ensure high performance and deliverability in supply chain function is obtained.

Waiting activities between two processed could be triggered by both controlable and uncontrolable factors. Controlable factors are for example unbalance work load, high number of PR to be processed, lack of monitoring/supervision, etc. Uncontrolable factor for example is waiting that caused by un-expected distruption to the supply chain process. In oil and gas business, there could be some unexpected condition or urgent request that could arise any time during the operation process which need to be prioritized and settled immediately. However, in this research, the assumption is the procurement process performed under normal operation condition and unexpected disruption from operational side is not taken into account in this review.

Value Adding Activities with long lead time data or big lead time variability are need to be reviewed and evaluated to seek for improvement to reduce the lead time. Necessary but Non Value Adding Activities (necessary waste) are also subjects for continuous improvement, since the existence of those activities is necessary but they not significantly contributing to result or value for the process especially related with the lead time of supply chain process. Waste (in this case additional lead time) as result of those Necessary but Non Value Adding (necessary NVA) Activities are need to be maintained as low as possible, to assure minimal waste impact to the overall process.

4.2.3. Dominant Waste Identification

Based on data collected from available sources within PT.X and combined with developed current state map of the material supply chain process, waste that considered as a dominant waste in Purchase and Commitment Follow-up Phase are listed in Table 4.7.

Table 4.7. Non Value Adding and Necessary Non Value Adding Activities in Purchase and Commitment Follow-up Phase

No	Activities	Category	Description	Lead Time	Phase
1	PR assignment process to Buyer through Buyer’s Coordinator	Necessary NVA	Released PR in SAP is assigned first to the Buyer's Coordinator, for further distribution within the team. This activity is necessary to allow proper workload distribution and correct PR assignment based on buyer's competencies. However, additional lead time occurs in this step and not all PR are directly assigned to related buyer once its released. In some cases, PR not yet assigned to buyer for more than 2 weeks from PR release date.	0.5 - 2 weeks	Purchase Phase
2	Clarification on un-clear requirement/ specification /scope of work	NVA	Un-clear requirement in PR could not be processed into procurement process properly. Clarification to stock team and technical user is required to clarify this issue, and will lead to additional lead time (for clarification and correction in the system).	2 – 7 Days	Purchase Phase
3	Notification to Bidder regarding Technical Evaluation Result & Objection Period	Necessary NVA	This activity is to notify and inform the Bidder regarding the technical evaluation result (whether they pass the evaluation or not).	3 Working Days	Purchase Phase

No	Activities	Category	Description	Lead Time	Phase
4	Objection from Bidder regarding technical disqualification decision or tender result	NVA	Objection is allowed by regulation, but it should be minimized if not eliminated. The objection period is mandatory in certain stages of tender process, so the objection period itself is categorized as Necessary NVA. If there is objection from Bidder, then the objection raised by the Bidder is categorized as NVA to the process.	3 - 10 Days (depend on complexity and number of objection issued by Bidder (1 or 2 times))	Purchase Phase
5	Order reconfirmation to stock team and technical user/requester	Necessary NVA	This activity exist as one of strategy to have a stringent purchase control. During purchase phase, there is possibility that the requirement from requester already changes, reduced, or even cancelled. Prior PO issuance, the initial order is then re-confirmed to stock team and related technical team/requester to assure that the requirement is still valid.	1 - 3 Days	Purchase Phase
6	Tender award acknowledgment by Vendor	Necessary NVA	This activity required to notify the Bidder regarding the award of the order, and to get confirmation from the awarded Bidder regarding their acceptance to the award. Printed PO document and complete tender document are sent from procurement team to the purchase admin team, then fax of tender award sent to Bidder. Document circulation from one location to another adds more unnecessary lead time to the process.	+/- 7 Days (2-3 Days for Document Circulation to Admin 3 Working Days for Vendor's Confirmation)	Commitment Follow-up Phase
7	Notification from Acceptance Team to Vendor regarding rejected material based on inspection result, and waiting material replacement from Vendor.	Necessary NVA	Rejection of supplied material need to be informed to Vendor for further collection and replacement with the correct/good material.	2 weeks (for material collection from company premises)	Commitment Follow-up Phase

No	Activities	Category	Description	Lead Time	Phase
8	Waiting (no activity between two processes)	NVA	No value adding activity conducted between two processes.	Vary (from only 1 – 2 days, or up to several weeks if the process is missed to be followed-up to the next step)	Purchase Phase and Commitment Follow-up Phase

4.2.4. Select Procurement Stage(s) for Further Review and Analysis

Data related with lead time for several stages of material supply chain process already collected and presented on part 4.1.2 of this chapter. Based on available statistical and historical information, also considering feedback from experts involved in this research evaluation, several stages of the supply chain process are then selected to be further reviewed and analyzed on the next chapter of this research.

Long internal lead time and big lead time data variability are two main considerations in selecting which stages to be further reviewed. Considering historical lead time average and standard deviation data, 3 stages are selected by researcher for further review as follow:

1. Initial Stage Lead Time on Purchase Phase → long average lead time and big data variability
2. Evaluation Stage Lead Time on Purchase Phase → long average lead time and big data variability
3. Material issuance from Warehouse until received by Requester → big data variability

CHAPTER 5
ANALYSIS AND DISCUSSION

Following data collection and processing that already conducted and presented in previous chapter, further review and analysis is conducted in this stage of research. To ensure that the final conclusions of this research are in line with the research objective and scope, analysis and discussion in this chapter is conducting with refer to initially formulized and identified problems. Root cause analysis of the lead time problem will be the first step of analysis, to allow researcher to develop improvement strategy for lead time reduction on the next step of the analysis and evaluation. Future state map of the material supply chain process then to be developed based on proposed improvement strategies, and potential impact of the proposed improvement strategy(s) will then be estimated at the end of this chapter.

5.1. Root Cause Analysis of Lead Time Problem

Root Cause Analysis conducted to identify causes of the lead time issue in material supply chain of PT.X, specifically for material of Field Operation. As defined earlier in previous chapter, stages of supply chain process that to be further reviewed and analyzed for lead time improvement possibility are Initial Stage of Purchase Phase, Evaluation Stage of Purchase Phase and Material issuance from Warehouse until received by Requester in Commitment Follow-up Phase. Combining Cause and Effect Diagrams (Fishbone Diagram) and brainstorming with experts in supply chain process, identified possible root causes of the lead time problem for those stages are presented in Figure 5.1, 5.2 and 5.3.

Root causes identified and presented on Cause and Effect Diagrams then further reviewed and analyzed to identify possible improvement strategy for lead time reduction. Identified possible improvements to current business process that might have impact to supply chain lead time reduction are presented in Table 5.1.

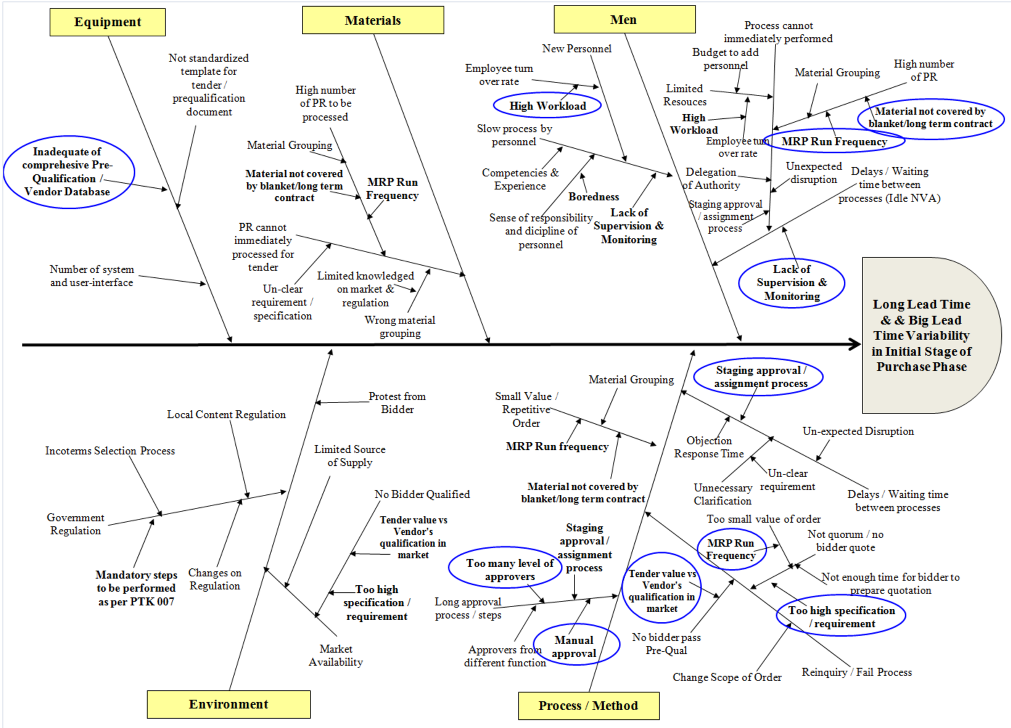


Figure 5.1. Cause and Effect Diagram of Lead Time Problem in Initial Stage of Purchase Phase

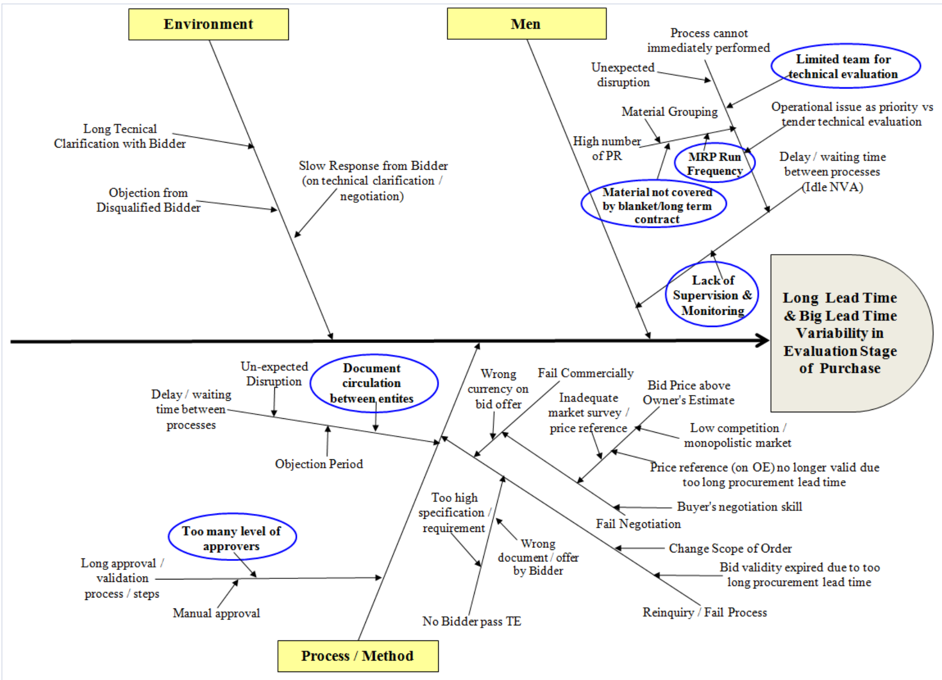


Figure 5.2. Cause and Effect Diagram of Lead Time Problem in Evaluation Stage of Purchase Phase

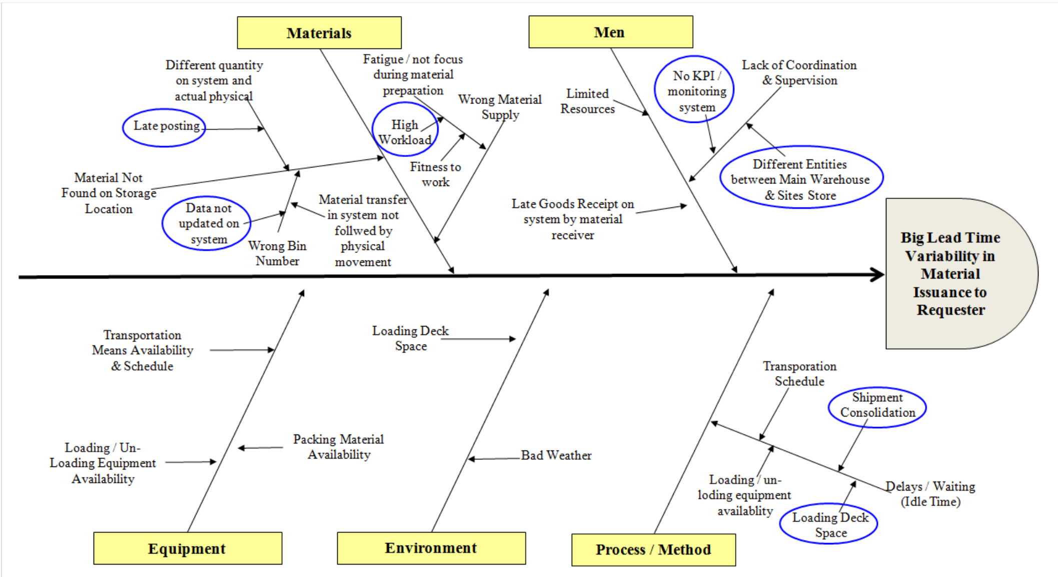


Figure 5.3. Cause and Effect Diagram of Lead Time Problem in Material Issuance Process until Received by Requester

Table 5.1. Improvement Recommendation for Identified Root Causes of Lead Time Problem

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
1	Lack of Supervision & Monitoring	Initial Stage of Purchase	Men; Process/ Method	Waiting	1.1. Set up KPI for each stage of procurement process. Monitoring tools to be developed and data recorded properly to allow performance evaluation to be performed. Percentage of backlog process to be distributed to all team periodically.
		Evaluation Stage of Purchase	Men		
2	Staging approval/ assignment process	Initial Stage of Purchase	Men; Process/ Method	Waiting; Processing	2.1. Monitoring tools & KPI for PR assignment is to be set-up. PR assignment process shall not exceed 1 week period from PR release in SAP system.

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
3	High Workload	Initial Stage of Purchase	Men	Waiting	3.1. Review current workload on procurement team. Assess any requirement to add more personnel, or to rearrange the work distribution among the team. 3.2. To assign PR for call out order PO to a dedicated team/personnel, not to be mixed up with team to handle PR for spot order PO. 3.3. Maximize implementation of blanket/long term contract/agreement.
4	Competencies & Experience	Initial Stage of Purchase	Men	Waiting	4.1. Set up new comer induction program. 4.2. Motivate team through refreshment training session (soft & technical skill training). 4.3. Motivate team through direct appreciation, such as 'buyer of the month' title. Criteria could be based on agreed KPI and actual performance of the buyer. 4.4. To rotate personnel those already long enough on the same position. 4.5. Improve buyer's skill on negotiation through training and sharing negotiation experience.
5	MRP Run frequency (which lead to number of PR that need to be processed)	Initial Stage of Purchase	Men; Process/ Method; Materials	Waiting; Processing	5.1. MRP Run frequency (retrieval of requirement consolidation data in SAP system) proposed to be conducted per 2 months, instead of monthly basis --> expected to resulting higher PR value and items quantity. 5.2. Material parameter setting to be periodically reviewed, to assure the minimum-maximum stock level setting is up to date,
		Evaluation Stage of Purchase	Men		

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
					considering also current lead time supply.
6	Material not covered yet by blanket/ long term contract/ agreement	Initial Stage of Purchase	Men; Process/ Method; Materials	Waiting; Processing	6.1. Maximizing implementation of blanket contract/agreement to cut procurement process lead time significantly.
		Evaluation Stage of Purchase	Men		
7	Manual/ paper based approval process	Initial Stage of Purchase	Process/ Method	Waiting; Processing; Transportat ion / Movement Between Different Department	7.1. Implementing electronic/digital approval for tender document approval, especially for those that not requiring SKK Migas approval. 7.2. Centralizing paper document review & approval for Pre-Qualification process on one work station/location, with periodically team review (e.g. twice a week).
		Evaluation Stage of Purchase	Process/ Method		
8	Too many level of approvers	Initial Stage of Purchase	Process/ Method	Waiting; Transportat ion / Movement Between Different Department	8.1. Implementing electronic/digital approval for tender document approval. 8.2. Change level of technical evaluation result approval and validation to be up to Head of Department (instead of up to Head of Division). 8.3. To review current level of value that managed by Internal Procurement Team, from 50,000 USD to be at least 500,000 USD to simplify the approval and circulation process. As per regulated in PTK 007, Internal Procurement Team could handle procurement value up to 1,000,000 USD.
		Evaluation Stage of Purchase	Process/ Method		
9	Too high specification/ requirement	Initial Stage of Purchase	Process/ Method; Environment	Processing	9.1. Review technical requirement of frequently fail items, also reason of technical disqualification. If the requirement is not available in market (specification too high) or the
		Evaluation Stage of Purchase	Process/ Method		

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
					specification still un-clear, to review and redefine the requirement. Issue technical derogation request if necessary.
10	Tender value not match with vendor's qualification that able to supply the material (too small value of order	Initial Stage of Purchase	Process/ Method; Environment	Processing	10.1. Review historical fail process due to market availability issue, and the constraint to be communicated in supply chain and technical team coordination meeting. Feedback regarding market knowledge to be informed to PR creator and technical team that perform the final material grouping.
11	Protest / Objection from Bidders	Initial Stage of Purchase	Process/ Method; Environment	Waiting	11.1. To assure that the objection responded at the soonest (not to wait until the limit period to respond); to assure also that disqualification of Bidder(s) is conducted professionally and justified, to minimize possibility of objection from Bidder regarding the disqualification decision. 11.2. Maximizing implementation of blanket contract/agreement.
		Evaluation Stage of Purchase	Process/ Method; Environment		
12	Mandatory steps to be performed as per PTK 007 regulation	Initial Stage of Purchase	Environment	Waiting; Processing	12.1. Certain steps regulated in PTK 007 including the minimum duration to perform the task/step. To set the process with the minimum required duration as per regulation whenever possible.
13	Changes on regulation (related with tendering process) which might need adjustment to	Initial Stage of Purchase	Environment	Waiting	13.1. This type of waste cannot be controlled by company. To respond the changes as soon as possible. Dedicated team/task-force to be deployed to speed-up any adjustments that need to be implemented.

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
	the existing business process				13.2. Implementation of blanket/long term contract/agreement to avoid such delay due to change on regulation related with tender process.
14	Inadequate comprehend-sive pre-qualification/ vendor database	Initial Stage of Purchase	Equipment	Waiting; Processing	14.1. Enhance current vendor's database to accommodate database of Pre-Qualification process. 14.2. Maximize utilization of previously conducted Pre-Qualification result whenever relevant same commodity/category) and still valid (as per regulation). Information on pre-qualification category/commodity and the validity shall be available on the vendor's database. 14.3. Pre-Qualification Result template to be standardized, to be able to be incorporated in the vendor's database. 14.4. Need to assign dedicated person/team to maintain data and requirement related with Vendor's qualification process.
15	Un-clear requirement or specifications which add more time for clarification to requester and request modification (if necessary).	Initial Stage of Purchase	Process/ Method; Materials	Waiting; Defect	15.1. This kind of waste shall be avoided as much as possible. Filter on stock team shall be increased, to assure PR quality already adequate to be processed in to procurement process. Increase technical knowledge of stock team through internal knowledge sharing (with technical user), visit to warehouse or manufacturer if possible, etc.
16	Change scope of order	Initial Stage of	Process/ Method	Processing	16.1. Changes of specification after tender

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
		Purchase			process launched shall be avoided as much as possible (since it will lead to tender cancellation and new tender to be issued). User's supervisor is to assure that request placed on system shall already confirmed, and to assure no double request for the same requirement (handover process between end-user's back-to-back shall be comprehensive and proper).
		Evaluation Stage of Purchase	Process/ Method		
17	Work prioritization between operational and administrative task of technical team	Evaluation Stage of Purchase	Men	Waiting	17.1. Technical team responsibility is not only related with technical review in tender process, but also other operational task as well. To set an agreed timeline/lead time for technical evaluation, considering complexity and type of materials reviewed.
18	Limited team for technical evaluation & clarification	Evaluation Stage of Purchase	Men	Waiting	18.1. Reduce number of tender process to be reviewed by technical evaluator, by reducing load for procurement process (reduce PR number, maximized utilization of blanket contract). 18.2. Review option to add personnel in technical team to accelerate the technical evaluation process.
19	Document circulation between entities	Evaluation Stage of Purchase	Process/ Method	Waiting; Transportation / Movement Between Different Department	19.1. Utilize electronic document instead of paper based document.

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
20	Slow response from bidders during clarification process	Evaluation Stage of Purchase	Environment	Waiting	20.1. Re-emphasized supplier relationship management approach 20.2. Maximize utilization of blanket/long term contract/agreement
21	Inadequate market survey / price reference on Owner's Estimate preparation	Evaluation Stage of Purchase	Process/ Method	Processing; Defect	21.1. Assure Owner's Estimate prepared with sufficient market and price information.
22	Loading Deck space availability	Material issuance from warehouse to requester	Process/ Method; Environment	Waiting	22.1. To review and assess possible improvement on loading deck space and layout. Check possibility to set-up transit area near the loading deck of possible.
23	Shipment consolidation process	Material issuance from warehouse to requester	Process/ Method	Waiting	23.1. To set-up agreed waiting time for shipment consolidation process, to be incorporated in KPI of material issuance lead time. 23.2. To assure monitoring on material shipment status.
24	Loading/un-loading equipment availability	Material issuance from warehouse to requester	Equipment	Waiting	24.1. To review occurrences and impact severity of loading/un-loading equipment unavailability to lead time of material issuance, also reason of the unavailability (occupied on other location, break, under maintenance, etc.). Decision to add loading/un-loading equipment or not shall be based on futher deep analysis on current condition.
25	Transportation means availability and schedule	Material issuance from warehouse to requester	Equipment	Waiting	25.1. To review occurrences and impact severity of transportation means unavailability to lead time of material issuance, also reason of the unavailability (occupied on other location, break, under maintenance,

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
					material preparation schedule not meet with transportation schedule (missed the schedule), etc.). Decision to add/modify transportation means schedule or not shall be based on further deep analysis on current condition.
26	Late posting in SAP system	Material issuance from warehouse to requester	Men; Materials	Defect	26.1. Assure all Goods Receive process posted immediately on SAP system to assure same quantity between data on system and actual physical quantity, and to close the material issuance process on system (as confirmation that material already received by Site). Late posting shall be minimized as much as possible if not able to be eliminated. 26.2. Set up agreed KPI for goods receive lead time on Site. Monitor the lead time performance.
27	Data of material location not updated on SAP system	Material issuance from warehouse to requester	Materials	Movement	27.1. Assure material located on correct location and Bin Number updated anytime there is movement or modification. 27.2. Assure all Goods Issuance transaction posted immediately on SAP system to assure same quantity between data on system and actual physical quantity. Avoid material picking without a proper record on system.

No	Root Cause	Stage	RCA Point	Waste Category	Improvement Recommendation
28	High workload	Material issuance from warehouse to requester	Men; Materials	Waiting; Processing	28.1. Conduct work load analysis and scope of work of current available team. Re-define scope of work if necessary (e.g. in the case of one person handling to many tasks with short deadline), assess manpower requirement for each station. 28.2. Re-emphasized to personnel regarding the importance of self fitness and proper working condition awareness.
29	No KPI / monitoring system	Material issuance from warehouse to requester	Men	Waiting	29.1. To set-up KPI regarding material issuance process, and develop monitoring tools for these activities.
30	Different entities between main warehouse and remote store on sites location	Material issuance from warehouse to requester	Men	Processing	30.1. Periodic coordination meeting to review supply chain performance need to be conducted. 30.2. Review current organization structure where Main Warehouse and Site Storage Location are managed under different Division. To consider to re-arrange Site Store Keeper role to be under Main Warehouse management for easier coordination and communication.

5.2. Develop Improvement Strategy for Lead Time Reduction

Considering input and discussion result with several experts involved in this research, incorporate also literature review conducted earlier, several specific improvement strategies are set up as detailed in Table 5.2 and 5.3, which including also the estimated possible lead time reduction from the proposed strategies. Expected lead time reduction on Purchase Phase of material supply chain set up in Table 5.2 is taken into account as well the lead time for tender process that regulated by *Satuan Kerja Khusus Pelaksana Kegiatan Usaha Hulu Minyak dan Gas Bumi (SKK Migas)* through *Petunjuk Pelaksanaan Tender Nomor: EDR-0167/SKKMH0000/2017/S7* issued 2017. To be noted that lead time considered in this evaluation is for one cycle of tender process, not yet considering additional lead time for retender process if required.

As mentioned on the Chapter VII Article 22.1 of *Petunjuk Pelaksanaan Tender Nomor: EDR-0167/SKKMH0000/2017/S7*, material procurement process shall be conducted with maximum duration of 60 working days which counted started from tender announcement until winner announcement (excluding process approval involving SKK Migas if required). It is mentioned also some minimum duration for specific activities along the tender process, i.e.:

1. Tender Announcement: minimum 2 working days.
2. Bidders Registration period: minimum 2 working days, started 1 day after announcement date.
3. Potential Bidder objection on disqualification on qualification result: sent by Bidder maximum 2 working days after announcement of disqualification result (started 1 day after announcement date). Response from company (PT.X) sent maximum 2 working days (started 1 day objection received).
4. Tender document collection by Bidder: minimum 2 working days, started 1 day after latest registration day or qualification result announcement.
5. Pre Bid Meeting (if required): minimum 2 working days from latest days of bid collection period.
6. Protest on tender document content: maximum 4 working days before Bid Submission date or as per defined by tender committee.
7. Response on protest: maximum 2 working days, counted 1 day after protest letter received.
8. Bid Submission: minimum 5 working days after latest pre bid meeting or clarification meeting.

9. Objection period for 1 envelope system tender: 2 working days after winner announcement date.
10. Objection period for 2 envelopes or 2 stages tender: 2 working days after technical evaluation result announcement, and 2 working days after winner announcement date.
11. Response on objection: maximum 2 working days, counted 1 day after objection letter received.
12. 2^{nd} Objection: allowed 1 time only, by maximum 2 working days after deadline for 1^{st} objection response is ended.

Table 5.2. Improvement Strategy Recommendation for Lead Time Reduction in Purchase Phase

Scenario #	Improvement Recommendation	Impact to	Current Lead Time Statistics		Expected New Lead Time Statistics	
			Average	Standard Deviation	Average	Standard Deviation
1	Maximizing implementation of blanket/long term contract/agreement to cut procurement process lead time significantly.	Initial Stage	33.03	22.97	3	2
		Evaluation Stage	54.21	41.72	0	0
		Finalization Stage	18.02	17.59	10	3
		Tender Award	7	2	2	1
2	Implementing electronic/digital approval for tender document approval.	Initial Stage	33.03	22.97	32	22
3	Pre-Qualification: - Enhance current vendor's database to accommodate database of Pre-Qualification process - Maximize utilization of previously conducted Pre-Qualification result - Pre-Qualification Result template standardization - Dedicated person/team to maintain data and requirement related with Vendor's qualification process	Initial Stage	33.03	22.97	31	21

Scenario #	Improvement Recommendation	Impact to	Current Lead Time Statistics		Expected New Lead Time Statistics	
			Average	Standard Deviation	Average	Standard Deviation
4	Buyer's workload review. Consider rotation position of Buyers. Assign PR follow-up for Call-Out Order PO to specific team/Buyer, not to be mixed up with Buyer's for Spot-Order PO tender process.	Initial Stage	33.03	22.97	29	19
5	Additional person in technical team to accelerate process evaluation on technical user's side.	Evaluation Stage	54.21	41.72	47	35
6	Agreed standard technical evaluation lead time with technical team. Include the monitoring on tender lead time monitoring tools.	Evaluation Stage	54.21	41.72	43	21
7	Modify approval level of technical evaluation result validation (up to level of Department Head instead of Division Head). This will reduce document circulation process and lead time approval.	Evaluation Stage	54.21	41.72	51	41
8	MRP Run Frequency from monthly basis to be bi-monthly basis (every 2 months)	Initial Stage	33.03	22.97	23	16
		Evaluation Stage	54.21	41.72	37	29

As previously mentioned, material issuance process from Warehouse to Requester is involving several different functions which are Warehouse team, Logistic Team, and Sites Store Keeper. Based on previously performed Root Cause Analysis, improvement strategy recommendations for this material issuance process are listed on Table 5.3.

Table 5.3. Improvement Strategy Recommendation for Lead Time Reduction in Material Issuance Process

No	Root Cause of Lead Time Problem	Improvement Recommendation
1	No KPI / monitoring system. Currently there is no specific KPI that used to monitor this particular activity. Lack of monitoring and awareness causing some lead time from Goods Issuance until Goods Receipt in SAP system is fall on the area that considered too long and unrealistic (more than 1 year).	1.1. To set up Key Performance Indicator (KPI) and monitoring tools/report. 1.2. Review current organization structure. Propose to move Site Store Keeper function to be under Warehouse Management instead of User's entity. 1.3. Periodic coordination meeting between parties.
2	Limited Resources	Conduct work load analysis and scope of work of current available team. Re-define scope of work if necessary (e.g. in the case of one person handling too many tasks with short deadline), assess manpower requirement for each station.
3	Late posting of Goods Receive in SAP system	Assure all Goods Receive process posted immediately on SAP system to assure same quantity between data on system and actual physical quantity, and to close the material issuance process on system (as confirmation that material already received by Site). Late posting shall be minimized as much as possible if not able to be eliminated.
4	Material not found on recorded storage location	4.1. Assure material located on correct location and Bin Number updated anytime there is movement or modification. **4.2.** Assure all Goods Issuance transaction posted immediately on SAP system to assure same quantity between data on system and actual physical quantity. Avoid material picking without a proper record on system.

For material issuance process lead time, it is expected that the future improved lead time is around 20 days in average (from material preparation on warehouse until material received by requester) from current average lead time which is 29 days (7 days for material preparation and 22 days for transportation and receipt). This target lead time 20 Days is based on some assumptions as per discussion with experts and input from several related function, which are:

- Material preparation by Warehouse until Good Issue = 5 – 7 days
- Transportation by Logistic (Shipment Start until Shipment End) = 8 days
- Goods Receipt (Shipment End until Good Receipt) = 7 days

Standard deviation of the lead time performance of material issuance process also expected to be significantly reduced by stringent control and monitoring on the lead time process. New expected standard deviation is 14 days compare with current figure which is 55 days. Big data variability in this material issuance process is mainly triggered by lack of monitoring and awareness, also high work load to be managed which resulting in late posting in the SAP system for actual process that already finished.

5.3. Future State Value Stream Map

Future state map Development based on implementation of proposed recommendation that applied on Initial Stage of Purchase Phase, Evaluation Stage of Purchase Phase, and Material Issuance Process in Commitment Follow-up Phase are presented in Attachment B, Figure B.1., B.2., B.3. and B.4. The value stream map shows information on some changes such as modification of document type from manual (paper) to be electronically/digital, eliminating certain level of approver, and so on.

5.4. Simulate the Potential Lead Time Improvement to Estimate Possible Impact of the Proposed Recommendation

In this stage, potential lead time improvement from the developed future state Value Stream Mapping is simulated by using Monte Carlo Simulation approach, to estimate possible impact of the proposed Value Stream Mapping and recommendation for process improvement. Part of lead time improvement that will be simulated in this stage is improvement on the Purchase Phase of material supply.

5.4.1. Set up the Lead Time Model

Lead time model for this evaluation is as follow:

$$TLTP_j = LT_{1,j} + LT_{2,j} + LT_{3.j} + LT_{4,j} \tag{5.1}$$

where

$TLTP_j$ = Total Lead Time Purchase Phase for iteration *j*

$LT_{1,j}$ = Lead Time Initial Stage of Purchase Phase for iteration *j*

$LT_{2,j}$ = Lead Time Evaluation Stage of Purchase Phase for iteration *j*

$LT_{3,j}$ = Lead Time Finalization Stage of Purchase Phase for iteration *j*

$LT_{4,j}$ = Lead Time Tender Award Stage of Purchase Phase for iteration *j*

5.4.2. Fit Probability Distribution

Prior performing Monte Carlo Simulation, distribution and parameter(s) for each input used in the Total Lead Time model need to be defined. Based on normality test using Anderson Darling, Ryan-Joiner and Kolmogorov-Smirnov to all available sample data of each stages being reviewed, none of those data are normally distributed. Further test is conducted to check whether the data follow a Poisson distribution or not by conducting Goodness of Fit Test for Poisson, with result that none of the data follows Poisson distribution.

Individual Distribution Identification (Minitab function) then executed to obtain the suitable distribution type for each evaluated data. Goodness of Fit test conducted with hypothesis and significance level (α) as follow:

Hypothesis:

Ho : the distribution type adequately describe the data

H1 : the distribution type not adequately describe the data

$\alpha = 0.01$

Results of the distribution identification process are detailed as follow:

Initial Stage of Purchase Phase

Two distribution models are considered best fit for initial stage of purchase phase lead time data, i.e. Loglogistic Distribution (AD = 0.863, p-value = 0.015) and Lognormal Distribution (AD = 0.981, p-value = 0.013). Loglogistic distribution model is selected to represent the Initial Stage of Purchase Phase lead time, with parameters as follow:

Location = 3.29029

Scale = 0.33970

Evaluation Stage of Purchase Phase

Two distribution models are considered best fit for evaluation stage of purchase phase lead time data, i.e. Gamma Distribution (AD = 0.994, p-value = 0.017) and Loglogistic Distribution (AD = 0.905, p-value = 0.010). Gamma distribution model is selected to represent the Evaluation Stage of Purchase Phase lead time, with parameters as follow:

Shape = 1.80992

Scale = 29.95229

Finalization of Purchase Phase

Three distribution models are considered best fit for finalization stage of purchase phase lead time data, i.e. 2-Parameter Exponential Distribution (AD = 1.586, p-value = 0.025), Gamma Distribution (AD = 0.942, p-value = 0.022) and Weibull Distribution (AD = 0.974, p-value = 0.015). 2-Parameter Exponential distribution model is selected to represent the Evaluation Stage of Purchase Phase lead time, with parameters as follow:

Scale = 17.08392

Threshold = 0.94047

Tender Award of Purchase Phase

Based on information collected and discussion with experts, Tender Award of Purchase Phase is assumed to be normally distributed with parameters as follow:

Average = 7

Standard Deviation = 2

Correlation between Stages

Correlation between Initial Stage, Evaluation Stage and Finalization Stage of Purchase Phase is analyzed in this stage. Spearman Rank Order and Pearson product moment correlation coefficient used to evaluate any correlation between two variables, where they measure the degree of linear relationship between those two variables. Correlation of those 3 stages with Tender Award Stage of Purchase Phase are not evaluated here due to the lead time profile of this Tender Award Stage is considered quite standardized and no historical sample data available to be compared in this correlation analysis. Correlations between Initial Stage, Evaluation Stage and Finalization Stage in purchase phase are as follow:

Table 5.4. Data correlation between each stage in Purchase Phase

	Initial Stage	**Evaluation Stage**
Evaluation Stage	Spearman’s rank correlation = 0.251 Pearson correlation = 0.111	
Finalization Stage	Spearman’s rank correlation = 0.031 Pearson correlation = 0.642	Spearman’s rank correlation = 0.062 Pearson correlation = 0.055

As shown in Table 5.4 above, all correlation coefficients are positive for all analyzed variables, which means those two variables (with positive correlation coefficient value) are tend to increase together. Positive correlation of lead time data between one stage to another stage is likely to exist in the purchase phase, due to different urgency from one tender process to another. For urgent tender process, normally shorter lead time in one stage will also likely to occur on the next stage, except there is any significant disruption to the process.

5.4.3. Perform Monte Carlo Simulation and Sensitivity Analysis

After data distribution and parameter defined, the next step is to generate the random number for iteration purpose. In total 100,000 random numbers generated for each data distribution. Random number with Uniform distribution between 0 and 1 is generated, to be used as input variable in Inverse Cumulative Probability function. Inverse Cumulative Probability for each predetermined distribution is performed for 100,000 iteration in Minitab Software.

Monte Carlo Simulation performed for 100,000 iterations with pre-determined total lead time formula. Result of the simulation (As Is Total Lead Time Purchase) then compared with the actual total lead time data obtained from collected samples to identify any significant differences between those two data distribution. This process conducted to ensure that the developed model used for Monte Carlo Simulation already valid to perform further analysis.

To examine differences between two distributions statistically, first the normality test perform to As Is Total Lead Time Purchase and Actual Sample Total Lead Time Purchase which suggesting that both data are not following normal distribution. Mann-Whitney U-test then performed to examine both data, with hypothesis and significance level (α) as follow:

Hypothesis:

Ho : the two population medians are equal

H1 : the two population medians are not equal

$\alpha = 0.05$

Based on result of the Mann-Whitney U-test, the test is significant at 0.6919, so we may conclude that the medians of both As Is Total Lead Time Purchase data and Actual Sample Total Lead Time Purchase are equal. Total Lead Time Purchase model in this simulation considered valid for further evaluation.

To compare sensitivity of data input changes on certain stage to the overall lead time result, further analysis is performed by simulating the changes on the parameter on certain stage while maintaining same parameter on other stages. Best case output is the As Is Total Lead Time Purchase data resulting from the simulation of the model. Simulation then re-run with the modified input parameter for each stage that the sensitivity is being analyzed. Input parameter that modified in this simulation are the Scale parameter for Initial Stage, Evaluation Stage and Finalization Stage which adjusted by 50% smaller, and Average of Tender Award Stage that adjusted by 50% smaller also. Output changes as impact of the input modification for each scenario then calculated. Sensitivity of the particular stage then calculated by dividing the percentage changes of output with the percentage changes in the input. Based on this simulation, it is shows that the most sensitive stage is the Evaluation Stage, followed by the Initial Stage, Final Stage and the least one is Tender Award Stage.

5.4.4. Perform What-If Analysis

In this stage, what-if analysis performed based on improvement strategy scenarios listed in Table 5.2 which then introduced to the simulation model that already developed. New parameter for probability distribution of the introduced scenario is defining based on discussion and information gathered from all related subject matter experts involved in this research. New lead time distributions as result of the scenario implementation simulation were defined by adjusting statistical parameters of the original lead time distribution. Simulation results for each proposed scenario are as follow:

Table 5.5. Estimated Impact of Proposed Improvement Strategy for Purchase Phase

Scenario #	Improvement Recommendation	Current Condition Total Lead Time	Improved Condition Estimated Total Lead Time	Estimated Reduction Impact to Average Lead Time (%)	Estimated Reduction Impact Standard Deviation Lead Time (%)
1	Maximizing implementation of blanket contract/agreement to cut procurement process lead time significantly.	Average = 111.94 Standard Deviation = 51.20	Average = 16.10 Standard Deviation = 32.35	-85.62%	-36.82%
2	Implementing electronic/digital approval for tender document approval, especially for those that not requiring SKK Migas approval (internal document approval only).		Average = 111.07 Standard Deviation = 50.78	-0.78%	-0.82%
3	Pre-Qualification: - Enhance current vendor's database to accommodate database of Pre-Qualification process - Maximize utilization of previously conducted Pre-Qualification result - Pre-Qualification Result template standardization - Dedicated person/team to maintain data and requirement related with Vendor's qualification process		Average = 110.23 Standard Deviation = 49.86	-1.53%	-2.62%
4	Buyer's workload review. Consider rotation position of Buyers. Assign PR follow-up for Call-Out Order PO to specific team/Buyer, not to be mixed		Average = 108.54 Standard Deviation = 49.13	-3.04%	-4.04%

Scenario #	Improvement Recommendation	Current Condition Total Lead Time	Improved Condition Estimated Total Lead Time	Estimated Reduction Impact to Average Lead Time (%)	Estimated Reduction Impact Standard Deviation Lead Time (%)
	up with Buyer's for Spot-Order PO tender process.				
5	Additional person in technical team to accelerate process evaluation on technical user's side.		Average = 104.85 Standard Deviation = 47.38	-6.33%	-7.46%
6	Agreed standard technical evaluation lead time with technical team. Include the monitoring on tender lead time monitoring tools.		Average = 100.56 Standard Deviation = 40.43	-10.17%	-21.04%
7	Modify approval level of technical evaluation result validation (up to level of Department Head instead of Division Head). This will reduce document circulation process and lead time approval.		Average = 109.70 Standard Deviation = 49.81	-2.00%	-2.71%
8	MRP Run Frequency from monthly basis to be bi-monthly basis (every 2 months) instead of monthly basis.		Average = 85.56 Standard Deviation = 37.91	-23.57%	-25.96%

5.4.5. Simulation Result Analysis

Significant lead time reduction could be achieved by maximizing the Call-Out Order PO mechanism instead of Spot Order PO. Based on historical lead time of Call-Out Order PO (data from PR to PO released in SAP), the average lead time of purchase phase could be reduced up to 85% from the historical performance. First priority to be using blanket contract is for materials with local sole agency status, and then for materials which considered critical and continuous and smooth supply to operation need to be guaranteed (e.g. chemicals). Routine consumable items also the ideal group of items that to be supplied through blanket contract instead of spot purchase.

Based on performed Monte Carlo Simulation for the rest 7 improvement strategies, Scenario #8 (i.e. changing MRP Run period from monthly to become bi-monthly basis) gives the biggest impact to the overall lead time reduction target for Purchase Phase. This is due to the less frequent MRP Run process executed will lead into less PR that resulting from the MRP Run Analysis; which less PR means lower workload in Purchase Phase. This option is less costly and could be implemented immediately. However, monthly basis MRP Run might still be required for certain selected materials that considered critical or high value items, such as pigging materials, chemical materials, etc. where reducing MRP Run frequency might had a consequences to the stock parameter for those items, increase risk of material shortage if stock parameter not properly adjusted, also the impact related with storage/space availability on Warehouse also need to be further assessed before reducing the MRP Run frequency for such materials. Monthly basis MRP Run process also could still be executed for materials that already covered by blanket contract (Outline Agreement/Price Agreement), which the re PR could then be directly converted into PO.

Related with strategy proposed to reduce frequency of MRP Run process, PT.X is suggested to also review the current level of value managed by Internal Procurement Team. Current level of value managed by Internal Procurement Team in PT.X is up to 50,000 USD, while in fact as per regulated in PTK 007 issued by SKK Migas, it is allowed for Internal Procurement Team to manage procurement process with value up to 1,000,000 USD. This is to balance the strategy of reducing the MRP run frequency with possible higher PR value per PR issuance. Historically around 70% of PR issued for Field Operation materials are below 50,000 USD, which the procurement managed by Internal Procurement Team only. By reducing the MRP Run frequency to be bi-monthly basis, there will be less PR issued to be processed, but most probably the value per PR issued will be increased. It is suggested to increase the level of authorized value managed by Internal Procurement Team to be be at least up to 500,000 USD.

Several other proposed strategies are also considered less costly and need no big effort to be implemented, i.e.:

1. Scenario #2 (electronic/digital approval for tender process): Current approval process is still manual/paper based approval.
2. Scenario #4 (buyer’s work load review, rotation, separate the team for tender process and for call-out order process): Review and rearrange

buyer’s tasks and load. Assign small team to focus on the call-out order process (non tender), which could be added to the scope of admin or expediting team which also under purchasing function.

3. Scenario #7 (modify approval level for Technical Evaluation result validation): Current approval and validation process for the Technical Evaluation result is up to the Head of Division. There are 4 persons involved in the validation process, i.e. Technical Evaluator Coordinator, Head of Service, Head of Department and lastly Head of Division. It is proposed to reduce the approval and validation level only up to Head of Department of User’s entity.
4. Scenario #6 (agreed standard technical evaluation lead time with technical team): Long technical evaluation for Field Operation materials is a long time issue and still occurs. Lead time for technical evaluation duration need to be agreed and monitored. Proposed to set up a reminder mechanism for tender process that the process duration under certain step already exceeds a certain limit.

The other strategies will need more efforts or might have a cost impact to be implemented, which are:

1. Enhancement to current Vendor’s Database to be more comprehensive, informative, and has a user friendly interface. The enhancement expected to be able to reduce lead time on preparation steps and Bidders selection process in Pre-Qualification stage.
2. Additional person in technical team to accelerate the technical evaluation or clarification process. Current lead time for technical evaluation process is still considered quite long.

Above data presented in Table 5.5 is estimated lead time reduction by implementing each proposed improvement recommendation. Combining several improvement strategies could lead to further lead time reduction. Overall estimated lead time reduction by implementing Scenario #2-8 are 40% average lead time reduction from initially 111.94 days in average to be 66.84 days in average.

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CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Based on Value Stream Mapping developed for current and future state of PT.X's material supply chain process for Field Operation Material, Root Cause Analysis of the lead time problem and Monte Carlo Simulation performed to several proposed improvement recommendations, it could be concluded that:

1. Initial Stage of Purchase Phase, Evaluation Stage of Purchase Phase and material issuance process on Commitment Follow-up Phase are main areas that the lead time needs to be improved first.
2. Some root causes of the long lead time problem in Purchase Phase of material supply chain of PT.X are number of document approvers involved, not yet implementing electronic approval process for certain stages, lack of supervision in some areas, unavailability of adequate support system such as comprehensive vendor's database, also there is indication of unbalance condition between available resources and load to be managed.
3. In Commitment Follow-up Phase, long lead time issue is mostly due to late posting in SAP system. Neither KPI nor monitoring system exists yet for the material issuance process until received by requester.
4. Implementation of Call-Out Order PO will provide the most significant lead time reduction (up to 85% reduction from existing purchase lead time of Spot Order PO). Another significant impact is by reducing MRP Run frequency from monthly basis to be bi-monthly basis (estimated to give 23.57% reduction impact to the average lead time).
5. Overall estimated lead time reduction by implementing Scenario #2-8 of proposed recommendation in Purchase Phase of Spot Order PO with Direct Selection method is 40% reduction of average lead time; from initially 111.94 days in average to be 66.84 days in average, for Spot Order PO procured through Direct Selection process.

6.2. Recommendation

1. Main areas that proposed to be improved first to reduce the lead time are Initial Stage and Evaluation Stage of Purchase Phase of material supply, and material issuance process from Warehouse to Requester.
2. Lead time for call-out order PO used as estimated improved lead time on Scenario #1 of Purchase Phase lead time improvement strategy is taken from historical lead time data for 2012-2016 call-out order PO. Further review on the call-out order lead time performance is proposed to be conducted.
3. Agreed Key Performance Indicator (KPI) among all related functions need to be set-up and monitored properly. KPI and company's objective need to be well communicated to all team and working level.
4. Review and evaluation of another stages along the material supply chain process is proposed to be conducted as well, to seek further possible improvement(s) related with material supply chain lead time.
5. External lead time review and analysis proposed to be considered for future research study related with supply chain lead time in oil and gas industry in Indonesia.
6. Studies related with force majeure situation or unexpected disruption impact to supply chain activities in oil and gas industry is proposed to be considered for future research study.

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ATTACHMENT A

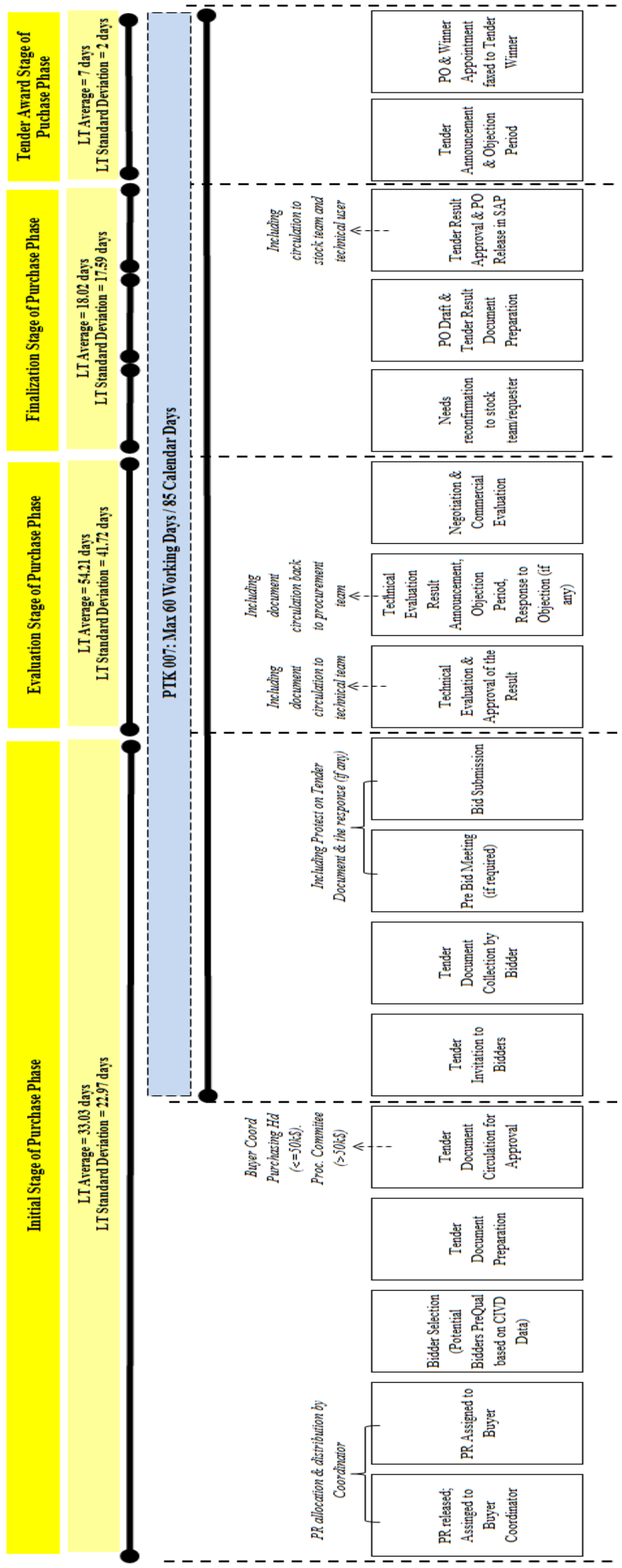


Figure A.1. Overall Stages in Purchase Phase (Current Condition)

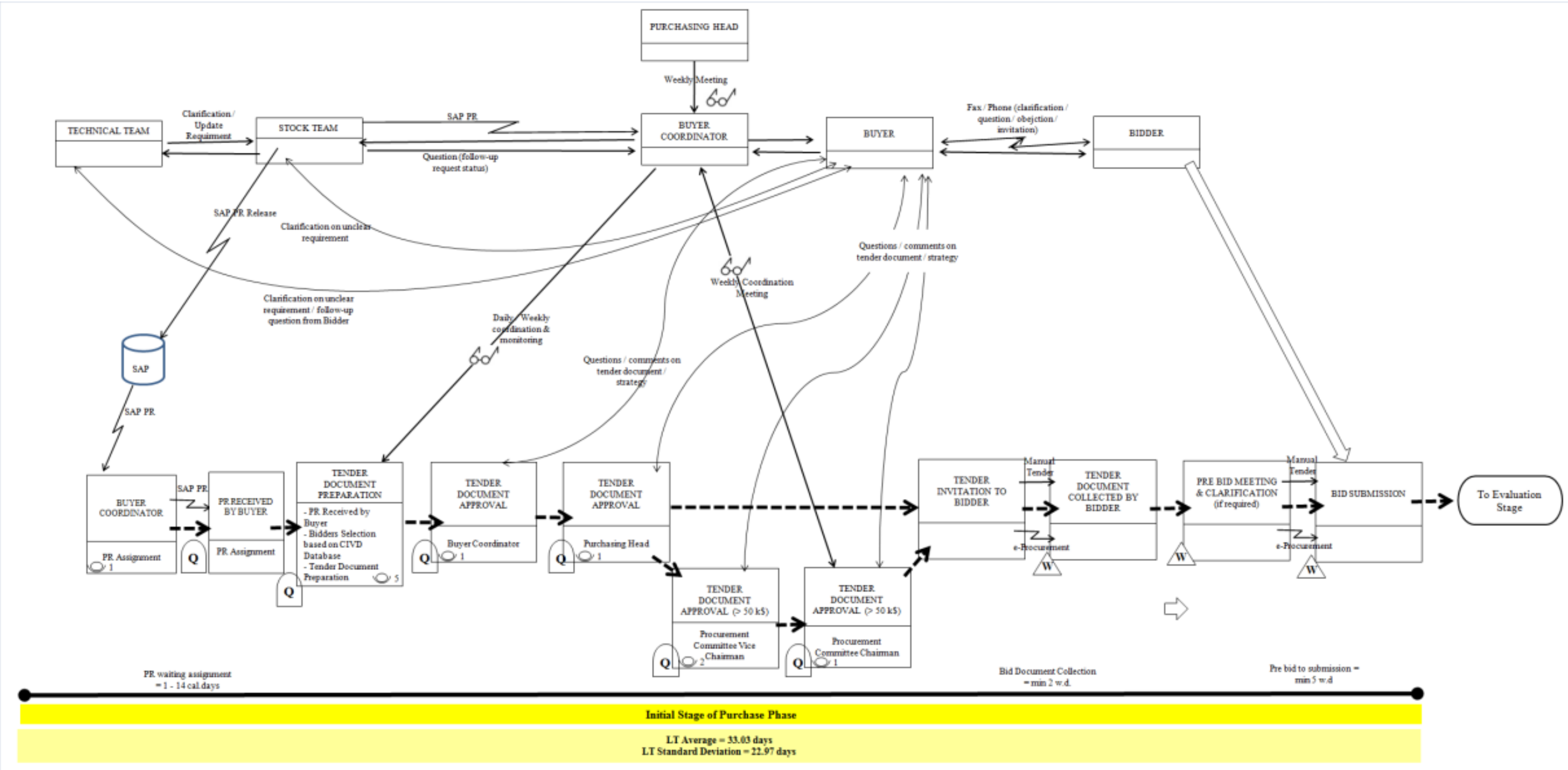


Figure A.2. Current State Map of Initial Stage of Purchase Phase

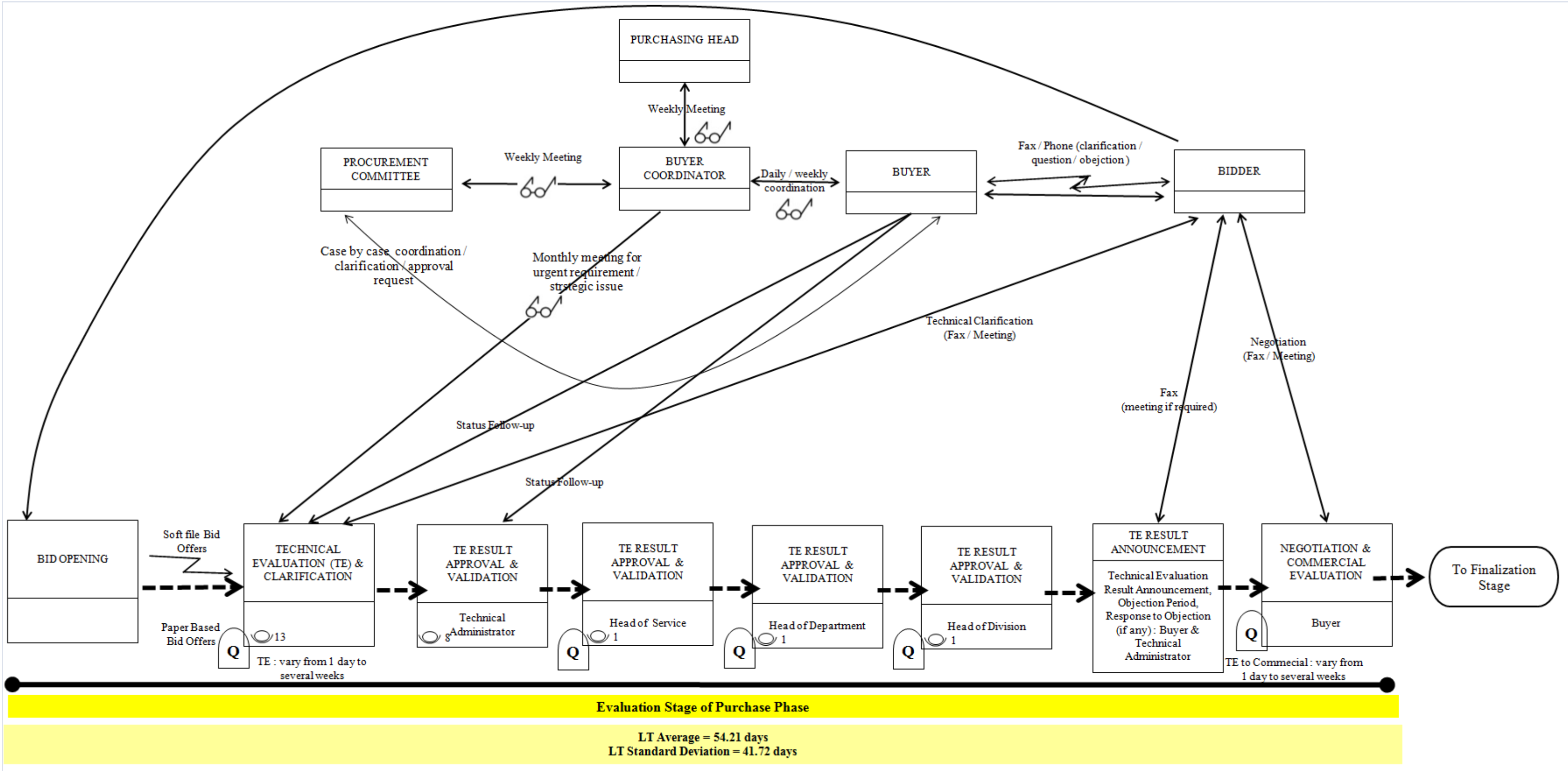


Figure A.3. Current State Map of Evaluation Stage of Purchase Phase

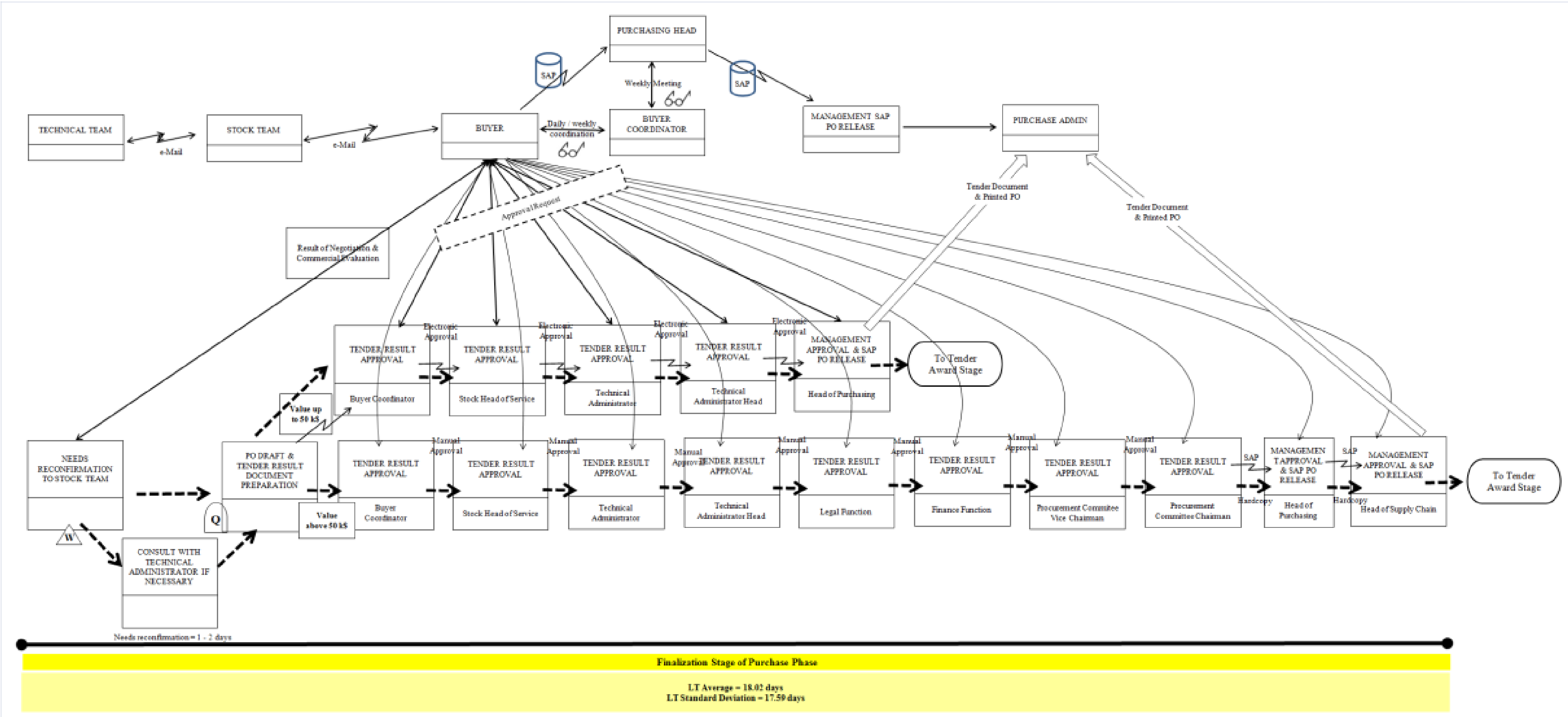


Figure A.4. Current State Map of Finalization Stage of Purchase Phase

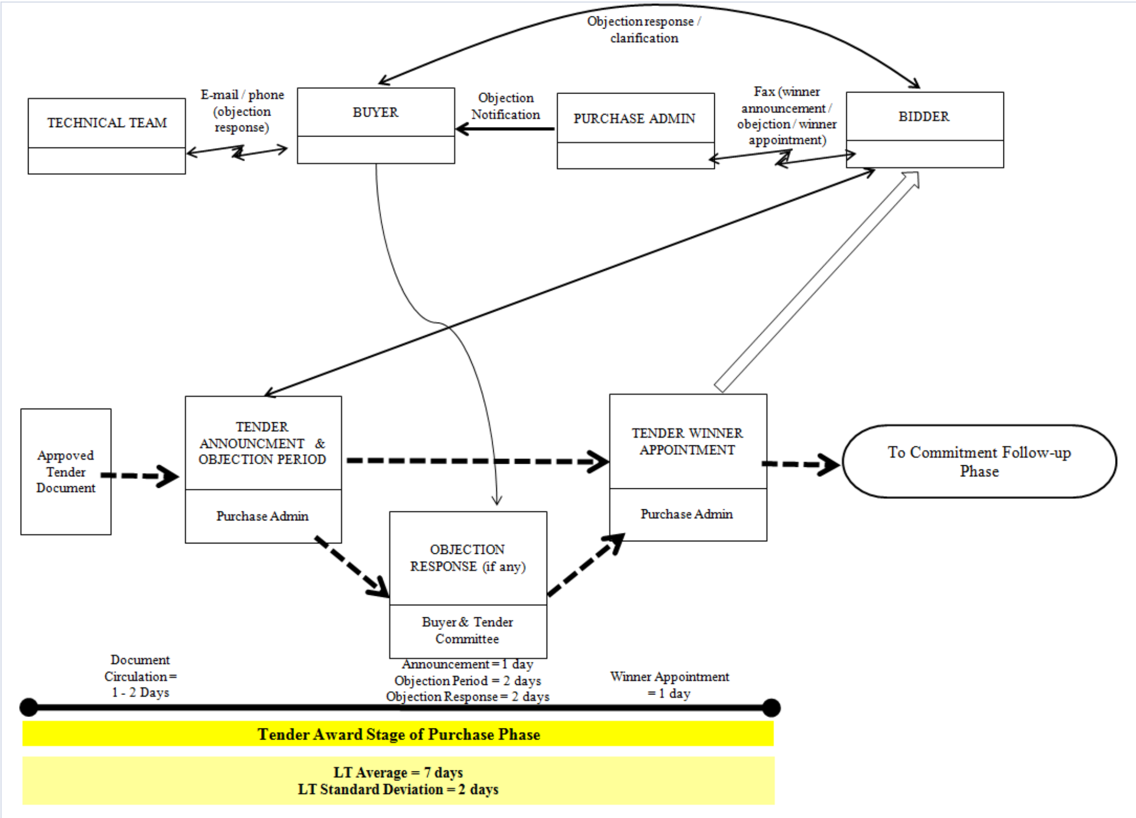


Figure A.5. Current State Map of Tender Award Stage of Purchase Phase

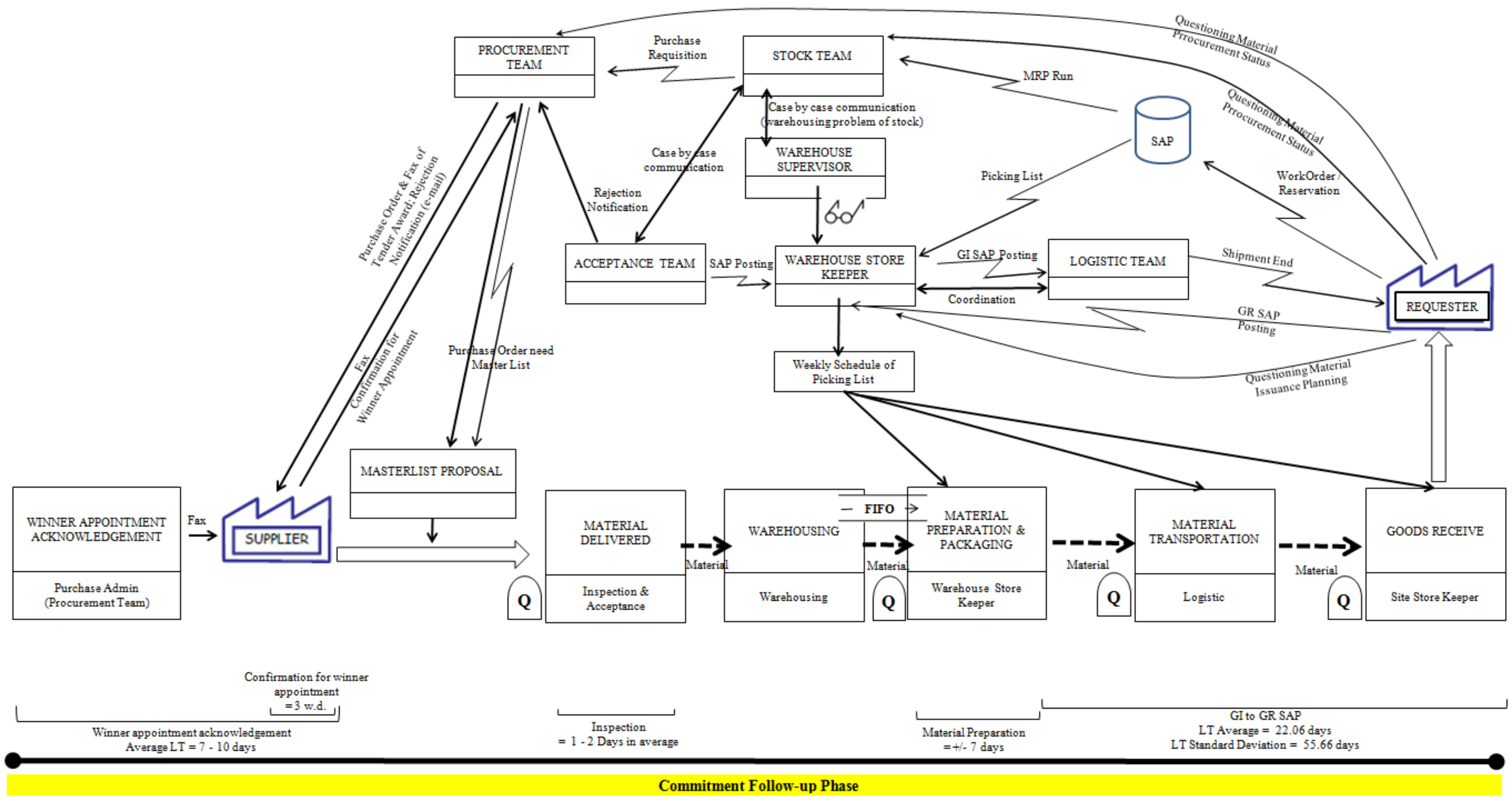


Figure A.6. Current State Map of Commitment Follow-up Phase

ATTACHMENT B

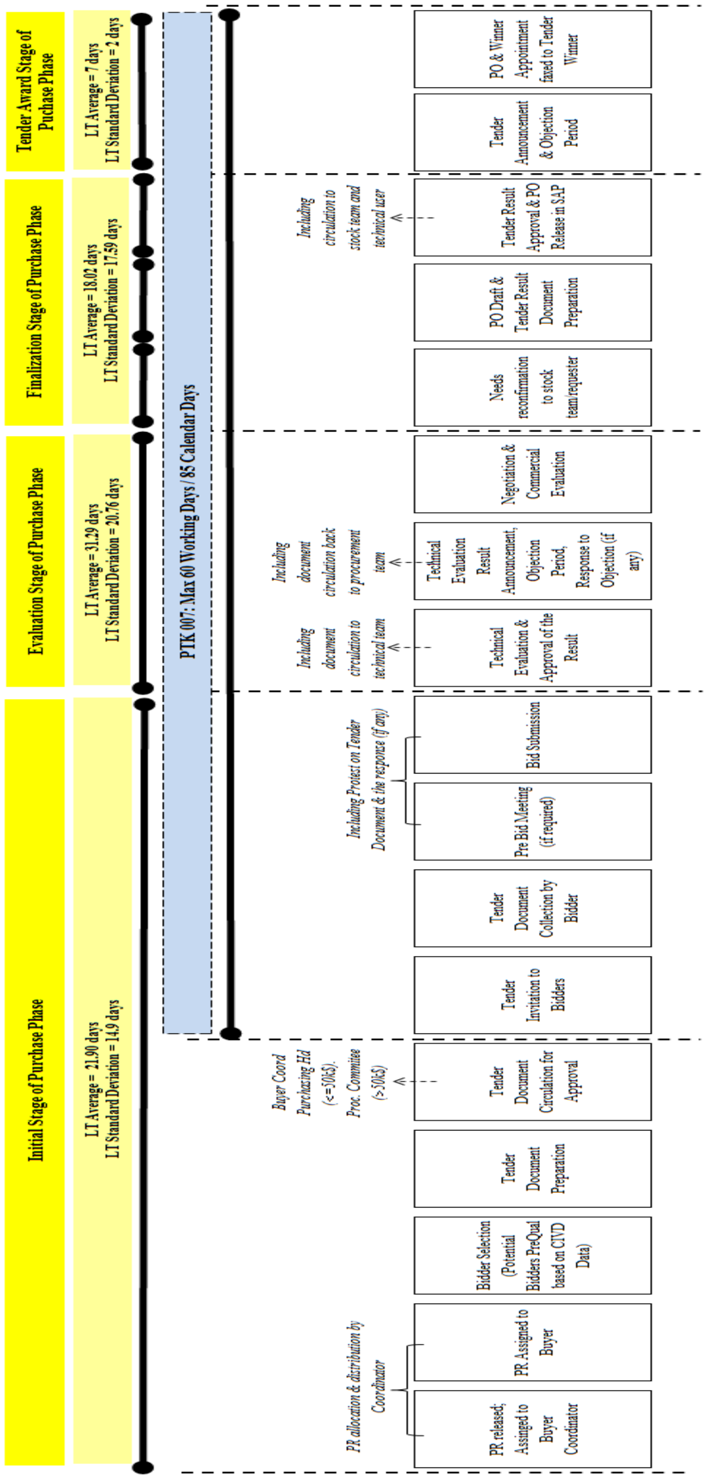


Figure B.1. Overall Stages in Purchase Phase (Improved)

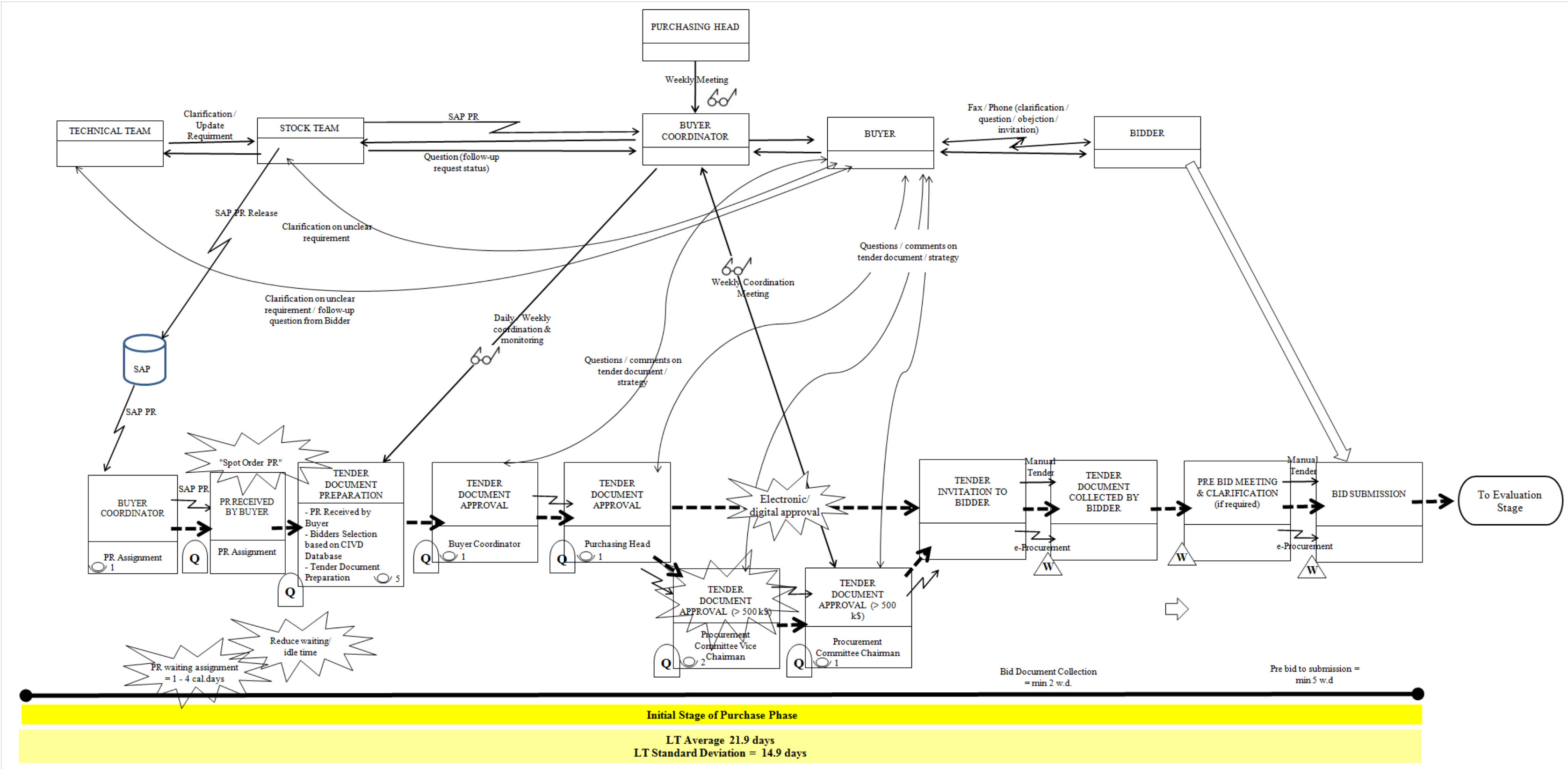


Figure B.2. Future State Map of Initial Stage of Purchase Phase

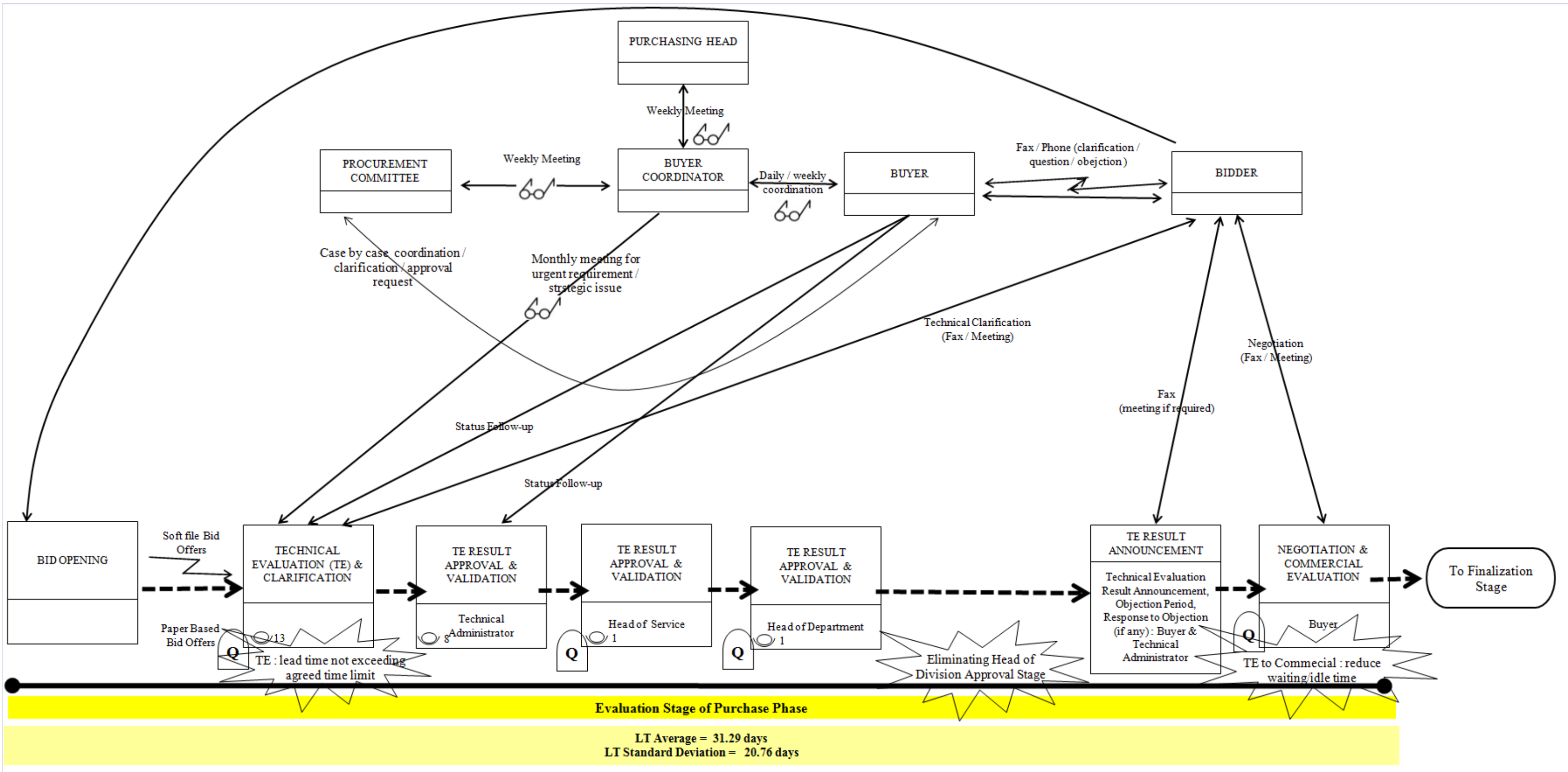


Figure B.3. Future State Map of Evaluation Stage of Purchase Phase

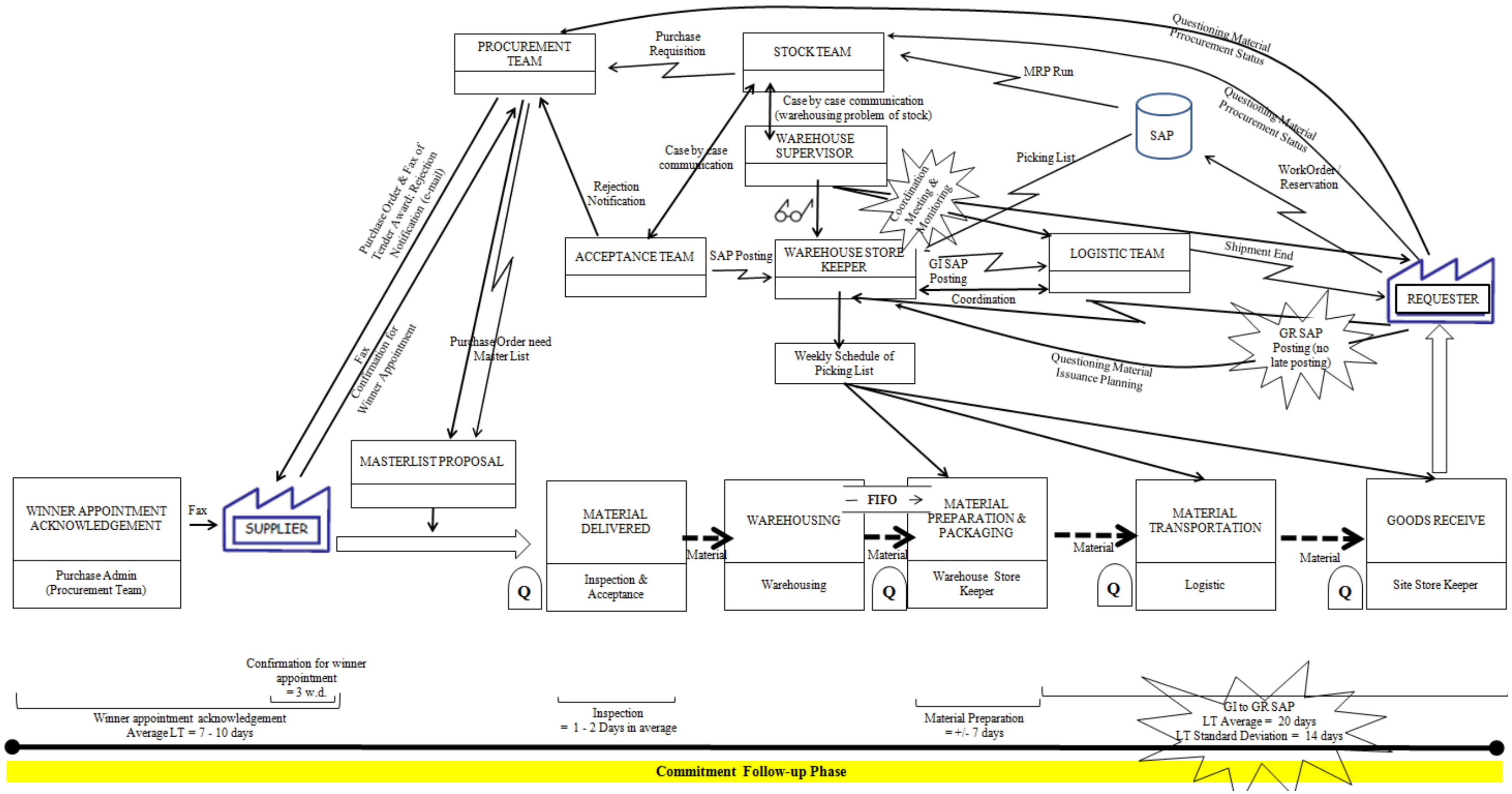


Figure B.4. Future State Map of Commitment Follow-up Phase

ATTACHMENT C

Initial Stage of Purchase Phase

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
287	0	33.0348	22.9272	25	5	144	2.07319	5.38415

Box-Cox transformation: Lambda = 0

Johnson transformation function:
-1.82216 + 1.17533 * Asinh((X - 10.3490) / 7.22469)

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	15.361	<0.005	
Box-Cox Transformation	0.981	0.013	
Lognormal	0.981	0.013	
3-Parameter Lognormal	0.793	*	0.347
Exponential	24.886	<0.003	
2-Parameter Exponential	12.608	<0.010	0.000
Weibull	6.521	<0.010	
3-Parameter Weibull	3.708	<0.005	0.000
Smallest Extreme Value	31.815	<0.010	
Largest Extreme Value	4.200	<0.010	
Gamma	3.763	<0.005	
3-Parameter Gamma	2.346	*	0.000
Logistic	9.115	<0.005	
Loglogistic	0.863	0.015	
3-Parameter Loglogistic	0.507	*	0.057
Johnson Transformation	0.265	0.694	

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	33.03484		22.92719	
Box-Cox Transformation*	3.30949		0.60202	
Lognormal*	3.30949		0.60202	
3-Parameter Lognormal	3.24786		0.63819	1.35596
Exponential			33.03484	
2-Parameter Exponential			28.13287	4.90198
Weibull		1.60547	37.20538	
3-Parameter Weibull		1.35099	30.84452	4.92242
Smallest Extreme Value	46.30893		33.60973	
Largest Extreme Value	23.93722		13.89353	
Gamma		2.81407	11.73916	
3-Parameter Gamma		1.92275	14.78222	4.61227
Logistic	29.33983		11.08887	
Loglogistic	3.29029		0.33970	
3-Parameter Loglogistic	3.15391		0.39186	3.14202
Johnson Transformation*	-0.02498		1.00705	

* Scale: Adjusted ML estimate

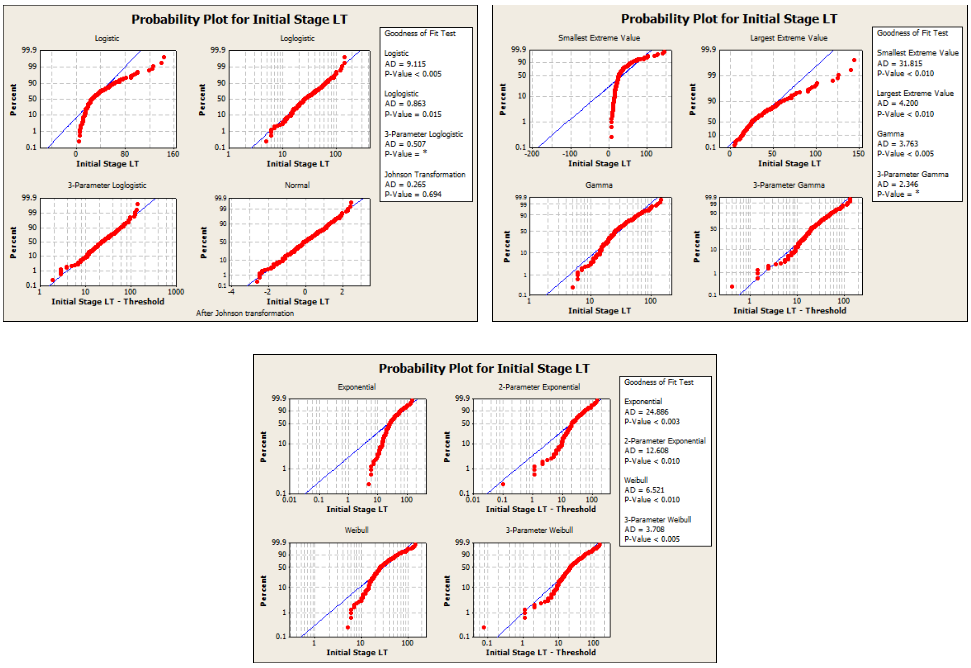


Figure C.1. Probability Plot for Initial Stage of Purchase Lead Time

Evaluation Stage of Purchase Phase

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
284	0	54.2113	41.7152	42	1	278	1.73664	4.07404

Box-Cox transformation: Lambda = 0.289750

Johnson transformation function:
-4.41231 + 1.67233 * Asinh((X + 10.2770) / 7.80317)

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	10.899	<0.005	
Box-Cox Transformation	0.807	0.036	
Lognormal	2.716	<0.005	
3-Parameter Lognormal	0.457	*	0.000
Exponential	10.974	<0.003	
2-Parameter Exponential	9.898	<0.010	0.003
Weibull	1.700	<0.010	
3-Parameter Weibull	1.627	<0.005	0.290
Smallest Extreme Value	26.000	<0.010	
Largest Extreme Value	2.339	<0.010	
Gamma	0.994	0.017	
3-Parameter Gamma	0.982	*	0.707
Logistic	6.609	<0.005	
Loglogistic	0.905	0.010	
3-Parameter Loglogistic	0.444	*	0.004
Johnson Transformation	0.457	0.264	

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	54.21127		41.71523	
Box-Cox Transformation*	2.99979		0.68606	
Lognormal*	3.69188		0.86196	
3-Parameter Lognormal	3.99121		0.60109	-10.55119
Exponential			54.21127	
2-Parameter Exponential			53.39929	0.81197
Weibull		1.38364	59.58016	
3-Parameter Weibull		1.35353	58.56184	0.65455
Smallest Extreme Value	77.75253		59.50108	
Largest Extreme Value	36.87916		27.39734	
Gamma		1.80992	29.95229	
3-Parameter Gamma		1.86247	29.32312	-0.40215
Logistic	48.24640		21.20804	
Loglogistic	3.74399		0.45864	
3-Parameter Loglogistic	3.89713		0.37776	-6.23127
Johnson Transformation*	-0.00723		0.99332	

* Scale: Adjusted ML estimate

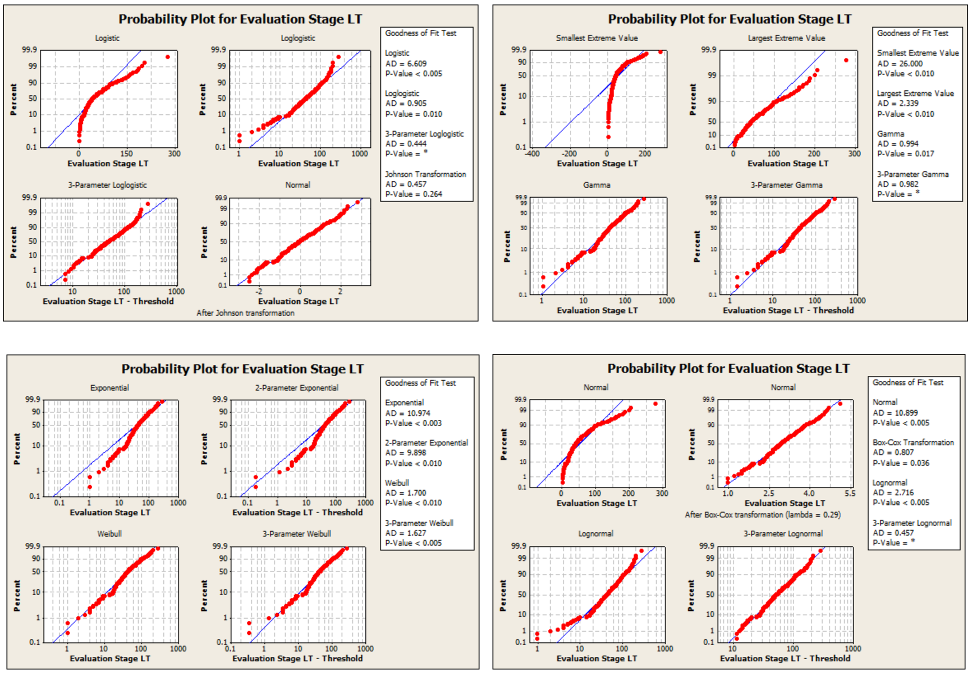


Figure C.2. Probability Plot for Evaluation Stage of Purchase Lead Time

Finalization Stage of Purchase Phase

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
287	0	18.0244	17.5916	13	1	111	2.16324	6.69281

Box-Cox transformation: Lambda = 0.152087

Johnson transformation function:
1.99716 + 0.913074 * Ln((X + 0.330339) / (131.479 - X))

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	14.139	<0.005	
Box-Cox Transformation	0.687	0.072	
Lognormal	1.577	<0.005	
3-Parameter Lognormal	1.153	*	0.165
Exponential	1.586	0.025	
2-Parameter Exponential	0.995	0.117	0.000
Weibull	0.974	0.015	
3-Parameter Weibull	1.179	<0.005	0.000
Smallest Extreme Value	31.696	<0.010	
Largest Extreme Value	5.502	<0.010	
Gamma	0.942	0.022	
3-Parameter Gamma	1.550	*	0.000
Logistic	9.117	<0.005	
Loglogistic	1.591	<0.005	
3-Parameter Loglogistic	1.728	*	0.560
Johnson Transformation	0.574	0.135	

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	18.02439		17.59160	
Box-Cox Transformation*	1.46545		0.22430	
Lognormal*	2.43346		1.03412	
3-Parameter Lognormal	2.51670		0.94668	-0.59370
Exponential			18.02439	
2-Parameter Exponential			17.08392	0.94047
Weibull		1.10008	18.72527	
3-Parameter Weibull		0.94204	16.63178	0.95796
Smallest Extreme Value	28.24208		27.01000	
Largest Extreme Value	11.02262		10.63170	
Gamma		1.23101	14.64199	
3-Parameter Gamma		0.85954	19.83617	0.97431
Logistic	15.32015		8.64024	
Loglogistic	2.48006		0.59585	
3-Parameter Loglogistic	2.45040		0.61942	0.25849
Johnson Transformation*	-0.04016		1.05104	

* Scale: Adjusted ML estimate

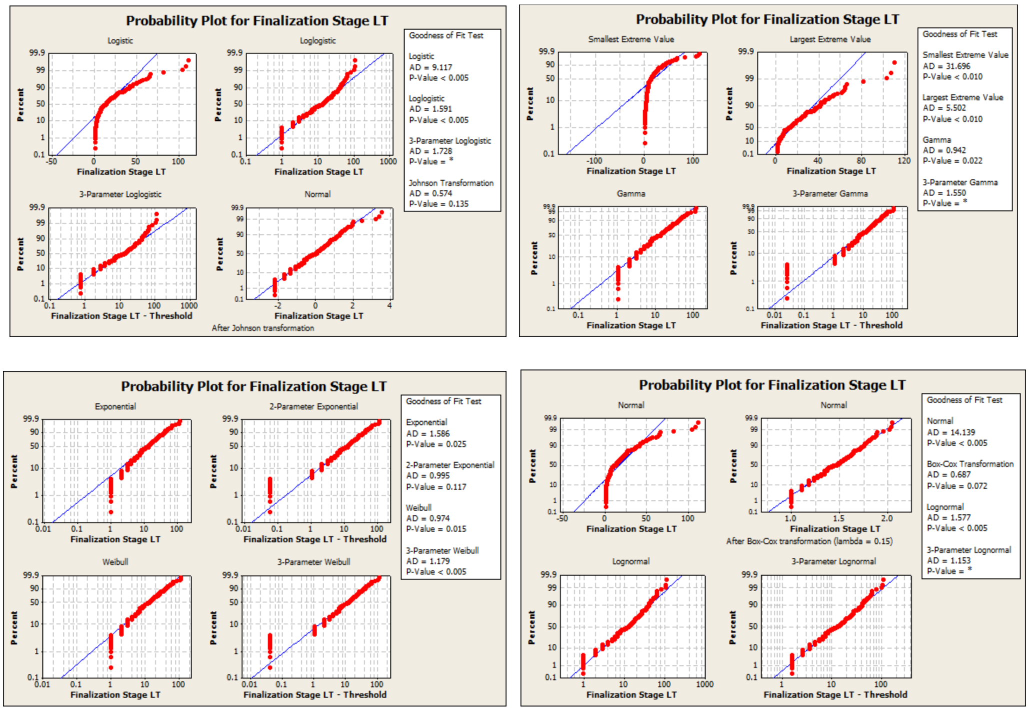


Figure C.3. Probability Plot for Finalization Stage of Purchase Lead Time

Correlation between Stages

Correlations: Initial Stg_CorD, Evaluation Stg_C, Finalization Stg

```
                    Initial Stg_CorD  Evaluation Stg_C
Evaluation Stg_C               0.111
                               0.077

Finalization Stg               0.029             0.045
                               0.642             0.469


Cell Contents: Pearson correlation
               P-Value
```

Correlations: Ranked_Initial LT, Ranked_Evaluation LT, Ranked_Finalization LT

```
                    Ranked_Initial L  Ranked_Evaluatio
Ranked_Evaluatio               0.251
Ranked_Finalizat               0.031             0.055

Cell Contents: Pearson correlation
```

__Iteration Running to Set-up Model__

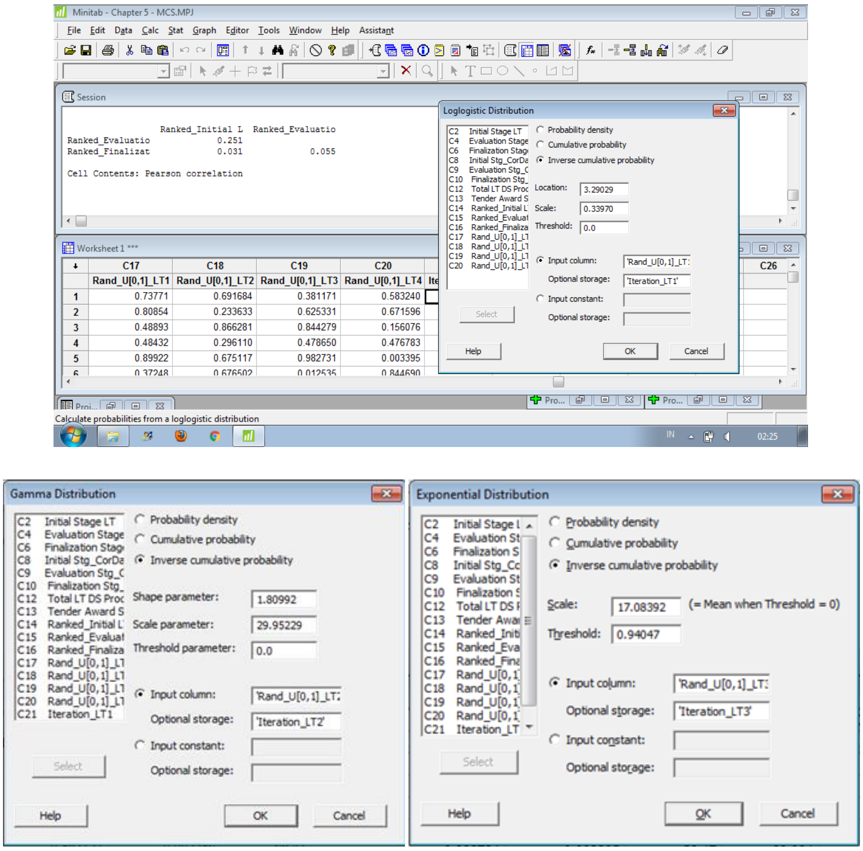


Figure C.4. Minitab Screen Capture of Iteration Running Process

__$TLTP_j$ (As Is Total Lead Time) Calculation based on iteration performed for each stage:__

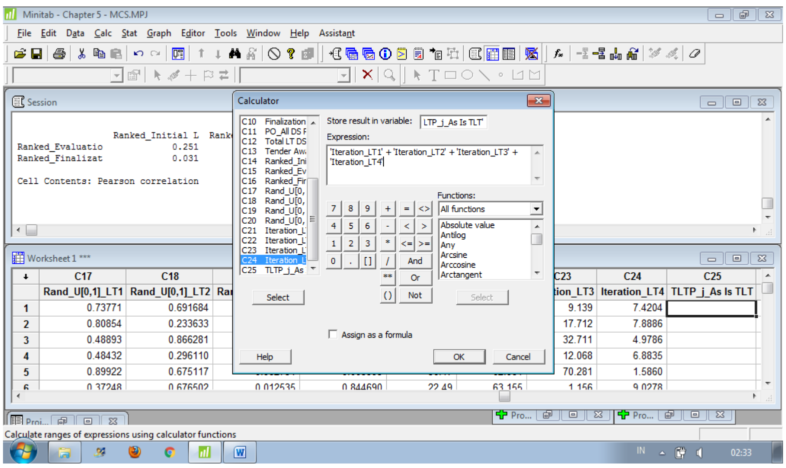


Figure C.5. Minitab Screen Capture of Total Lead Time Simulation

Check re-produce ability of the model (comparing TLTP$_j$ (As Is TLT) with Actual Lead Time Sample Data)

Graph → Empirical CDF → Multiple →

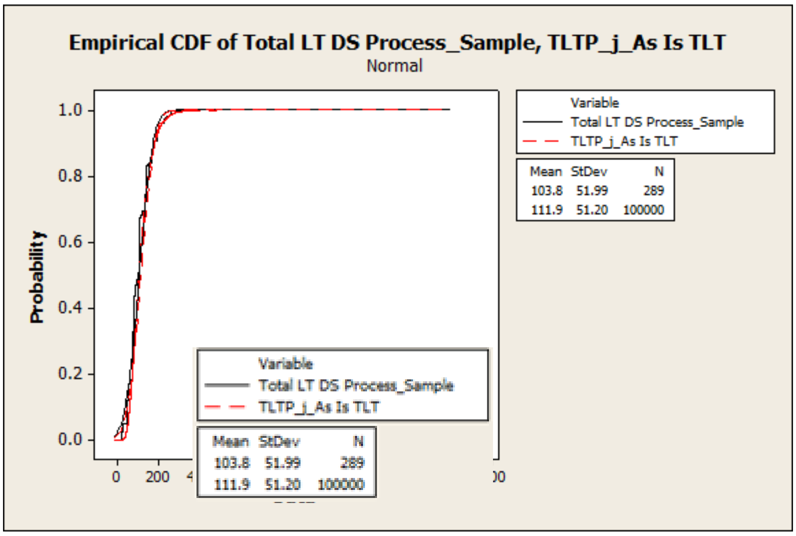


Figure C.6. Plotting of Cumulative Distribution of Simulation Result and Actual Lead Time Data

Mann-Whitney U-Test

Actual TLT_sample = Actual LT1+LT2+LT3 Data + LT4 random data

LT4 random data: normal distribution

Stat → Nonparametrics → Mann-Whitney

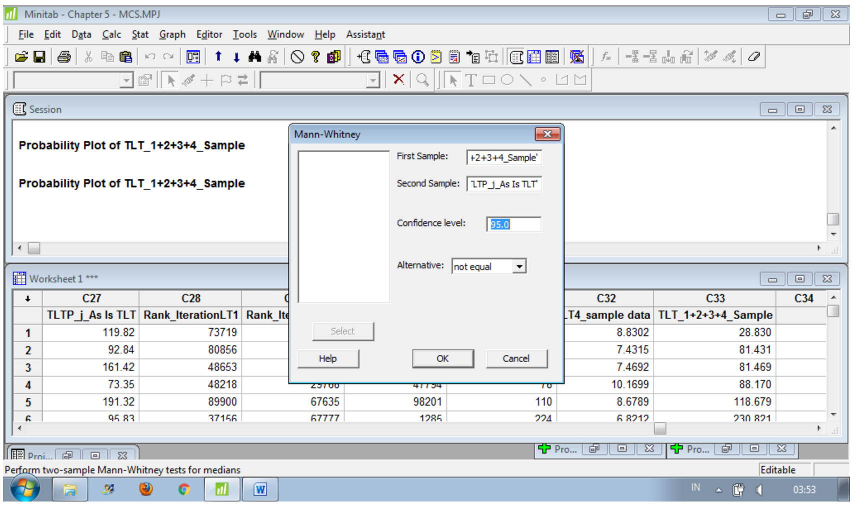


Figure C.7. Minitab Screen Capture of Mann-Whitney Test

Mann-Whitney Test and CI: TLT_1+2+3+4_Sample, TLTP_j_As Is TLT

```
                              N  Median
TLT_1+2+3+4_Sample          257  104.21
TLTP_j_As Is TLT         100000  102.64


Point estimate for ETA1-ETA2 is -1.11
95.0 Percent CI for ETA1-ETA2 is (-6.60,4.38)
W = 12699536.5
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.6919
The test is significant at 0.6919 (adjusted for ties)
```

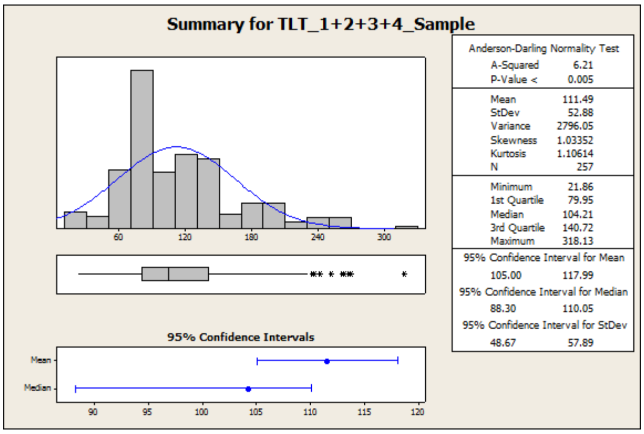


Figure C.8. Actual Sample Data Graphical and Statistical Information

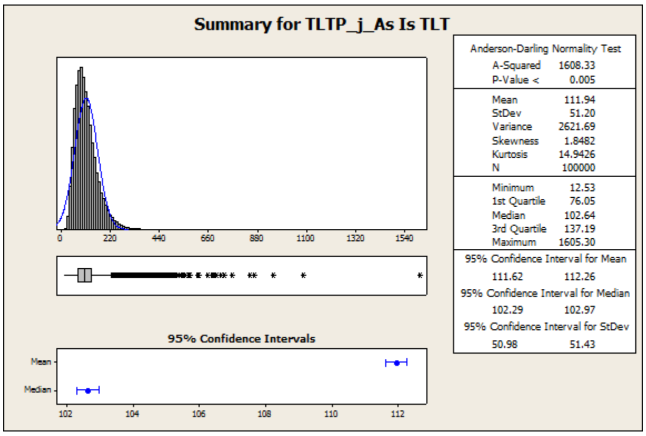


Figure C.9. Simulation Result Graphical and Statistical Information

<u>Actual TLT_sample Descriptive Statistic:</u>

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
257	0	111.494	52.8777	104.215	21.8637	318.132	1.03352	1.10614

Box-Cox transformation: Lambda = 0.262179

Goodness of Fit Test

Distribution	AD	P	LRT P
Normal	6.207	<0.005	
Box-Cox Transformation	2.045	<0.005	
Lognormal	2.291	<0.005	
3-Parameter Lognormal	1.938	*	0.007
Exponential	36.596	<0.003	
2-Parameter Exponential	22.126	<0.010	0.000
Weibull	3.797	<0.010	
3-Parameter Weibull	2.772	<0.005	0.000
Smallest Extreme Value	15.036	<0.010	
Largest Extreme Value	1.904	<0.010	
Gamma	2.168	<0.005	
3-Parameter Gamma	2.140	*	0.725
Logistic	4.541	<0.005	
Loglogistic	1.800	<0.005	
3-Parameter Loglogistic	1.769	*	0.242

ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	111.49353		52.87770	
Box-Cox Transformation*	3.36877		0.42303	
Lognormal*	4.60179		0.48941	
3-Parameter Lognormal	4.89328		0.35976	-30.81913
Exponential			111.49353	
2-Parameter Exponential			89.97996	21.51357
Weibull		2.23974	126.19802	
3-Parameter Weibull		1.82054	104.01655	19.02822
Smallest Extreme Value	140.13511		64.08158	
Largest Extreme Value	87.76053		40.67766	
Gamma		4.61732	24.14683	
3-Parameter Gamma		4.26863	25.27353	3.61023
Logistic	105.85597		28.71036	
Loglogistic	4.61404		0.27086	
3-Parameter Loglogistic	4.75989		0.23197	-15.22233

* Scale: Adjusted ML estimate

TLTPj (As Is Total Lead Time) Descriptive Statistic:

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
100000	0	111.939	51.2024	102.644	12.5257	1605.30	1.84822	14.9426

Box-Cox transformation: Lambda = 0.0583354

Johnson transformation function:
6.99575 + 2.26294 * Ln((X + 3.60789) / (2437.87 - X))

Goodness of Fit Test

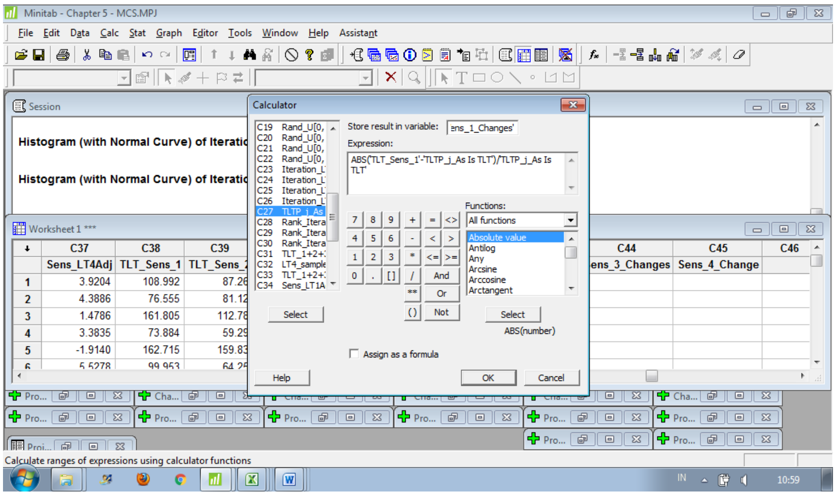
Distribution	AD	P	LRT P
Normal	1608.329	<0.005	
Box-Cox Transformation	1.588	<0.005	
Lognormal	13.287	<0.005	
3-Parameter Lognormal	2.278	*	0.000
Exponential	15559.565	<0.003	
2-Parameter Exponential	12535.461	<0.010	0.000
Weibull	1030.295	<0.010	
3-Parameter Weibull	657.190	<0.005	0.000
Smallest Extreme Value	20741.286	<0.010	
Largest Extreme Value	41.130	<0.010	
Gamma	118.935	<0.005	
3-Parameter Gamma	44.265	*	0.000
Logistic	907.106	<0.005	
Loglogistic	82.421	<0.005	
3-Parameter Loglogistic	85.293	*	0.000
Johnson Transformation	0.595	0.120	

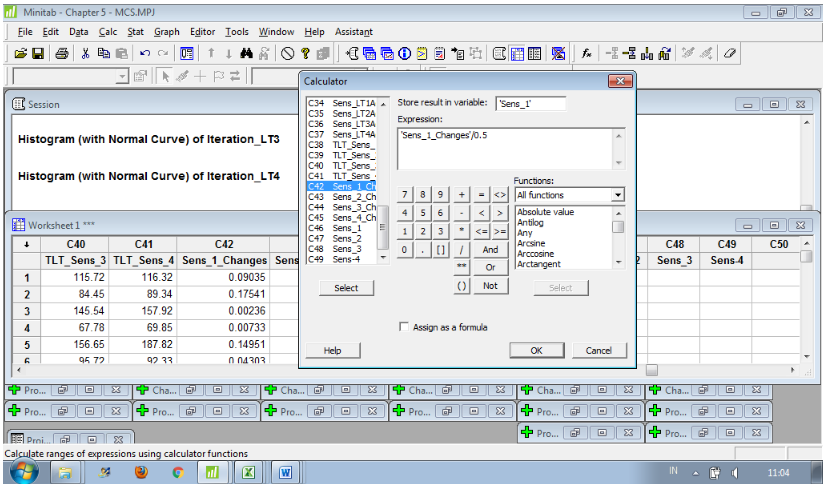
ML Estimates of Distribution Parameters

Distribution	Location	Shape	Scale	Threshold
Normal*	111.93878		51.20243	
Box-Cox Transformation*	1.30995		0.03350	
Lognormal*	4.62262		0.43881	
3-Parameter Lognormal	4.68166		0.41344	-5.64969
Exponential			111.93878	
2-Parameter Exponential			99.41433	12.52444
Weibull		2.27210	126.39342	
3-Parameter Weibull		2.04880	112.46659	12.52124
Smallest Extreme Value	138.13418		161.07535	
Largest Extreme Value	89.61063		37.70965	
Gamma		5.40586	20.70693	
3-Parameter Gamma		4.14957	23.97580	12.44947
Logistic	106.83679		27.09971	
Loglogistic	4.62663		0.25074	
3-Parameter Loglogistic	4.59264		0.25979	3.25997
Johnson Transformation*	0.00139		1.00344	

* Scale: Adjusted ML estimate

Sensitivity Analysis





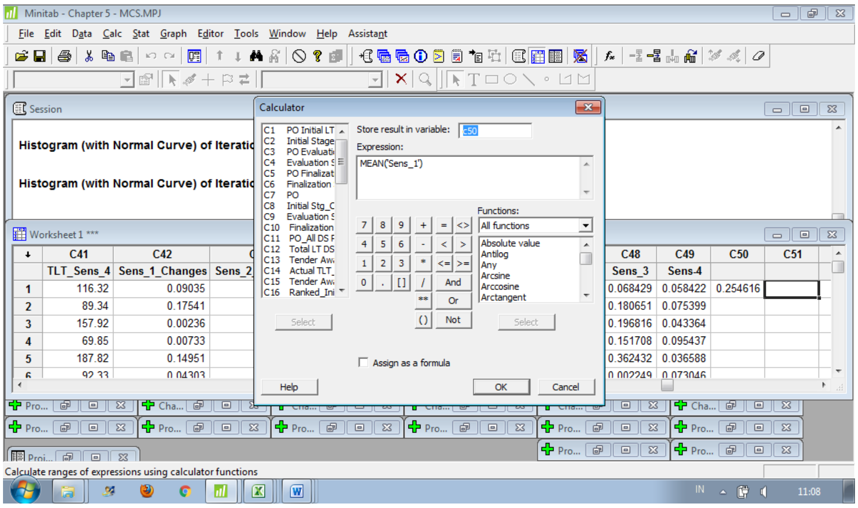


Figure C.10. Minitab Screen Capture of Sensitivity Analysis