Supplier Risk Assessment and Selection under Disruption based on DMAIC and AHP Approaches

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Abstract:

Supplier Risk Assessment and Selection under Disruption based on DMAIC and AHP Approaches.

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In today's competitive business environment, different organizations are advancing their supply chain network to improving the quality of products and to reduce lead-time and total costs. Supplier risk is defined as "the possibility that a supplier will fail to supply their commitments to buyer company." Business processes and projects that build trust only on suppliers may face higher risks/ failure/ loss. In some circumstances, businesses decide to mitigate these risks by diversifying their suppliers.

With the complication and globalization of outsourcing in today's supply chains and from the other side with consideration of optimization techniques such as lean and just-in-time manufacturing for improving efficiency, they all together increased supply chain sensitivity and disruptions to even minor supply disruptions. Although these models facilitated companies to moderate overall costs and grow rapidly into new markets, they also exposed these companies to be at risk of supplier disruption, closing operations, or being acquired for companies. Considering several types of supply disruptions, the most intensive disruptions have a fairly low probability of occurrence with very high severity of impact when they occur, like COVID. While such risks cannot be eliminated, however, its intensity can be reduced.

It’s almost unmanageable to eliminate risk from the supply chain totally. However, businesses can minimize the risk and even eliminate the impact of certain risk events with cautious planning, tools, and processes to expect and manage risk more effectively.

There was many discussions and case studies about the affect of agility, lean manufacturing, and innovation of the enterprise and how it can help the companies to be more comparative in business environment. However most business they are neglectful about disruptions failures and necessary actions to face it.

Keywords: Supplier Selection, Supply Chain, Supply chain disruptions, Order allocation, Metaheuristics, DMAIC, Project Charter, Cost of Delay, Voice of the customer (VOC), Critical to Quality (CTQ), AHP, SIPOC, Pareto chart, Cause and Effect Diagram, Process Map Analysis, Regression Analysis, Supplier Development

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Chapter 1

Introduction

1.1 Supply Chain Problem

Back to 1980s the supply chain management (SCM) definition was created. This definition was established in order to guide the necessity of crucial business methods integration from end-user all through first suppliers. Primary suppliers are the ones who offer products, information, and services that add meaning and value to their clients. One of the main and vital perception in the back of SCM is that corporations and businesses by exchange market information and related variations and production capabilities engage themselves in a supply chain.

The principal target of supply chain management is delivering and carrying out customer demands by using the most efficiently of resources and distribution capacity, inventory, and labor. In philosophy, the supply chain matches demand with supply with a nominal inventory. There are several different features for optimizing the supply chain and maximize the productivity of companies like the strategy of sourcing to keep a balance between optimal material cost and transportation, a good communicating system with suppliers to remove bottlenecks, applying just-in-time methods to improve manufacturing flow, sustaining the right location of operation plants and warehouses to can cover markets, location and allocation of demands, transportation routing analysis, dynamic transportation, and logistics optimization to maximize the productivity of distribution.

Supervision of supply chain involves several decisions about the movement of information, product, and funds, which are together termed “Supply Chain Management (SCM)” [15]. These

decisions mostly span multiple organization functions and are usually made on multiple levels (Figure 1).

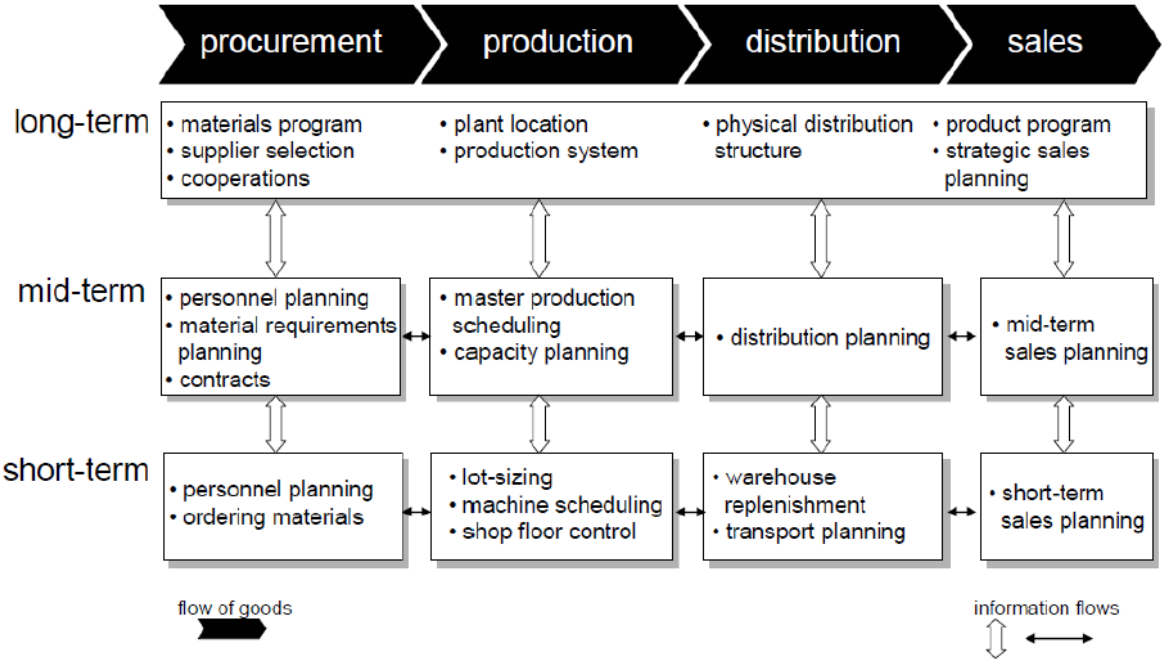


Figure 1. Different types of decisions in MSC. Adapted from (Fleischmann et al. 2002).

At the strategic or long-term level, a company decides about the supply chain's design and structure over the next several years [14,15]. The category of this kind of decisions related to the capacities of production and location of facility based on market and raw material and warehouse facilities, the strategy of operation and manufacturing and also management of different storage and related locations and at the end supply channels.

Mid-term decisions timeframe is usually based on the quarter of the year. Strategic decisions constrain these decisions for a supply chain. For instance, based on the network configuration, a supply chain manager must decide which markets will be covered.

In the lowest level which is operational or short-term level, the time period is usually daily based or weekly. At the short-term level the arrangement of supply chain, supply chain configuration and arrangement policies are previously defined. At this level target and plan is in the best possible style deliver the ongoing customer orders. Through this phase, replacement orders for raw materials need to mange in best and optimize way and also management need to allocate inventory or production capacity for orders based on the delivery and initial production plan[15].

The central idea in SCM is that we must have a systemic view about all these decisions and functions, and they must be integrated and coordinated to improve customer service, cut costs and increase the profit for a company [15]. To this aim, a company may collaborate with other actors in the supply chain (e.g., its suppliers).

1.2 Supplier Selection Problem

The selection of accurate suppliers is one of the crucial strategies for increasing the quality of output of any company, and it has a direct influence on the company's reputation. Reliable suppliers allow manufacturers to reduce inventory costs and improve product quality.

In any company specially in manufacturing sector, supplier selection is one of most important and vital decision because in this kind of industries, raw materials and outsourced components are usually the two highest costs. The procurement department regularly plays a dynamic role in reducing the purchasing cost and selecting the appropriate suppliers. Only when a supplier encounters certain standards and shows competitive assets within the fields desired by a company is considered by the buyers.

The supplier selection problem can be considered as a simple selection when the selection parameters and criteria are known and definitive. However, in reality, the majority of them are

qualitative, uncertain, and conflicting in nature. This makes the selection process difficult. Variations in customer demand, price, quantity, and lead time uncertainty from suppliers add further complexity to the problem [9,10]. In fact, Lee et al. define supplier selection as models or methods utilized to select the appropriate supplier [11]. The type and method of supplier selection can have a significant effect on the selected results. In this regard, the key role of decision-making, preferring one method over the other available approaches, is clear. While different selection methods have existed for years and are being further developed, new approaches are also emerging.

When a supplier meets certain standards and exhibits competitive strengths within the fields desired by a company, the buyers consider it. According to Chen et al, there are two main types of supplier selection: single and combined models [12].

Single models include three main categories: mathematics, statistics, and artificial intelligence, whereas combined models are hybrid approaches combining these three types. The mathematical models include Analytic Hierarchy Process (AHP), Linear Programming (LP), Multi-Objective Programming, Total Cost Ownership (TCO), Goal Programming (GP), Data Envelopment Analysis (DEA), Simulation and Heuristics. The statistical methods also consist of Multiple Regression, Cluster Analysis, Conjoint Analysis, Discriminant Analysis and Principal Component Analysis. The artificial intelligence models include Neural Networks, Software Agent, Case Base reasoning, and Expert System, Fuzzy Set Theory (FST).

Size of order allocation and supplier selection in stochastic situations is always an exciting problem [13, 14]. Buyers may face a reduction in order quantity, lead-time variations, increased price, and penalties from suppliers under changes in promised demand, which is detrimental to the business performance. Under these circumstances, buyer organizations need efficient decision-

making approaches that help them identify which suppliers to continue business with, which ones to consider for new business, and which ones to eliminate.

From electronics to aviation, pharma, and food, almost no industry is protected to COVID-19. Based on a Supply Management Institute survey, almost 75% of companies south of the Canadian border experienced disruptions in their supply chains due to the COVID-19 pandemic, especially transportation restrictions. Around 44 % percent of the companies out of that 75 percent did not plan to handle this kind of disruption. Despite that, the global economic impact of the COVID 19 is uncertain. What is certain is that there will be several more months or might years of operational impact from COVID-19 all over the domestic and global supply chains.

1.3 Research Problem Overview

Supply chains in two hundred years ago had just and only one link, i.e., the farm. However, in today and current business environment, the supply chain from it's first point which is natural resources to the end point which is end users might simply contain of ten successive relations or even more. From the other side the sequence of transportation, warehousing and storage actions from the first point which is raw material suppliers to the last point which is market and end users has also transformed to new character over the years and progressively developed from a stepwise logistical chain to a supply chain. In today's manufacturing world no single business can controls more than just a minor percentage of the total operational process for many products. Therefore, today more focus is directed towards the supply chain, and less attention is paid to the individual company in the chain, nevertheless in reality and practice only the individual company as a element of supply chain can be starting point for any solutions with supply chain perspective.

In many years, the emphasis on supply chain optimization was to cut inventories, minimize costs and increase an asset which results to removed inventory buffers and flexibility to handle disruptions. So COVID-19 proves that many businesses are not completely aware of the liability of their supply chain relationships to global shocks.

Companies can naturally increase their control and visibility through supply chain networks by using and applying new technologies in supply chain. This kind of technologies help them to be stronger and flexible for nay disruption shocks. The old-fashioned supply chain methods also can improve and change to digital supply chain networks. Businesses can be connected in a complete supply network to enable end-to-end relationship, visibility, optimization, and agility. Leveraging innovative technologies such as artificial intelligence, the Internet, robotics, and so on can be considered to forecast and meet future disruptions, whether it is an incident like COVID-19 or other risks such as terrorism or supplier bankruptcy.

Considering the recent and modern global economy with all of the competition in market, it become more critical for nay individual company to be more visible in part of this comparative supply chain network. This visibility in supply chain help companies to have more share in market and it is vital for any company to find and recognize their own comparative edge and added values in supply chain. This kind of advantage helps them to be more comparative in business world. Many companies now realize that high odds of risks do not lie within the company itself; instead, it is due to dependency on the supply chain, and they also need to determine that better responsiveness need to be compensated to risk features when they are dealing with supply chain concerns.

With recent and modern technologies, the manufacturing sectors become more and more dependents on specialization and globalization and from another hand dependence to mass-

production. There is almost no company that can make the complete product unless it is a very simple product. In fact, industrialized society depends on highly integrated supply chain streams. Disruptions in those streams can rapidly affect individual companies, the supply chain, and the socio-economic status. Alternatively, the opportunities to deal and handle different type of disruptions are much better today than before. However, to handle such possibilities, companies need to gain knowledge of such risks and how to manage them.

1.4 Introduction to the research project

Right suppliers' selection is one of the critical strategies for increasing the quality and productivity of any company, and it has a direct impact on the company's reputation. Consistent suppliers allow manufacturers to reduce inventory costs and improve product quality. One of the main and important decisions specially for manufacturing in supply chain management is selecting the suppliers, because raw material, transportation and outsourced elements are normally high-cost components.

Generally, the procurement department has a critical role in reducing the purchasing cost and selecting suitable suppliers. The suppliers need to meet certain standards and show a strong competitive point in their fields can considered by a buyer's company. The supplier selection problem is simple if the selection criteria are identified and deterministic; however, most of them are qualitative, uncertain, and conflicting in nature which causes the selection process difficult. Variations in customer demand, price, quantity, and lead-time uncertainty from suppliers add further complexity to the problem. This study aims to discover optimal suppliers and optimal demand allocation among the selected suppliers under supply disruption risks.

COVID-19 experience recently pushed so many companies and whole industries to restructure the strategy of their overall supply chain model. Without any doubt, COVID 19 has test and evaluated the supply chain agility of so many organizations, particularly those that have been severely connected and dependent to China for raw materials, operations, and any kind of outsourcing.

In the current world's economy with considering a China as a main manufacturing country, any kind of major disruption can put the global supply chains at risk. Businesses whose supply chain requires direct or indirect suppliers in China are expected to experience significant disruption, even optimistically changing, and becoming normal in China.

Many past studies categorized selection suppliers under supply chain disruption and risk management. These studies highlighted several limits. Based on the limitation presented by these studies, some insights are presented here include the following.

- The supplier's selection is a strategic process that protects the long capability of the company. The main portion of current researches in suppler selection fields are based on some parameter for instance delivery time, cost, quality or price. Current reports do not consider the consequences of the business/ markets decisions by including new criteria like flexibility, risk, disruption, quality management, etc.
- One of the main aspects of supplier selection problem is the quantification of the disruption risk. Nevertheless, most of the studies concentrated to consider qualitative methods by calculation total cost and decision-making methods. Considering this aspect of the problem, it may impose some assumptions, especially in terms of qualitative criteria into quantitative criteria, which requires the involvement of the subjective criteria by decision maker group in selecting the supplier. Some of methods which is popular and mostly used

in the previous studies for qualitative methods are like metaheuristics methods, linear programing, multi objective programming, total cost of ownership, goal programming, questionnaire survey and so on.

- As we can see in current researches many studies concentrated on the supplier selection problem by considering qualitative and quantitative criteria in order to improve and optimize the cost and time. Although in today competitive environment suppliers are more observable to the risk of disruption at all over the links in the supply chain network, however, the supplier flexibility and ability also needed to be measured, and also it needs to consider cost and risk altogether. There are so many approaches for control risks in previous studies specially for industrial processes. In the research area the disruption risks for suppliers is a new perception. The current suggested solutions in the literature do not provide the applied answers to specific demands of these organizations and doesn't provide ant practical solution in order to deal with disruptions in supply chain. The literature on the subject focuses only on some specific case studies. Practical solution and techniques specially in operational level are still has lack of attention and incomplete. Thus, it is interesting to use quantitative techniques to measure supplier risks under the supply chain disruption situations.

1.5 Research Structure

This research aims to design and develop a framework for DMAIC based approach for evaluation of supplier risks and selecting suppliers and demand allocation under disruption risks. In this research we specifically will address the following problems.

1. Conduct a literature review on supply chain risks (supply, demand, price, network disruption)

2. Development of DIMAIC models for supplier risks considering disruption situations.

3. Development of multicriteria AHP based models for supplier selection under disruption risks.

4. As apart of this research we will do the validation and verification of the planned model. A case study with Luxxeen Inc. will be conducted, and the results will be compared against other standard approaches.

1.6 Thesis outline

This thesis is divided into three sections: In section 1, earlier studies in the literature are reviewed, and proposed research is presented. Section 2 present the DMAIC based approach for supplier risks modeling. We explain and overview the proposed case study problems in this section. In section 3, proposed approaches to explain the supplier selection problems are considered. Lastly, we discuss our progress, contribution, and future research.

Chapter 2

Literature review

Risk can be describing as "being exposed to the possibility of a bad outcome" [1]. This type of definition in this research is a universal definition of the risk perception. Any occasions and incident with negative impacts can be define as a risk and in order to be able to handle the risks, risk management is necessary. During the last years in both media and in research area, numerous classes of risks have received growing consideration [2]. For example, electrical outages in advanced countries reflected modern societies' fragility and total codependency on material and technologies. Nevertheless, there is not too many countries that they have the new strategies and regulations and also making it obligatory for companies to have risk assessment information in the yearly report. The September 11th catastrophic events had additional stressed the weakness of today's society [3]. From other side environment and climate change in long term might help and improve to facing the extreme weather circumstances like hurricanes and flooding. With the current divergence from companies to supply chain, it is essential to become a member of a larger supply chain that distributes a fair share of its profit.

Therefore, it is becoming vital for individual companies in the supply chain to investigate possible outcomes. Variable supply chain design and management solutions need to be found, and being promoted, especially in highly competitive atmospheres, becomes essential for the individual companies.

What we can observe in industry and specially in manufacturing sectors, the immediate company and operation productivity has priority and can dominated the other policies in company. However, in the designing of the supply chain, companies need to consider different kind of risks around the

supply chain network specially in large scale of supply chains or in complex products. So many companies they are in believe and understood that the increasing the profitability and competitiveness is against to invest and improves their system against risks in short term. In supply chain network we can see the major company risks are not inside the company and operations and mostly the risks are in other elements of company and other dependence in supply chain like supplier of supplier .[6] Based on the recent studies on the many company occasions affected by supply chain disruptions, we can find out the disruptions in any elements of supply chain network could easily broadcast to any other elements in supply chian[7].

In today modern and competitive economy situation so many businesses investing and improving their supply chain systems in order to get higher quality products or decreasing the lead-time and decreasing total costs. Selecting the precise and right suppliers is a crucial strategy for most productive companies and directly impacts their reputation. Generally, components of the supply chain are consistent. For instance, manufacturers can reduce their inventory costs and improve product quality by selecting reliable suppliers; however, in reality, supply chain disruptions occur in the supply chain network and can harmfully affect the performance of one or more components in the supply chain. Furthermore, considering conditions such as globalization, specialization, and mass-production may cause more serious problems. A supply chain disruption by definition is any kind of incident that might happening at any point of supply chain. This event can harmfully disturb the routine of one or even more members of supply chain and also affect the flow of goods or materials inside the supply chain network [8.]

One of very important and critical decisions in supply chain management and allocation is to find out the optimal number of suppliers for specific items[1]. Earlier research studied the problem of finding the ideal number of supplier's [16]. Nevertheless, there is not many studies about the problem of finding optimal number of suppliers for specific items under uncertainty of disruption events. Berger group is the first pioneer group to incorporate supplier failure probability into supplier selection. In order to calculate the ideal number of suppliers in case of risks for supplier failure, they developed the method based on mathematical prototype. Intriguingly, Ruiz-Torres and Mahmoodi, 2007 et al extended Borger et al. studied on different possibility failure risk for different suppliers, and they have an assumption that all suppliers have equal change of faille.[1,18]. Sarkar and Mohapatra 2009 et al. presented a method based on mathematical. They consider three different level of disruption (big event , medium event and small event) in order to find out the ideal number of suppliers. [19]. In an earlier study by Moritz and Pibernik et al. presented the method based on the quantity of order and related cost and also possibilities of volume discount for suppliers. [20]. Lately, Meena 2019 et al. has created a model to find out the ideal population of suppliers considering the disruptions risks [21]. The weakness of their model is related to demand allocation. In their model they didn't consider the allocation issue.

The study and research about allocation of demand can be categorize into two main classes; the first group consider the dividing the demand orders between different selected suppliers without any study and consideration of supplier risks and second group consider the order allocation between pre selected supplies and also by reflecting the probability of supplier disruption.

In the first category, most of the studies have specifically focused on splitting the demand among multiple suppliers to minimize the total cost or improve the supply chain's performance. In

additional to the that we also know, Sculli and Wu et al. are the first to address the order splitting problem [22]. They research is mainly in inventory problems. In their study, they consider the supplier lead times are generally distributed and their results demonstrate that the possibility of running out of stock in dual suppliers is less than single supplier. A.C. Pan 1989 studied order quantity allocation among multiple sourcing to improve the supply chain's performance. Ramesh et al. present a method for dividing the order quantities among two different suppliers which is called dual sourcing [23].

and their research results recommend that in case of high lead-time uncertainty, the best and effective solution for saving the cost is the dual sourcing.

Lau and Zhao 2004 et al. also developed a method in such a circumstance when we have stochastic demand and also unknown lead times for allocation of order quantity between suppliers [25]. Chiang and Benton et al. considered the order allocation problem, and they proofed when the cost of ordering is so high and also variation in lead time is low dual sourcing is much better option than sole sourcing [26]. Also, Sedarage et al. developed a model to determine both reorder and order-split quantities under multiple sourcing in single-item inventory systems where suppliers' lead-time and demand are stochastic [27].

The problem of demand (order) allocation among suppliers has been the considered by many past studies. Tsai and Wang et al have investigated the problem of order allocation and solved it using a multi-objective mixed-integer programming approach in order to resolve the problem in the condition of multiple products and several suppliers. The main weakness of this research is they didn't consider the supplier failure risk parameters in their model [28].

Even if several researchers studied the allocation of demand, however not too many of studies have considered the risks of supplier failure for demand allocation problem in case of disruptive events. Ruiz-Torres and Mahmoodi have considered the risk of supply delivery failure for demand allocation problem. In their model, they have measured only unique events which might be result of failure of a single supplier and this research is very similar to the work [1] and they have also considered suppliers' capacity capability to cover other suppliers in case of one or more supplier fails to deliver. Output flexibility in their research is defined as capability of suppliers to increase their production in case of emergency, this can be done either by running extra capacity or by having and managing additional inventories. In this research they didn't consider a variation in capacity for different suppliers.

Mahmoodi and Ruiz-Torres et al, they developed a model for the demand allocation between suppliers and they are the pioneers because they considered the risk of supplier fails [18]. Moritz and Pibernik et al. also extended the work of J. Blackhurst et al. by adding the factor of order volume and its dependency to procurement costs and different types of reward possibilities such as order volume dependent and order volume independent reward for suppliers [20,34].

Their outcomes show that suppliers that have lower offered price for specific items, products or service have more chance to acquire the order volume in compared to those how has higher price with potential compensation for large scale orders,

Normally, considering the discounts price based on order quantity offered by suppliers adds extra complexity for on demand allocation problem. Burke et al. for the proposed in demand allocation models have taken into account range of discount-pricing based on order quantity including linear discount pricing, progressively discount pricing for extra units, and also all unit discount pricing

based on total volume. Newly, Meena has presented the order allocation problem by taking into account of order volume discount and the risks of supplier failures. Nevertheless, in their model there is a lack of supplier selection method [36–38]. suppliers' selection and demand allocation studies are still in its initial stages. More studies are in need in allocation studies, especially in quantity discount pricing schemes under supplier failure risks.

In our study, we have tried to stimulate and find out the ideal number of suppliers and the allocation of demand between the preselected optimal number of suppliers and also by considering the possibility of supply disruption risks. We also have taken into account of different failure probabilities and different supplier capacities for every single each supplier.

One of the distinguishes and distinct main contributions of this study is the case study in Luxxeen productions with investigating supplier failure risks, supplier compensation probability and quantity discount pricing together in supplier selection and order demand allocation problem. This level of consideration on top of using real data in practical environment makes this study different from the current and existing previous researches in the literature and also the integration and combination of all these elements together in the model has made the problem too complex.

In the next step, we define the problem and development of the analytical model in Luxxeen Productions Inc.

2.1 Selection Number of Suppliers Problem

In today's competitive business environment, many companies invest in their supply chain to reduce total costs, lead-time and improve the quality and relationship with suppliers.

An optimal number of selected suppliers is a problem with much attention from academicians to general practitioners. One of the main and vital problem that we can point specially in

manufacturing sector is define and decide about the number of suppliers that each company need for every single item or products. Number of suppliers and related costs specially for supplier management cost and related supplier over heads can easily affect the overall cost of procurement and consequently cost of each item.

2.2 Supply chain disruptions problem

Disruption in supply chain is a situation that takes place at one link in the chain and can harmfully affect the performance of one or more components located elsewhere in the supply chain and the normal flow of goods and materials within a supply chain [34].The supply chain risk is the predictable exposure interruption of materials or products flows in supply chain because of the possible impact of disruptions which is usually categorized by the possibility of disruption, and the impact of disruption if it occurs [35]. Because the supply chain is set as a network, disruption can happen in any node (e.g., a supplier or the manufacturer) or link which is the chains of raw material and transportation between supplier and manufacturer. The disruption may be happening inside or outside the chain. For instance, a disruption in the estimated flow of materials from a supplier can be happening because of the supplier's bankruptcy or caused by catastrophes (e.g., an earthquake) or political events in the supplier's region. A disruption may affect several performance indicators in a supply chain. Usually, the supply chain performance is analyzed based on customer service level, number of late orders, financial aspects, profit, operational cost or a group of parameters [5]. For example, an emergency shutdown in one of the suppliers may delay the order delivery to customers and reduce the expected profit. Nevertheless, the influence and effect of disruption, is not always right away and immediate, in many cases it may take some time for the show the related impact or full impression on the system performance (Figure 2).

Disruption also might have a long-term impression on the business or whole supply chain system. For instance, if a relationship with clients or company reputation is getting damaged then the disruption footprint can be very problematic to recover and last long[7].

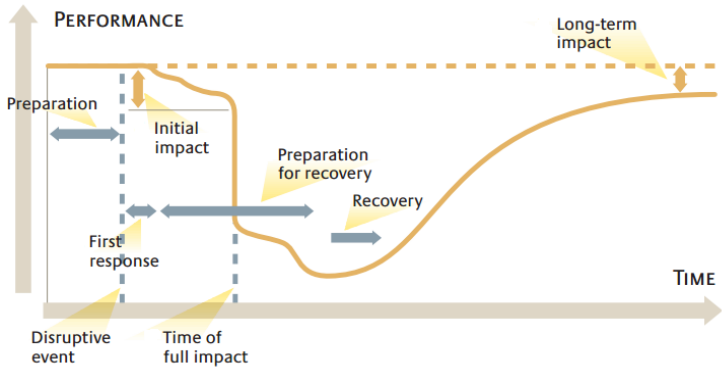


Figure 2:. The impact of disruption on the performance (adapted from Sheffi and Rice, 2005).

Several buying companies use the order splitting strategy (splitting the total demand among multiple suppliers) to increase service level, quality and reducing the supplier power on the buyer and procurement costs by taking advantage of competition among the suppliers [37, 38]. Besides, potential catastrophes such as economic, environmental, and geopolitical are constantly disrupting the world's supply chain operations in current scenarios. Consequently, an order-splitting strategy is becoming a viable means for managing the risks of disruptive events.

2.3 Quality management techniques

Quality management as a foundation of competitive benefit is acknowledged for a long time and

also it is a key and main significant driver of global competition [126]. There is not too much study that they have tried to recognise the influence of TQM employment on corporation performances in both industrialized and developing countries [126]. Bunney and Dale described the overview and outline of the quality management techniques according to the stage of the development process. The overview of TQM can summarise in three stages. First stage is the analysis and preparation, second stage is management concentration and commitment, and third stage is comprehensive improvement. The first stage of the total quality management needs some techniques in order to finding the facts, some of these techniques are COQ, cost of quality and DPA, departmental purpose analysis. The second stage in order to recognise problem zones and measure their effects and rank the requirement for solution also need to use some data analysis tools like cause & effect analysis or flowcharts or Pareto analysis. All through in the third stage of total quality management needs more complex tools like FMEA, failure mode and effects analysis or SPC, statistical process control to enable corporate improvement[127].

Quality Management contains four important components, Quality Planning, Quality Improvement, Quality Control and Quality Assurance

Total Quality Management			
Quality Planning	**Quality Improvement**	**Quality Control**	**Quality Assurance**
Cost-Benefit Analysis	Lean/Six sigma	Cause and Effect Diagrams	Affinity Diagrams
Cost of	failure modes and	Flowcharts	Process Decision

Quality(COQ)	effects analysis		Program Charts (PDPC)
Brainstorming	Flowcharts	Check Sheets	Interrelationship Diagraphs
Force field analysis (FFA)	Process mapping	Pareto Diagrams	Tree Diagrams
Nominal group technique (NGT)	Statistical process control	Histograms	Prioritization Matrices
Project Charter	Root cause analysis	Control Charts	Activity Network Diagrams
	Decision trees	Scatter Diagrams	Matrix Diagrams
	Clinical audit	Benchmarking	Quality Audit
	Collaborative Improvement	Design of Experiments	Process Analysis
	Kaizen		

Table 1: Quality Management tools and techniques

2.4 Industrial practices and techniques for disruption risks mitigation

In this section we are explore and reviewing some of disruptions that companies experienced including the risk and approaches they have taken in order to mitigate the disruption. The analysis of the case studies proofs that manufacturing industry especially aerospace and automotive faced different type of

disruptions particularly when they are associated with more suppliers.

Bombardier which is one of the main players in aerospace and transportation industry with around 100 different production lines, research center and service facility in 25 countries. Bombardier operates two main business category which are rail transportation and aerospace as well as research centers for future airplanes. The main disruption in Bombardier is related to the COVID-19. Pandemic harmfully effected the worldwide economy and disrupted overall supply chains and also caused substantial uncertainty in economic specially in financial markets. As a result, Bombardier end up decreasing or postponed operations in many different production lines around the world in order to control the costs. (Source: Bombardier annual reports)

Management tools and approaches in bombardier for mitigate the disruptions risks include:

- Routing supplier performance control and monitoring for on time delivery and quality
- Improvement of supplier performance
- Waste reduction and elimination
- Product flow improvement
- Utilization Six Sigma methodologies for supplier improvement plan in disruption situations
- Continuous Improvement
- Suppliers and products auditing
- Business Process Audits
- Risk Analysis

Pratt & Whitney is one of the world-class aerospace manufacturers of engines, aircraft systems and parts and also aircraft services. Pratt & Whitney's engines are installed on more than 25 percent of the

aircrafts around the world in 160 countries. Pratt & Whitney's always trying to cover the customer expectations quality and performing continuous improvement.

Supplier reliability and be proactive for any type of supply chain disruption is one of the crucial components of Pratt & Whitney strategy for providing the world class service to the customers. One of the main strategies of Pratt & Whitney for managing the supplier chain disruption is supplier training and on-line self-assessments. Disruption supplier training includes methods and approaches provide a necessary action that needs to be perform by suppliers in case of disruptions. Another method is on-line self-assessment system for control and evaluate the supplier reliability level. Pratt & Whitney has a specific supplier award in order to encourage the supplier for better service which call it Gold Award. This Award is designed for on-time delivery and high-level supplier performance and this award is part of company programs to manage and mitigate any future disruption.

Bell Helicopters is also one of the aircraft companies with more than 35,000 aircraft in different countries around the world. The main operation for supply and service centers are concentrated in Canada, United State, Europe, and Singapore. Supplier quality development of Bell Helicopter for managing the possible disruption comprises of following activities:

- Continuous Improvement consists of:

1- Elimination of Waste principally through Lean operations and tools

2- Supplier selection through DMAIC methods

3- Suppler reliability control and improvement (Six Sigma)

- Auditing Supplier Facility consist of:

1- Audits of supplier reliability and capability

2-Supplier’s certification programs like ISO 9000/9100 system(s) for quality control of products or services

3-Evalute the supplier of supplier and subcontractors

4-Inspection System

4- Material control and assign required certifications

5-Supplier contribution for supplier development in disruptions situations

6-Systematic problem-solving techniques

7-Quality Management

(Source: Bell Helicopter annual reports, website and supplier quality portal)

Nissan is a Japanese international car manufacturing. Initially Nissan was one of the sub companies of the Nissan Group, however it become more autonomous after Nissan hired Carlos Ghosn as a (CEO) and his company restructuring. Nissan after GM, Volkswagen, Toyota, Hyundai and Ford was the sixth major car manufacturer in the world in 2015. Methods and requirements for supplier development for mitigation of disruption risks are:

- Supplier facility auditing by Nissan Supplier Quality Assurance (SQA) group
- Implementing of Lean Manufacturing‖ and utilization with visual Factory approaches
- Allocation of safety level for warehouse and supply flow control for case of disruption
- Continuous improvement all over the supply chain

Honeywell which includes more than 100 subcompanies, is focused on manufactures of high-level technology for fuel system controls, avionic system for aircrafts, security, and energy. Honeywell service and product sectors are consisting of avionic systems for cockpit, fuel system for aircraft engines, automation, transpiration systems and technology. All the Honeywell suppliers are mandate to have ISO 9001 certification as well as TS 16949 standard. In order to make sure the supplied products or materials meets the Honeywell requirements, so supplier evaluation process

and selection is considered as a first action in supplier chain management. Every potential new supplier in Honeywell will be nominated according to price, lead time, customer service and so on and also need to join a Honeywell continuous quality improvement program. From other side supplier performance is observed according to product quality and delivery performance quality. For disruption risks mitigation, Honeywell has different monitoring programs like, routine supplier performance measurement, reliability analysis, and development methods to guaranty reliability and continuous improvement.

Honeywell mainly use Six Sigma tools, DMAIC, Advance product quality planning (APQP) and Lead Time Scoring (LT) to review and monitor possible supplier disruptions as well as to manage enhancement of processes, service, and products (Source: Honeywell website, company annual reports and portal)

2.5 Research Gap

Table 2 presents different studies on supply chain management under disruption. As we know there is different level of disruptions like low level disruption, medium level and high-level disruption and nowadays we have COVID 19 which is another type of high-level disruption. Whether the approach will perform the same or different when we have massive large-scale disruption like CORONA virus or when we have miner disruption such as production defects on the items that supplied to the organization, in the current studies there is lack of experimentation and investigate on different type of disruptions and also the impact of high-level master disruptions like COVID 19 and study about impact of supplier development for disruption situations and also changes on quantity of materials in case of disruptions.

Existing quality management studies provides different approach's like PDCA approach (Plan-do-check-act cycle), statistical process control, just in time, statistical and management approach, however when we look at the manufacturing companies like Luxxeen such type of defects like supplier behavior or supplier quality management not addressed. In the literatures we cannot see any studies to investigate the type of contract between buyer and supplier considering the stock safety margin in case of disruptions. Existing quality techniques do not handle this type of challenging situations which I am addressing in this thesis and also this study is includes the recommendation for low level and high disruptions.

From another point of view, most of the current studies that they used DIMAC methods are focused on supplier performance improvement like improving cost or time and we can't find concentration on the supplier disruption challenges with DIMAIC.

Type of Disruption		Method	Sector	Journal Name	Year	Author
Type	**Details**					
Supplier	Local and global	digital SC transformation	Digital supply chain	Operations Management Research	2023	Vu Minh Ngo,et al.
Supplier	Local disruption	The quantitative research approach	Manufacturing firms	Journal of Manufacturing Technology Management	2023	Zulaiha Hamidu et al.
Supplier	Local disruption	Blockchain technology	-	Supply Chain Forum: an International Journal (SCFIJ)	2022	Rami Alkhudary et al.
Supplier & Demand & Process	Supply and demand	Literature Review	-	International Journal of Logistics Research and Applications	2021	Mansoor Shekarian
Supplier	Local and global	Information management model	vehicle assembly sector	The International Journal of Logistics Management	2020	Dario Messina, et al.
Supplier & Demand	Supplier & Demand	Baseline analysis and archival data	Global business and strategy	Journal of Asian Finance, Economics and Business	2020	Jarrah Al-Mansour, et al.
Supplier	Supply and demand	Analytical model	-	IFAC Conference on Manufacturing Modelling, Management and Control MIM	2019	Ivanov and Sokolov
Supplier	Quality issues	Bayesian network, decision trees	manufacturer	Annals of Operations Research	2019	Hosseini and Ivanov
Management	Supply	agent-based modeling	-	Journal of the Social Sciences	2018	Kochan et al.
Supplier	Risk – Costs performance	Optimization-stochastic programming model	chemical supply chain	European Journal of Operational Research	2019	Snoeck et al.
Supplier	Inventory control	Hybrid model – discrete event simulation and agent-based model	transportation	Global Supply Chain and Operations Management	2017	Ivanov
Supplier	Supply risk	Graph theory	Synthetic resins	Omega	2018	Nakatani et al.

Supplier	local disruption	Stochastic Mixed Linear Programming	Service	International Conference on Advanced Logistics and Transport	2014	Faiza Hamdi
Supplier	Disruptions and yield uncertainty supplier reliable and reliable	Heuristic	-	Computers & Operations Research	2012	Schmit and Snyder
Supplier	Global risk	FANP	Manufacturing	Expert Systems with Applications	2011	Vinodh et al.
Supplier	Quality risk management	p-chart model	Automotive	International Journal of Production Economics,	2012	J. Sun, M. Matsui and Y. Yin
Demand	Environmental	Expert Interviews	Service	Management Science	2011	M. Srinivasan, D. Mukherjee
Supplier	Uncertainty	mixed integer linear programming	Transportation	Computers & Industrial Engineering	2013	A.J. Ruiz-Torres, F. Mahmoodi and A.Z. Zeng,
Supplier	Local disruption	-	-	International Conference on Industrial Engineering and Operations Management	2011	P. L. Meena and S. P. Sarmah,
Supplier	Quality issues	analytical model	-	The International Journal of Advanced Manufacturing Technology	2015	Lal Meena1 & Sarada Prasad Sarmah2
Demand	Environmental	Meta-heuristic Approach	Service	Journal of Industrial Engineering and Management	2014	Masoud Rabbani, S.M. Khalili, H. Janani, M Shiripour
Catastrophic	Catastrophic	-	Automotive	Operations, Information & Technology	2014	Erjie Ang, Dan A. Iancu, and Robert Swinney
Demand	Supply and demand	Conceptual framework	-	Production and Operations Managemen	2005	Paul R. Kleindorfer, Germaine H. Saad
Supplier	Local and Global	Literature Review	-	SSRN	2012	Behzad Behdani, Arief Adhity
Supplier	Production facility failure	Catastrophe classification framework	-	Journal of Marketing Channels	2009	Sodhi and Lee, Stecke and Kumar
Quality	Quality problems in End Product	-	Medical	Journal of Operations Management	2010	Pyke and Tang, Dani and Deep
Supplier	Human resource problems	Best Worst Method (BWM)	-	International Journal of Supply and Operations Management	2010	Stecke and Kumar
Supplier	Local and Global	Literature Review	-	the International Journal of Production Economics	2014	Guljana Shakir Ullah*, Luisa Huaccho Huatulco and Thomas F. Burgess

Earthquake	Earthquake,	-	Manufacturing	Research Institute of Economy, Trade, and Industry (RIETI)	2014	Vasco M. CARVALHO
Supplier	Local and Global	Literature Review	-	Business Science and Applied Management	2015	Irène Kilubi
Internal	-	Litrecture Review	-	Omega	2012	Lawrence V. Snyder
Supplier	Probability Disruption of a foreign and local supplier	Analyze of expected profit functions (EPFs) probability	-	Omega	2009	Yu et al.
Demand	Demand and supply risks	heuristic	Public organization	OPERATIONS RESEARCH	2008	Federgruen and Yang
Internal	Disruption risk and credit period	Analytic model	Buyer firm	Industrial Engineering International	2011	Arkan et al. (2011)
Demand	Demand disruption	Linear program	Manufacturing	Computers & Industrial Engineering	2011	Chen et Zhuang (2011
Catastrophic	Catastrophic	Simple heuristic	-	Transportation Research	2011	Meena et al. (2011)
Supplier	Local and global	Mixed integer programming	-	Omega	2011	Sawik (2011 a)
Supplier	Local and Global	Stochastic Mixed Linear Programming	Service	International Conference on Advanced Logistics and Transport	2014	Ahmed Ghorbel
Internal	Disruption risks	Stochastic model	Manufacturing	Computers & Operations Research	2012	Xanthopoulos and al.
Supplier	Disruption risk	Stochastic newsvendor program	Manufacturing	Industrial Engineering and Management	2013	Zhu and Fu (2013)
Supplier	Local and semi-global supplier	A mixed integer programming	-	Omega	2013	Sawik
Catastrophic	Disruption of domestic suppliers and disruption of the foreign supplier	mixed integer program	-	Computers & Operations Research	2014	Sawik
Supplier	Global disruption	Stochastic Mixed Linear Programming	Service	International Conference on Advanced Logistics and Transport	2014	Faouzi Masmoudi
Bankruptcy	Bankruptcy	Discrete-event simulation	-	Proceedings of the Winter Simulation Conference	2010	Finke et al
Supplier	Disruptions	Discrete Time Markov Chain simulation	Transportation	Transportation Research	2011	Schmitt
Supplier & Demand	Supply disruptions and demand uncertainty	Discrete-event simulation	-	International Journal of Production Economics	2012	Schmitt and Singh(2012)
Supplier	Local disruption	Mixed integer programs	-	International Federation of Automatic Control	2016	F.Hamdi

Supplier	Global disruption	Hybrid fuzzy AHP-fuzzy	Manufacturers	Transportation Research	2016	S. PrasannaVenkatesan
Supplier	Local disruption	Stochastic Mixed Linear Programming	-	International Journal of Advanced Manufacturing Technology	2016	Purushottam Lal Meena

Table 2: Survey of previous effort under disruption

The supplier selection problem can be a simple activity if the selection criteria are known and deterministic; however, most of the criteria are qualitative, unreliable, and conflicting in nature, making it a problematic selection process. Variations in customer demand, price, quantity, and lead time uncertainty from suppliers add further complexity to the problem.

Selection of suppliers and allocation of orders to desire supplier usually are carried out in three stages. In the first stage, pre-qualification or short-listing of suppliers is based on different criteria such as price, lead-time, capacity, quality, location, etc. In the second stage, the buyer selects the optimal number of suppliers from the list of pre-qualified suppliers. In the final stage, the buyer decides how much order quantity (demand) to be allocated to each selected supplier based on the supplier's information related to price, quantity discounts, the maximum capacity, and failure probability. This study focuses on determining the group of supplier(s) that they need be selected from the pool of pre-qualified suppliers and amount of order quantity that needs to be allocated to each selected supplier with considering the disruption events.

Source of supply chain Disruptions			
Natural disasters		**Man-made disasters**	
Earthquakes	Tsunami	Environmental disasters	Train or other transport issues
Floods	Ash clouds	gas leaks & oil spills	global warming
Agricultural diseases	Drought	mine explosions & arson	Construction disasters

Pandemic influenza	Extreme heat	Stock exchange/trading disasters	Economic environment
Hail	Hurricanes	Supplier bankruptcy	Terrorism
Landslides	Wildfires	War, Fraud	Cyber attacks
Ice storms	Lightning	Labour Disputes	Theft

Table 3: Source of supply chain Disruptions

In table 3 we can observe the different source of disruption in supply chain which includes the natural events and man-made disasters. The example of natural events are earthquakes, floods, tsunami, agricultural disease and the recent one COVID 19. Also, the examples of man-made disasters are like; environmental disasters, mine explosions & arson, stock exchange and trading disasters, global warming and so on.

Chapter 3

Solution Approach

3.1 Risk and Uncertainty in Global Supply Chains

Back to 1921, Knight examined the difference between predictable risks (understandable probabilities) and unpredictable risks with uncertainty (unknowable probabilities) in his work [123]. If we don't know what will happen, but we know the probabilities, that is a risk. In case we are not sure about the probabilities that are uncertainty and uncertainty is totally different from the concept of risk, which has never been accurately separated.

Holton defined risk as a combination of exposure and uncertainty [124.] Also, Adams recommends that all the formal behaviours of risk and uncertainty and related probabilities needs to be known and these kinds of risks can be in operations research, game theory, economics, and management science. Even possible, we need to the probabilities and scales of possibility outcomes [125].

3.2 Global Supply Chain Risks Management

While there is no best method of defining SCRM, Norman and Lindroth [112] described SCRM as the collaboration of supply chain associates and employ risk management development tools to moderate and manage the risks and uncertainties which is happened or influenced by logistics activities or resources [112]. In constructing the risk management policies, we can split the strategies into six classes:

1- Avoid – Delay enters a product to the market

2- Extend – Extend the resource commitment to sustain highest flexibility

3- Concept – Take advantage of risks to achieve competitive advantage

4- Control – Data and material integration of corporation and suppliers

5- Transferring/sharing risk – outsourcing, offshoring, contracting.

6- Security –Recognizing atypical activity and practicing safety measures. Managers need to pay attention to both market risk and business risk and balance these two aspects.

DMAIC based approach for supplier risks

3.3 Impact of Global Supply Chain Disruption Risks

Global supply chain interruptions like recent event COVID 19 can destructively disturb the operational and economic performance of corporations. Bearing in mind the long-term influence of disruption risks on organizations, market shares and economy, handling the risks and mitigating become vital to getting out from uncertainties. Supply chain performance often affects financial reports' precision; CEOs need to seek a deeper understanding of supply chain risks and find out early red-flag events that can affect their company’s performance. Accepting the fact and reality

of disruptions and understanding how it will broadcast the effects over the supply chain is very essential to implement supporting security and competent movement.

The DMAIC involves five steps, Define, Measure, Analyse, Improve, and Control. These all components working together and have a correlation in order to generate the DMAIC method. This DMAIC method is one of the extremely important six Sigma methods, which helps bring various teams from different departments of the company together to perform and model a processor problem; they can share their work and ideas to find the solution for existing problem. Also, DMAIC can be used for improving an existing business process. DMAIC contains the following phases:

- Define the first stage is defining a goal for process improvement by considering customer demands and the enterprise strategy.
- Measure crucial features of the existing process and collect appropriate data.
- Analyze the information to validate cause-and-effect relationships. Control and define the relationships and make sure all aspects have been considered.
- Improve, advance, and adjust the method based on data analysis using methods like the design of experiments and so on.
- Control to make sure and confirm the process improvement. Establish a test run and set up a control system to rapidly monitor the process.

Six Sigma Phases and related techniques	
Define stage	- PC - Project charter - VOC - Voice of the customer - VSM- Value stream mapping

	- SIPOC
Measure stage	- BPM - Business process mapping - PC - Process capability - Pareto chart
Analyze stage	-Root cause analysis -Failure mode and effects analysis -Multi-vari chart
Improve stage	-Design of experiments -Kaizen
Control stage	-Control plan -Statistical process control -5S -Poke-yoke
D M A I C	

Table 4: DMAIC Phases and related techniques for each phase

3.1 Define

The risk of disruption grows whenever supply chains continue to develop more global and compound. Most organizations are aware of the related risks however, many are not

prepared to handle disruption. With increasing probability of experiencing a disruption, it become critical and necessary for corporations to be ready and able to manage risks proactively. However, the prospect of possible failure facts and the global impact of these risks is always challenging. In order to model the risk and have the overall view around the supply chain management risks, systems thinking ideas are used in order to be able to modeling the supply chain risks. At this stage we are aiming to create a general, methodical and measurable risk evolution process in order to be capable measuring the complete risk behavior, by considering systematic perception, the hypothetical outline for supply chain risks is developed in this section. This hypothetical outline of risk management methods comprises of three main sections; identification of risks, assessment od risks, and risk mitigation, as we can seen in Figure 3.

Figure 3: Framework for supply chain risk. adapted from Abhijeet Ghadge et al.,

The first step in the outline is classification of risks, where the risks are recognized. The

second phase is to be identifying the risks and finding out trending risks. This process involves forecasting the risk variables' operational restrictions. By implementing and using the risk modeling based on disruption, we can discover and find the impacts of potential risks in terms of cost and time and the probability of failure point. After identification of the risks with risk assessment process, we are able examine the sensitivity analysis through quantitative modeling techniques in order to evaluate the overall performance of risks. The risk mitigation method is divided to tactical planning phase and risk mitigation phase. The solid analytical data from risk trending, risk modeling, and sensitivity analysis provides risk mitigation instructions.

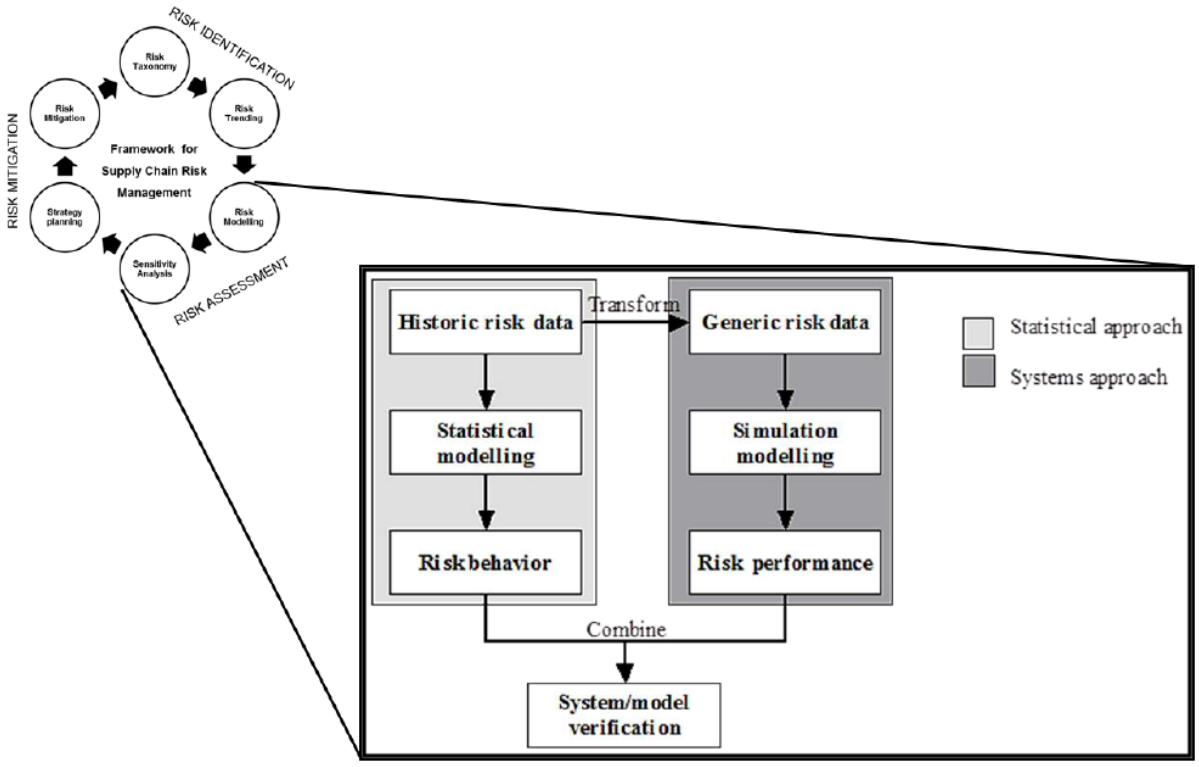


Figure 4: Modelling supply chain risks. Adopted from Abhijeet Ghadge

The systems thinking approach for risk assessment is present in following with step-by-step experimental research design. In the provided framework model for supply chain risk management, the modeling of supply chain risks primarily emphases on the risk assessment procedure. In order to find out the results, the experimental research designs use OR modeling, statistical study and simulation methods[42]. Figure 4 determines the created research design for supply chain risks modeling. It consists of two individual approaches for assessing the complete risk behavioral performance.

The model consists of two parts, which one side is named as 'statistical approach' and the output of this part will be the evaluation of risk behaviors, while the side is named as 'systems approach' and the output will be the determining and discovering the risk performance. To find out the complete results, both modeling stages during the risk assessment process needs to run parallel to each and getting combined.

With the collaborating of Luxxeen Productions Inc, this experimental study was conducted to examine the framework's feasibility in the real industry environment. The Luxxeen management team provided us with the data also the chance of the testing the framework in real environment for supply chain risk management.

Classification of risks. The primary phase of the framework for supply chain risk management is recognizing and categorizing the risks based on causal attributes. Risk classification can be defined as helping the systematic and repeatable identification of risks related to a given system [43]. Typical risk classification is based on sources of risks as organizational and network risks. Structural risks stand inside the organizational borders and from other hand all the risks related to company network arise from communications and infrastructures between the

corporations and other supply chain network associates [44]. The following table is classified risks based on essential dimensional relationships in terms of nature of risks, source, activity and attribute of risks. The classification that presented is not just restricted to classifying the risks according to source of risks, it also takes into an account of other significant co-dependent factors for instance business follows, type of work activities and characterise of the organization through risk classification creation. Based on what we used for recognizing supply chain risks applying enterprise architecture's classification, this delivers a systematic approach to selecting and recording unclassified activities of risks. Enterprise construction is categorised into business and system segments. The business segment characterises the main central work activities and assets in an organization and the essential business follows of the organizations as the principal class of requirements [45], emphases on internal business activities.

Level	**Business Enterprise**			**System Enterprise**		
Risk attribute	**Process**	**Organization**	**Location**	**Data**	**Application**	**Technology**
Sources/activities/ issues/practices	Emphases on internal business activities Which monitoring the company process and interrelated sequence	Emphases on human resources within an enterprise. Studies the abilities, values and roles of the people and studies the structure of team	Emphases on geographic location types. Problems related with infrastructure and physical facilities are measured in	Emphases on commercial information data. It discourses the structure, content and relationship related with information data.	Infrastructure, performance of the software used in the corporation. All problems related with IT are takes	Emphases on the technology related with the software's and hardware and all problems related with communication between hardware/software

		and organizational units related with the specified activity.	this group of the characteristic		care in this stage.	are measured in this section.
Nature of risks	Demand risk, Product design risk, Information distortion risk, Quality risk, Disruption risk , Operational risks,	Reputation risk, Financial risk, Performance and Skill risk, Poor management risk and Security and Safety risk	Political risk Safety risk Capacity risk Supply risks	Legal and Regulatory risk Risk of IP (Intellectual Property) Deformity of Information risks	Network risk Risks related to bossiness Integration	IT destruction Technology risk

Table 5: Risk Classification

Classification of risks delivers an organised approach for recording the risk behavior within the supply chain network.

Trending of risks. Trending of risks is specified as identifying upper and lower limit sectors of process which is detected for each risk characteristic. This is very obvious that every single supply chain network is projected to behave exclusively, and it might have different functioning limitations. Before understanding the overall risk behavior, it is crucial to understand and know

the essential nature of risks and be in believes the risk is a financial liability and it is critical to define the limit of its liability [46].

Every risk event comprises more than one kind of risk characteristic. In such a condition every risk should be independent with no suitable distributions considered. In order to explain the system's limit, the probability of upper and lower boundaries of an event and related impact in terms of delay and cost are very important parameters for the risk assessment. Also, service and quality related with customer sensitivity are expected to be the function of either delay or cost in the risk assessment process.

In order to recognizing risk events, we need to recognize, collect and document all possible risk events that may influence the corporation from meeting its goals. This is including classifying sources of risks and discovering risk. In the stage of determining of possible risk actions, we need to also create a comprehensive list of all possible risks that supply chain might face and be disrupted and recognizing and classifying which risk occasion has directly and indirectly effect on supply chain procedures.

Modeling of risk. The principal study on risk trending brings instructions on the way to understand vital components for modeling risks. The performance of risk modeling is essentially based on the way and structure of supply chain risk model development. The proposed model is a systematic combination of the working mechanism and risk theory in order to model the risk activity. In figure 3 the illustration of the supply chain risk model is shown.

When we are studying the risks of supply chain that means we need to extend our view and consider the suppliers of supplier to customers of customer and also the global environment they are operating in and any circumstantial with the possibility of interrupt linkages around the whole supply chain should be considered a risk event. Global supply chains have increased supply chain

risk significantly and are subjected to natural disasters and man-made disasters. The following figure is a comprehensive overall view of different supply chain risk modeling methods.

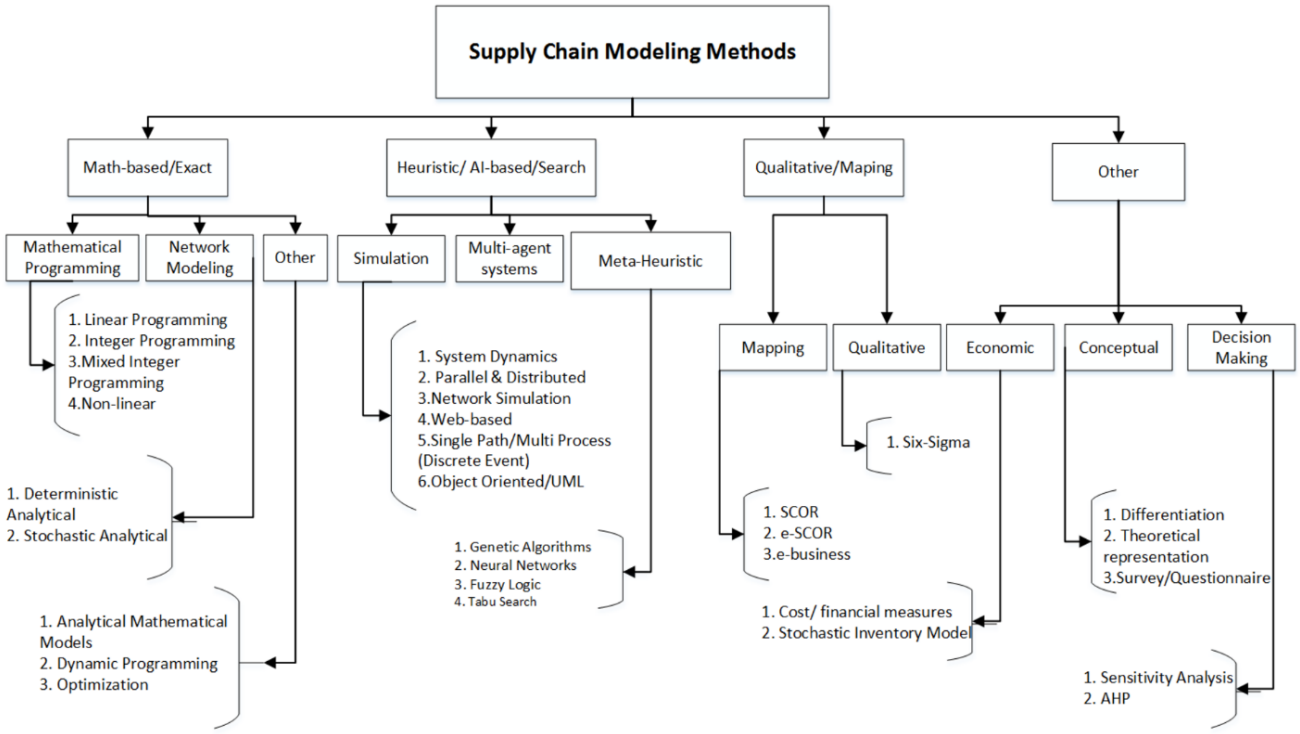


Figure 5: Supply chain risk modelling Methods

Measuring and Evaluating of Risks. The process of gathering and documenting every possible risk is called evaluation of risks. This process also includes collecting of the causes, likelihood, consequences and producing a complete list of the economic impact for whole risks that have a potential to disrupt the supply chain and also recognising which risks will decrease income and increase costs. Some of the usual issues in this regard might happen orders not delivered in full, commit date not met, document errors, and product not perfect.

Risks impact		
On	**Issues**	**Impacts**
Supply Chain Responsiveness	• Source speed not consistent • Make speed not consistent • Deliver speed not consistent	• Costs increase: Source, Make, Deliver • Reduces time for Make & Deliver processes • Delays Make & Deliver processes • Inability to meet commit date consistently • Delays getting paid; increased cash-to-cash cycle-time which increases cash flow issues • The customer cannot complete work or loses business
Supply Chain Agility	• Unable to meet an unplanned quantity increase (eg. 20%) within a specified period of days (eg. 30 days)	• Significant impact on cash flow • All costs increase in an attempt to meet unplanned demand • Significant impact on labor and assets to store materials make, store finished product and deliver
Supply Chain Cost Management	• Possibly, all supply chain cost elements could increase	• Cost of Planning • Cost of Sourcing • Cost of Material Landed • Cost of Production • Cost of Order Management • Cost of Fulfillment • Cost of Returns
Supply Chain Asset Management Efficiency	• Extensive Cash To Cash Cycle Time	• High net working capital required • Heavy reliance on other financial avenues • Increased storage costs

	• Low or no return on supply chain fixed assets	• Low profitability • The cost to maintain assets not recovered through sales

Table 6: Risk issues and Impacts

Mitigate of Risks. The critical factor in supply chain risk mitigation and management is identifying potential losses from unexpected events, although all risks of supplier disruption cannot be eliminated. Mitigate risk is the process of the movements required to remove, reduce or accept and screen the risks. By generating, approving, collaborating, and launching the risk mitigation plan, we can reduce the probability of risks occurring inside the supply chains. One of the sourcing risk mitigation approaches is multiple sourcing of supply which dropping the effect of risk. Strategic contracts and corporations and with suppliers are one of other approaches which can help to constant service in the occasion of capacity limitations. Partnership, cooperative planning, and replacement is also another different strategy. Data sharing related to demand and upcoming orders and forecasting a sale with supply chain associates reduces the risk of unpredicted demand and shortages. Also, cooperative product design and delivery time including designing products with suppliers can decreases the risk of material shortages or material non-performance.

Project Charter. Usually, project charter is an article to describing the target and overall view of a project and its opportunity. Project charter is an official article that allows the project to be start. In today's modern business environment, so many medium or big companies before opening and starting a new project, they ask and require a signed project charter.

Investors and all the group they have a contributor to the project in order to have a clear and better understanding of what this project will carry and what would be result at the end, they need to have a project charter. Nevertheless, it is essential to have enough knowledge that what kind of resources it needs before we sign for it which is the exact output of project charter.

Project Charter Components. Subjected to company culture and the individual company charters, the component contains in the project can vary. Generally, the project charter is included the following parameters:

Project Overview – Which includes of the name of the project, date of establishment, project manager, purpose of the project, author of the charter and version of charter.

Project Details – Project explanation and details, containing the purpose, the project process, the important stakeholders and customers.

Project Scope – Most of the companies intend to get the project scope soaked (mentioned) in the detail part. Although, huge projects require a separate section to provide a tangible understanding as to the project scope.

Project Team Organization – The name, contact details, the roles and some other information of team members who would take part in implementation.

Project Resource Planning – All the employed resources such as human and non-human resources, finances, etc.

Project Communication Plan – The plan has to be set up which revise changes and make sure the process will get to the point at the end and all goals and objectives are preserved. It sometimes happens that the anticipated way defined for the project may differ from the way it is walking along with, and this variation requires changes to the project charter. To do so, bi-weekly meetings and communication plans are inevitable parts of this way to our goals that would keep

out project path along with the right way.

Project Timeline – The timeline of the project is good to know since it will give the leaders and staff clues on if they accomplish the objectives. Both project management and clients need to know of the percentage of the project's being in time and the best way7 to estimate it is "timeline."

Signatories – the list of signatories to the project

Normally a project manager is responsible for developing the charter. To develop the charter, it is required that the project manager has some qualifications like a strong background, expertise, and experience. The manager has to have a close collaboration with the key stakeholders, customers, business sponsors, other departments within the organization to get the charter developed. Plus, there needs a few items such as problem solving, conflict resolution, meetings, expectations management, brainstorming and so on, that have to be taken into consideration to obtain the desired results. By signing the charter, the authority of project execution, use of organizational funds and resources will be officially given to the manager to let him achieve the goals.

Voice of the customer (VOC). VOC is used to satisfy customers' expectations, preferences, and dislikes. To be more precise, it is a market research method that generates a list of customer needs and requirements, structured into a hierarchical construction, and then the importance and satisfaction will help let it be prioritized based on current alternatives. The tow most key roles of VOC are played by qualitative and quantitative research steps. These two roles are defined at the beginning of any new product, service, or process to make a better understanding of the requirements. The nest step right after initializing a project and gathering voices of customers (customer of the project which can be internal in the corporation), we have to define the critical to quality needs.

Critical to Quality (CTQ). A critical to quality, also called CTQ, is a tool consists of six sigmas utilized to categorize (Classify) the customers' needs and turn that information into measurable product and process requirements. This could also be a helper in giving a more accurate understanding concerning the quality and characteristics of a product or service asked by customers to organizations.

The first step to initiating any process to improve a project is essential for a business. One of the important parts of the process is to designate the features of the product or service that are sensitive to quality- this is called CTQ. Making a suitable CTQ specifies the driver behind those characteristics and is also a way of meeting them.

Customer needs is the very first step to generate a CTQ tree whose data is usually gathered by interaction with clients. Afterwards, the mentioned needs are divided into three component areas.

Needs of project – The customer needs as a result of this project and their expectation need to define and be precise,

Drivers of project – From the customer judgment point of view, what factors are considered by customer?

Requirements of project – How to meet customer standards and needs through process modification or product manipulation??

Many steps exist to have a CTQ created so as to fill those areas with meaningful data. Project teams technically take care of developing CTQ trees.

- **Determine the Need –** interacting with the representatives or getting involved with customers would satisfy this requirement.
- **Defining minimum three drivers –** The components or bridge that transfer the quality for customers. Bear in mind that having these elements is a must to meet customers' needs.
- **Create the requirements –** List of the standards and necessities that is essential be done in the project n order to meet the expectations for customer of project.

The steps to make the changes or improvements can only be taken providing that the requirements are developed.

SIPOC to summarize the in/outputs of one or more processes, SIPOC will give us a hand as a tool. This method, which is utilised before starting the main work, defines a business process from the beginning to the end. SIPOC consists of suppliers of project, inputs that need to be inter in the system, process, outputs of project and at the end customers of project and these items are the founder of a column in the table.

The time to define the SIPOC is normally at the beginning of process improvement efforts like KAIZEN events or in the middle of define phase of DMAIC process. SIPOC's methods, based on audience has tree main types of uses.

- Providing people with a high-level overview and vision.
- To reawake people whose knowledge has become gray or out-of-date because of changes which is happening in the process.
- for helping employee and individuals to define a new process

There are several aspects of SIPOC that may not be easily disclosed are:

And also, there many more hidden SIPOC features to be discovered are:

- Customer and supplier might be inside or outside of the corporations that running the process.
- Inputs and outputs could be anything such as information, services or materials.
- The concentration on inputs and outputs are more into center of attention in comparison with the individual steps.

3.2 Measure

In the recent years, so many organizations have experienced almost bankruptcy due to unpredictable supplier vulnerabilities and disruptions which has a huge loss of dollars in industries ranging from manufacturing to pharmaceuticals and consumer goods to electronics and automotive. On top of that, companies, government, organizations and private businesses also facing and struggling with cybersecurity and losing critical intellectual property. During these crises, the lack of reliable processes to distinguish and control growing supply-chain risks becomes bolder. Cyber attacks are also a new kind of warning that are showing themselves combined with the traditional and confirmed and known supplier risks, such as supplier bankruptcy.

By globalization, the complication and difficulty of supply-chain risk management has been expanded. Even complex products for defense systems need to use raw materials and associated components that might have made in countries they are more exposed to disruption factor and the manufacturer process did not even know these components had their own supply chain. This higher complexity adds more level of potential failure points and higher stages of risk.

Obvious risks can be classified and are likely to measure and control over time. For instance, a supplier failure leading to a disorder in supply would be a recognised risk and the probability can be estimated based on the financial records and situation of supplier's and relevant impact on the organization can be study and measured by reviewing the products, target markets and also the channel of supplier disruption. In the supply chain, more latest risks such as cybersecurity risk factors also are now measurable over methods that use external analysis of a company's IT systems to measure cybersecurity risks.

Businesses should spend time and resources with an external team to find out a complete range of risks they face and construct a risk management structure that defines which system of measurement are appropriate for measuring risks and how to monitor and track these metrics rigorously. The assigned team needs also recognize the out-of-range areas where risks are difficult to understand or define. This analysis can dimensionalise the order and scope of unknown risks.

Unknown risks and uncertainties are those risks that they are hard and very rare to predict or very problematic to foresee. Consider the unexpected disruptions like the corruption of a cybersecurity weakness which might be in the deep back of the firmware of network servers or eruption of a volcano that disrupts a supplier we did not know it was part of our supply chain. Projecting this like of situations, is probably impossible for even the professional and experienced managers. For unknown risks, decreasing their chance of happening and increasing the response speed when they befall is critical in order to maintaining competitive advantage. Construction of solid layers of security and protection linked with a risk aware principle can add the advantage to corporations.

Supply chain risks can be moderated to a much better position by the adoption of the higher qualify and proper supplier. In order to identify how organization, control and manage their supply chain risks we can particularly concentrate to hire Failure Mode Effects and Analysis (FMEA). Supply chain hazards can be moderated to a better position by study and the qualifying and selection of the suitable and reliable supplier.

Failure mode and results analysis

FMEA is method for analysis of mechanisms, systems, and subsystems as much as possible in order to classify possible failure manners related causes and effects. For every single element, the failure modes and consequence impact on the rest of the organisation needs to be presents in a detailed FMEA worksheet.

The fundamental barrier and obstacle for successfully supply the material and successful operation in the firm is supply chain risk. Several chain risks can be eliminated and removed by the appropriate selection of right and reliable supply partners and supply chain systems.

FMEA is one of the best and well established procedure is using to estimate the risk of failing a product or a process within the companies. With using FMEA, all possible failure points will be assessed in terms of probability, quickness, and level of effects. Whatever the score of FMEA is higher that shows the probability of risk is higher. Standard variables in order to measure risks in different conditions are:

- Regularity of a specific action related with the failure
- Size and number of the elements connected with the defect
- Capability to sense the defect

- Possibility of the failure
- The harshness of the failure

The following phases (seven phases) is the steps needs to perform to complete an FMEA.

FMEA is a essential tool in an engineering character that can be used to gather information about the decisions of risk management in the companies. There is so many structure documents to develop an FMEA over industries particularly in automotive and manufacturing sectors and most managers agreed the FMEA tool is a very useful element which helping to estimate the risk of SCM. The seven phases to implement the FMEA are as follows:

1. Risk categories classification.
2. Potential risks documentation.
3. define rating for the possibility, opportunity and strictness of every risk.
4. Estimate the risk probability number for every single risk.
5. Examine the risks by RPN- Some techniques such as a Pareto distribution can be used.
6. Implement actions to moderate risks that they have higher risk probability.
7. Run another round of FMEA to reassess risks

FMEA is a very useful standard method and verified technique which usually used to estimate the risk of process or product design problems. Decisions related to supply chain management also can be estimated and evaluate very nearly the same style as process or product defects.

FMEA for SCRM

Most directors in believes that mitigation of risks to the supply chain proactively are not usually however, it can be main requirements to minimize disturbances. Most of organisation and operations supply chain environment, needs a practical tools or procedures in order to be able to

implementing FMEA. They also need to know the vital success elements for the implementation process. Also, one of the concern with FMEA is the irregularities in the ranking of occurrence, harshness and recognition and the inaccuracies that might make the interruption and effect FMEA implementation in a supply chain. Corporations need and want procedures for their systems to correct these issues in FMEA applications. Once tools or kind of procedures are available, companies can participate and integrate their FMEA method into a supply chain atmosphere.

Data Collection Plan

In the second phase of DMAIC model under the Six Sigma Method which is define phase, a Data Collection Plan needs to be created. By using the data collection plan technics, it can be confirming that each single person engaging on the Six Sigma project is match and is in the same sector concerning the data plan and it also approves that the data is correctly channeled to the appropriate corporate stakeholders who will responsible and help with the data requirements. The goal and target of the data plan is to make sure that the collected data is accurate, valid and important and that all associated data are assembled synchronously. The data collection strategy is crucial and essential in order to be more efficient and not wasting resources, corporations need to make sure the collected data are not inappropriate to the project or not practical. We can stress our efforts on answering detailed questions that have corporate value by creating a right and precise data collection strategy and the focused method with a Data Collection strategy supports to avoid placement and measurement of unrelated data.

Pareto chart. Pareto chart, which is also titled Pareto diagram or Pareto analysis, is a graphical bar chart. The measurements of the bars illustrate frequency or cost, which is time or money and these graphic style bars are ordered with the longest on the left side and the shortest to the right side.

Pareto chart steps:

1. We have to decide what clusters need to be used to group items.

2. What kind of measurement is suitable. Standard measurements are cost, time-frequency, and quantity.

3. What period of time for Pareto chart coverage: work cycle? Daily? Weekly?

4. Collecting the data method. Recording the time or gather exist data.

5. Individual category subtotal measurements.

6. Define the suitable scale for the measurements we have collected.

7. Suggestion for each category and tag of each bar. The left bar is highest, then to its right is the next highest and so on.

8. Estimate each category percentage.

9. Compute and draw collective sums

Measurement System Analysis. This step aims to classify and understand the modules of variation due to the measurement system and use the appropriate tool for analysis depending on the data type. **MSA** is an assessment of a measurement process and normally consists of a specially designed experiment that identifies the components of variation in that measurement process. MSA analyzes the group of equipment, operations, procedures, software, and staff that affects a

measurement characteristic. In six Sigma, one of the keys and essential components is measurement. We are using measurement system analysis (MSA) to have an investigational and mathematical method and define how much variation inside the measurement process exists in overall process variability.

Sigma Level Value. Sigma is a mathematical explanation that evaluates a process difference from fineness according to the quantity of defects per million units. A function with 70% defects (DPMO = 700,000) would have a Sigma Level of zoro. Naturally, a method with a Sigma Level of 6 or better is generally measured an outstanding process.

One Sigma = 690,000 defects / million items

Two Sigma = 308,000 defects / million items

Three Sigma = 66,800 defects / million items

Four Sigma = 6,210 defects / million items

Five Sigma = 230 defects / million items

Six Sigma = 3.4 defects / million items

3.3 Analysis

The DMAIC analysis phase objective is to be recognising the problems and failures which happened in the manufacturing or operation process and that was source the defects. Analysis phase is mainly for supports and help project groups for investigation of problems in corporations. This step of the Six Sigma technique provides a reliable tool to find the solution or optimize any manufacturing or operational process problems and accomplish the root causes of the problems.

The Analysis stage emphasizes and focuses on the data collection in the phase of measure in order to organize and categorize the cause of product defects. Distinguishing and recognising possible causes of defects in the typical Six Sigma methodology, is not based on the assumption. Six Sigma offers a group of tools for finding the possible cause.

Root cause analysis. Root cause analysis which also in some studies mentioned as RCFA, root cause failure analysis is fundamentally a technique or series of activities taken to determine the reasons of a specific problem and failure exists and launch a solution of altering the causes. A problem can be described and define in root cause analysis when performance of process is not the same level, or it is far a way from the defined targets and expectations (Latino and Latino, 1999). Root cause analysis is systematic method for determining any kind of causes of any undesirable event in the operation like the man-made causes, physical causes, or operational hidden causes. By considering and implementing the root cause analysis knowledge, corporations can develop an understanding of why errors occur and carry out solutions and require measures to fix and prevent errors from reoccurring.

Frequent failures in root cause failure analysis are shows the chances for systemic improvement and present the exclusive awareness for removing risks in the supply chain and making it more strong. However, once the comprehensive analysis is conducted, it is no longer a difficult or expensive approach for implementation.

Root cause analysis first step

Problem Recognition and Definition is the first stage in RCA. From overall corporations' point of view, every important deviation from distinct goal line necessitates a proper root cause analysis. If a good job was done in defining triggers and balanced investigative capacity at an appropriate level was conducted, problem recognition becomes easy. In the supply chain network, any failure or detected potential problem need to be allocated to several investigators to control and monitor the causes of the issue for precise investigation. After primarily investigation has been done, the investigate agents needs to generate a report by precise supporting detailed documents regarding the problem. The supporting documents need to have at least following information

- The title of issue.
- The approach occasion.
- Time table of the problem and occurrence
- Location and spot of the happening the issue in the supply chain.
- The influence of the problem and related effects on supply chain.
- The impact categories

Root cause analysis second step

Identify Causes is the second stage in RCA. The actual and efficient investigation for the manufacturing and operational problems is not only and exclusively based on brainstorming of probable roots. Brainstorming need to be in format of group to have different point of views on it. The modest procedure of analysis which typically is convenient when time is crucial, is a fishbone method. For identifying the causes, the most operative method is by beginning with the identification of the problem which is the RCA Step. After that by employing the consistent process the assigned investigation team can analyses the problem in order to recognise its fundamental causes.

Root cause analysis third step

Identifying the solutions is the third stage in RCA. As soon as the origins of the problems have been identified with their related consistent relationships and also supporting indication, then the investigation team is able to study and observe the different possible causes in order to find the best solutions. The efficient and optimal solutions, examine and control all the causes, individually and offer a solo solution for each cause to decreases the risk of the problem. Nevertheless, once several solutions offer to monitor and control of the causes are identified, the risk of repetition especially drops more.

Root cause analysis fourth step

Implementation of the solutions is the fourth stage in RCA. It would be a worth case whenever the investigation group recognising and identifying the problem in the best possible way, but implementation of solution for resolving the issues is not efficient and goes wrong. This is usually

happening when part of presented solutions is not implemented. Characteristic of strong RCA model is based on capability to implement resolutions in a appropriate time and this is consist of confirming that the implementation of proposed solutions do not make any additional complications in the supply chain. Also, it is vey crucial to appraise the efficiency and performance of solution after a specified time.

The main purpose and goal of analysis phase of DMAIC is to provide the necessary support to project team to recognise the issues in the production process that basis product faults. This Six Sigma methodology technique is an effective toll in order to find the problems in the manufacturing and operational process and also achieve if these issues are the root causes of the faults. The Analysis step mostly emphasizes on the output and data gathered in the previous phase which is Measure phase of DMAIC for classifying the cause of product defects.

Process Map Analysis. In order to capture the stages of a production process we can use some different methods. One of the tools that is normally used is Process map analyses which is uses a workflow illustration to record the process. The process map analyses is consist of considering the appropriate inputs into the process, performing process of tasks, decisions steps and outputs. The precision and high level of accuracy is essential for recording the production process in order to let the project group to have better undersigning through the current production process operations. A complete, detailed and reliable process map also can provide the ability for the project group to have better view and understanding for potential future changes in the process. For analyze the process, there are many methods however, the one of the main methods normally used is called 5W. The method is based on the provided answers of a questionnaire to discover more details about the specified process.

1. **What** would be the main and essential inputs to the problem?
2. **What** are the outputs of process?
3. **What** are the purposes?
4. **What** technology is used?
5. **Where** is the process location?
6. **Where** is the product confirmed?
7. **Where** is the product sold?
8. **Who** is the potential customer of the process?
9. **Who** is the potential supplier of the process?
10. **Who** performs the procedure?
11. **When** does the process start?
12. **When** does it end?
13. **When** is it evaluated?
14. **When** each sub process starts and finish?
15. **Why** the process is used?
16. **Why** the process is performs in the current way?
17. **How** is the process evaluated?
18. **How** is the process controlled?

3.4 Improve

This phase emphasizes defining a solution based on the discovered problem in the first three phases. This stage needs an understanding of the key process input variable that is causing the consequence. There are three main activity requirements.

1. Sharing and generating the idea by the project group and associates and also leader of project whose target is to discover a solution to solve the core problem
2. Testing the solutions
3. Evaluating the result of the executed solutions.

The main target of improve stage in DMAIC model is to determine the size and associations of variables to the project. Before performing a full-scale implementation, project owners need to conduct a test of the solution on a sample set and this would be the reliable and most effective way to find out the optimum settings. It is reasonable to select the most effective setting, which is also factored into its resources, procedures, and policies.

After selection and approval of the best and efficient solution, then crucial action is to execute a stakeholder analysis to make sure the operation group is ready to approve and carry out the new change. Standard tools used in this stage are; the Solution selection matrix, Five S, and the Benchmarking.

3.5 Control

The Control phase is where we finally control the implemented solution. Control is involves ensuring that the processes are in order to guarantee that the improvements are accepted by team members and the whole enterprise. The Control phase guarantees the solution is accurately implemented, documented, measured, and maintained, and we need to provide the infrastructure that enables the team to perform the new changes.

The Control stage in DMIAC method consists of following components:

· Implementing the measurable adjustments either they are cultural or physical.

· Reviewing work processes and procedures.

· Reinstructing the group members for the new procedures.

· Implementing monitoring and measurement system like control charts for the new process.

· Preparing an action plan.

The final stage of DMAIC requires participation of the Six Sigma project team and the team members to contribute in performing the new process. The production manager and his team and also the warehouse manager will also need to be involved. The control stage in order to monitor the process going forward, might also have a specific training on some data methods. We should have implementing of a process development at the end of the control phase and the process improvement by using DMAIC process should provided a reliable solution and answer to the problem on top of savings to the business.

Chapter 4

Case study in Luxxeen Production

Company description

Luxxeen Production is independently owned manufacturer of high-quality hygienic paper and cellulose products under LUXXEEN and SOFTLAND brands in Canada and US. The range of products consist of toilet paper, baby wipes, wet wipes, facial tissues, napkins and so on for Canada and US market.

The Luxxeen tissue group produces high- quality tissue paper products for several large-scale chain retail stores like IGA, Metro, Dollarama, GT and so on. The Luxxeen tissue group also offers private labels products under client's brands.

DMAIC based approach for Supplier risk analysis in Luxxeen Production

Due to the strong connection to the Luxxeen Productions company, a case study was chosen, which would allow a more in-depth detailed analysis of the proposed research approach. Luxxeen Productions Inc. is one of the manufacturers of a range of branded and private label paper products in Canadian like napkins, facial tissues, wipes, toilet papers and so on.

D M A I C		
D	**Define phase**	Project charter Voice of customer Value stream mapping SIPOC
M	**Measure phase**	Data collection plan Pareto chart Measurement System Analysis Sigma Level calculation
A	**Analyze phase**	Root cause analysis Process Map Analysis Business process mapping Process capability
I	**Improve phase**	Project Charter Design of experiments
C	**Control phase**	Control Plan Statistical Process Control

Table 7: DMAIC approach and techniques in Luxxeen

4.1 Define supplier Delivery Delay risks

4.1.1. Project Charter

The project charter is a document that describes the opportunities, objectives, and team who are contributing to a project, and it explains the purpose of the project, general specifications, the key stakeholders, and the possible outcomes.

Project Objective. The objective of this project for Luxxeen is reducing the supplier delivery time for orders.

Project background. The important and commitment of punctual order delivery in Luxxeen: generally speaking, on-time and punctuality on delivery is the privilege and ability advantage of any business like Luxxeen to satisfy the needs of the consumers and supply the goods based on planed schedule. Certainly, in supply chain one of the most critical concerns specially for manufacturing or most of buyers is on time delivery of suppliers. A company's commitment to delivery dates is a crucial factor that decides its success in an industry. Companies who are unable to reach their commitments for delivery date have a small chance of success in long term. Only as crucial as in Luxxeen corporation, the delivery timetable commitment is one of the most important factors affecting the companies' standing and reputation, consistency, and status.

No one in Luxxeen can disagree with the definite profits that the on-time delivery brings about. As firms continue to disappoint their clients, they will ultimately lose their customers. Thus, the consequence of on-time delivery cannot be ignored. On-time delivery in Luxxeen has become a company's key principle because of many reasons like increasing reputation, broadening relationships, encouraging customer confidence, raising profits, and improving efficiency. In order to keep and improve an efficient corporate relationship with Luxxeen customers and in order to reduce unanticipated chargeback payments, Luxxeen should recognize the essentiality of ensuring that their shipments are delivered on time. Detailed and precise delivery schedule in one of the mandates in Luxxeen by management team. The company strongly emphasise that they need to have a solid and detailed delivery programs to prevent any late shipment for conflict between different suppliers. On the other hand, Luxxeen's order delivery date is absolutely dependent on Luxxeen supplier's and raw materials flow.

4.1.2 Financial impacts and Cost of Delay

Profitability and benefit are the main aim of development and producing new products, and it is important to get them to market as quickly as possible. Specially for new products the time frame for entering the product to market is critical and business really need to understand the actual cost of being late.

Most of corporations in current modern marketing competition are typically aware that they need and have to develop a product faster and if their products goes to market first, ultimately they will have more market share for that products and a better margin than other companies who are late and have delays. Furthermore, if we can repeat the production cycle faster, we will have the market's dominant product after a few product releases. Delay's cost is the profit we will lose if we are late to market our product.

When any product has for instance one month delay to enter to the market, in reality we are not losing the sales of one month, and it is not like the corporation’s sales curve shifts one month to the right. Firstly, we spend more time and money to get it launched, and then when we ramp up, we typically do not get to the same sales volume we would have, and we will lose the difference between these two curves for the entire life cycle of the product.

For this specific project in Luxxeen, we are aiming to reduce the supplier's delivery time. Based on historical data average delivery time for main and critical suppliers is 28 days, and our objective is to reduce it to 19 days. Following we have data from the financial department regarding the related costs that accurse due to late delivery of Luxxeen products to clients.

Cost of Delays (COD)- 2019

	Jan 19	Feb 19	March 19	April 19	May 19	June 19	July 19	Aug 19	Sept 19	Oct 19	Nov 19	Dec 19	Year
Total expenses	$15,154	$8,599	$8,276	$7,738	$7,823	$8,619	$7,371	$8,211	$8,392	$8,152	$9,173	$7,372	$104,880
Cash short/extra	$15,154	$23,753	$32,029	$39,767	$47,590	$56,209	$63,580	$71,791	$80,183	$88,335	$97,508	$104,880	$104,880

Category	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Extra Wages	$2,297	$2,437	$2,419	$1,511	$1,658	$2,491	$1,728	$1,884	$1,918	$1,891	$2,336	$1,777	$2,482
Clients Penalties	$385	$2,381	$2,305	$1,987	$2,236	$2,394	$2,053	$2,245	$2,196	$1,913	$2,012	$1,620	$1,889
PL Stop cost	$6,532	$1,815	$1,875	$1,751	$2,274	$1,879	$1,557	$2,020	$2,487	$2,221	$2,402	$1,995	$2,036
Over Stocks	$5,940	$1,966	$1,677	$2,489	$1,655	$1,855	$2,033	$2,062	$1,791	$2,127	$2,423	$1,980	$2,029
Total	$15,154	$8,599	$8,276	$7,738	$7,823	$8,619	$7,371	$8,211	$8,392	$8,152	$9,173	$7,372	$8,436

Table 8: Luxxeen Cost of Delays during 2019

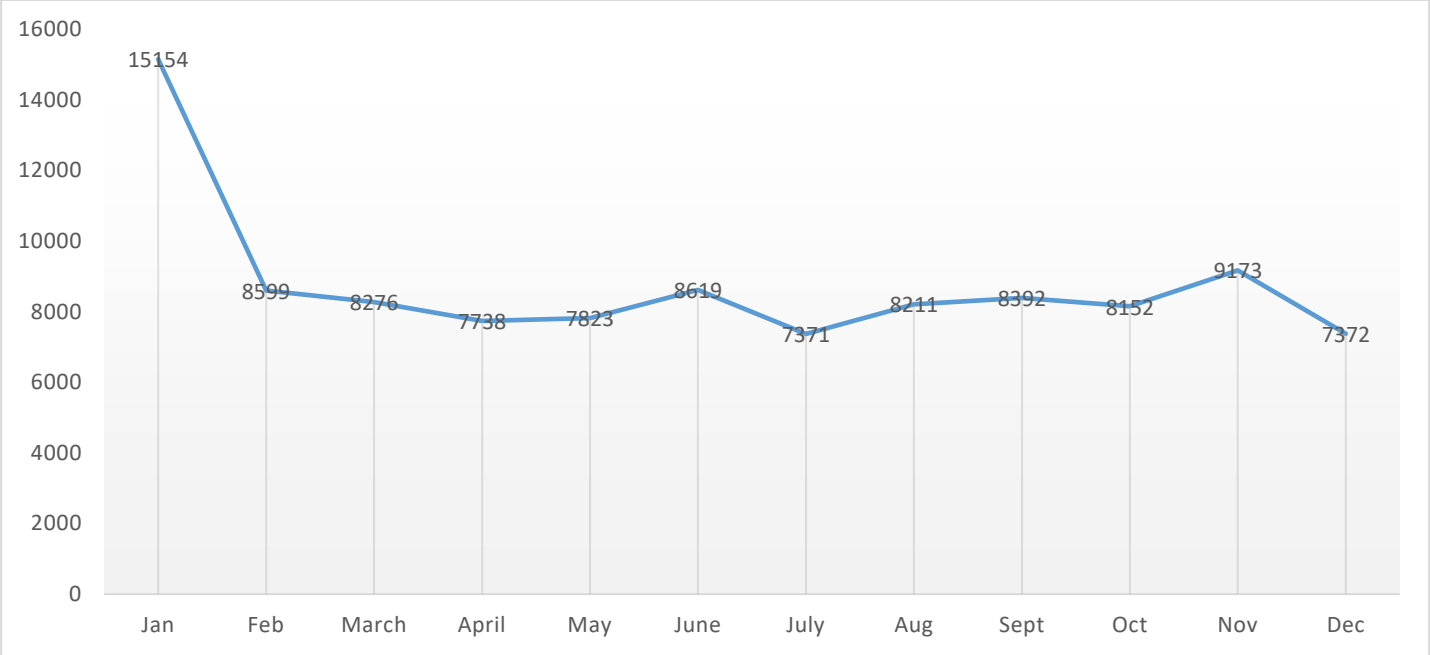


Figure 6: Luxxeen monthly cost of delays breakdown during 2019

As we can observe on the financial department report, there is over $100,000 cost of delays by suppliers.

Project Charter Model. This project chart was created to reduce supplier delay time in Luxxeen Production corporation.

1.0 Project Identification	
Name	Reducing Suppliers Delay Time
Description	Design and carry out the solution for managing the supplier's delay
Sponsor	
Project Manager	
Project Team Resources	Communications, Policy, Shipping Advisory group, Logistic, Customs, suppliers and procurement department

2.0 Business reasons for project

- Improve supplier delivery ability for on time delivery to increase production capacity and improve sales level based on raw material flow (with the suppliers, logistic and other levels of supply chain)
- Respond to the level of Luxxeen procurement and sales engagement and fulfill the production materials demand though on time delivery of materials.
- One of the main divisions of the corporate expansion Strategy
- Vital module of a lean production
- Element of the on-time delivery
- Transportation Optimization
- Improving sales and profitability of company activities
- Increasing capacity of production line
- Improving performance management

3.0 PROJECT OBJECTIVES (PURPOSE)

- Overall, to reduce the Luxxeen supplier's delivery time for orders which is placed and under process
- To recognize suppliers for their high-quality service and commitment for orders
- Emphasise on connections between business goals and performance of supplier and purchase department to accomplish corporate goals
- Develop a practical tools, procedures and support for departments to assist with purchasing process and on time delivery of suppliers
- To develop and implement supply chain management

4.0 PROJECT SCOPE

- To include reducing supplier delivery for all different departments
- To satisfy two main group of order processing - a corporate element and a supplier element
- Providing structure to Luxxeen suppliers and department activities
- Agenda, summary, procedures and tools to be established and employed

5.0 KEY PROJECT INDICATORS

Name	**Description**
Framework	General main elements of a roadmap for suppliers lead time
Project charter	Current under develop document

Logic Model	Project key activities, results and measures
Project Backgrounder	An additional document to the project charter descriptions and results
Research summary	General info, Real and accurate data of suppliers and commercial research
Guidelines	Comprise universal program strategies and financial strategies
Tools and resources	Include prototypes, guides, tester surveys, quotes, guidelines and so on for use of different departments
Communication and Implementation plan	Framework of communication, resources for stakeholder groups, communication strategy
Website	cover procedures, universal information, resources and tools of each departments, with needed materials on activities

6.0 MILESTONE AND DATES		
No	**Main Events – Milestones**	**Dates**
1.	Design the project framework	TBD
2.	Research summary completion	TBD
3.	Financial strategies development	TBD
4.	Validate with different departments like sales, purchasing, finance, production and external advisory team	TBD
5.	Informational event for all sectors	TBD
6.	Develop department templates and resources	TBD
7.	Execution and relation with stakeholder team	TBD
8.	Website launch	TBD
9.	Service Awards	TBD
10.	Award of Excellence	TBD
11.	Context assessment, lessons learned, consultations	TBD

7.0 KEY ISSUES	
NO	**Description**
1	Variety of stages of deployment
2	Some departmental operations are not compulsory

3	Lake of real data on supplier activities
4	Keep motion and sustainability of events
5	Timetable for management of the supply chain development plans
6	Time management for coordinating the supplier and providing real time data for implementation
7	Perceptions of employee and manager
8	Supplier perceptions for project

8.0 RISKS	
NO	**Description**
1	Support of project and tools from the sales group
2	Support of project and tools from managers
3	Support of project and tools from employees
4	Execution timelines
5	Supporting resources availability
6	Financial and capital support

9.0 PROJECT'S PRINCIPLES FOR ACCOMPLISHMENT – MEASURABLE

- Increase responsiveness and steady repetition of supplier delivery time all over the organization
- Expand Luxxeen ideal and preferred supplier list
- Create a improved and more supportive communication atmosphere with suppliers
- Enhanced supplier satisfaction and supplier development
- Improved responsiveness and relations between Luxxeen business plans and supplier's performance (survey results)
- Increased organize meeting with suppliers on regular basis
- Increased positive supplier perceptions for valued of their contributions
- Increased positive supplier perceptions for their high performance

10.0 CRITICAL SUCCESS FACTORS

- Support from managements, employees, sales dep and
- Operative and efficient communication
- Real time and reliable communication with suppliers collaboration

10.0 CRITICAL SUCCESS FACTORS
▪Suppliers contribution into development and implementation of lead time improving ▪Supplier awareness of Luxxeen purpose, priorities, objectives, goals and values ▪Improving lead time need to be appropriate, meaningful, reasonable and comprehensive ▪Process to be supportive of company principles

11.0 SIGNOFF
Project Sponsor: Luxxeen Management Project Member : Matt, Mey, Team leader : Ali Green Belt : Ali Champion: Financial department Date:

Table 9: Project charter for Reducing Suppliers Delay Time

4.1.3 Voice of the customer (VOC).

We used VOC methods in Luxxeen productions Inc. to describe the customer's expectations, preferences, and dislikes. In fact, the Luxxeen customers' voice is a market research method to produces a detailed set of customer needs and demands. We used this data to structure a classified construction and then prioritize qualified importance and satisfaction with current replacements. This voice of the customer involves qualitative and quantitative research steps. In the next section with using the classified voice of the customer (VOC), we are able to have more precise definition of the critical-to-quality outputs (CTQs).

4.1.4 Critical to Quality (CTQ)

Following is a breakdown of the critical requirements for reducing the delivery time of suppliers in Luxxeen Productions Inc. Luxxeen is trying to improve and expand the production capacity and the same time it needs to decrease delivery time of supply material. After researching a different potential solution, one of the company's critical needs is to identify "Reducing delivery time" from the Luxxeen supplier side. We take advantage of a CTQ Tree in order to generate a list of tangible requirements to support the company accomplish this improvement.

Overall Luxxeen's CTQ Tree is shown below, in figure 7.

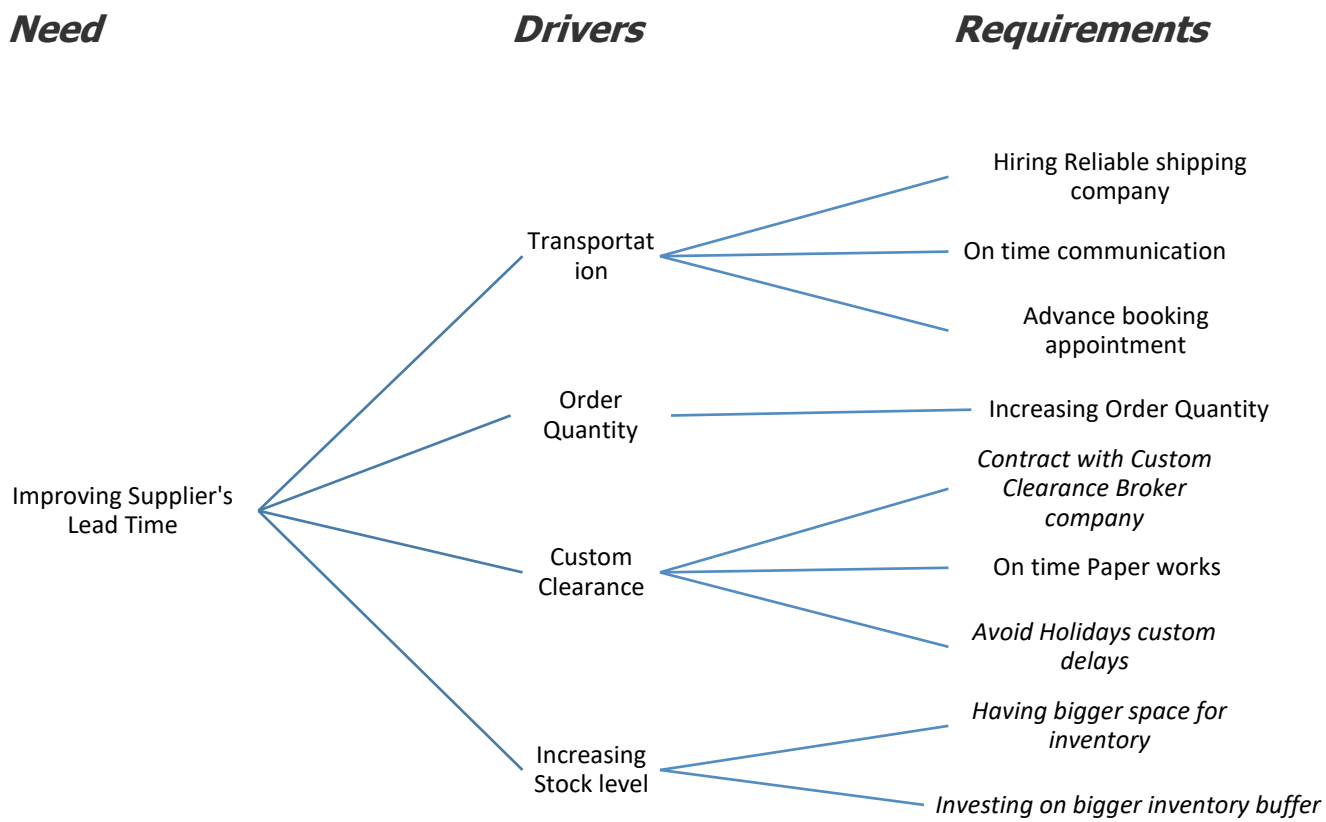


Figure 7: Critical to quality from internal point of view

Need

Improving Supplier's Lead Time

Drivers

1. Transportation
2. Order Quantity
3. Custom Clearance
4. Increase Stock level

Requirements

1.1 Hiring Reliable shipping company

1.2 On time communication

1.3 Advance booking appointment

2.1 *Increasing Order Quantity*

3.1 Contract with Custom Clearance Broker company

3.2 Avoid Holidays custom delays

3.3 On time Paper works

4.1 Having bigger space for inventory

4.2 Investing and improving on greater inventory size

With critical to quality (CTQ) model we are able to transfer the critical Luxxeen needs into measurable and systematic requirements. We can then use these requirements to deliver a

high-quality result for reducing supplier's delays. Originally, CTQ Trees was developed and offered as a component of Six Sigma procedure. We used the tool to identify the company's critical needs in order to reduce supplier delays. After that we fine out the main and related drivers that must be considered to meet each need. Finally, we classify measurable associated requirements that each driver needs to satisfy when we will offer an enhancement on suppliers' lead time. Luxxeen's CTQ Tree for lead time improvement also is shown below, in figure 8.

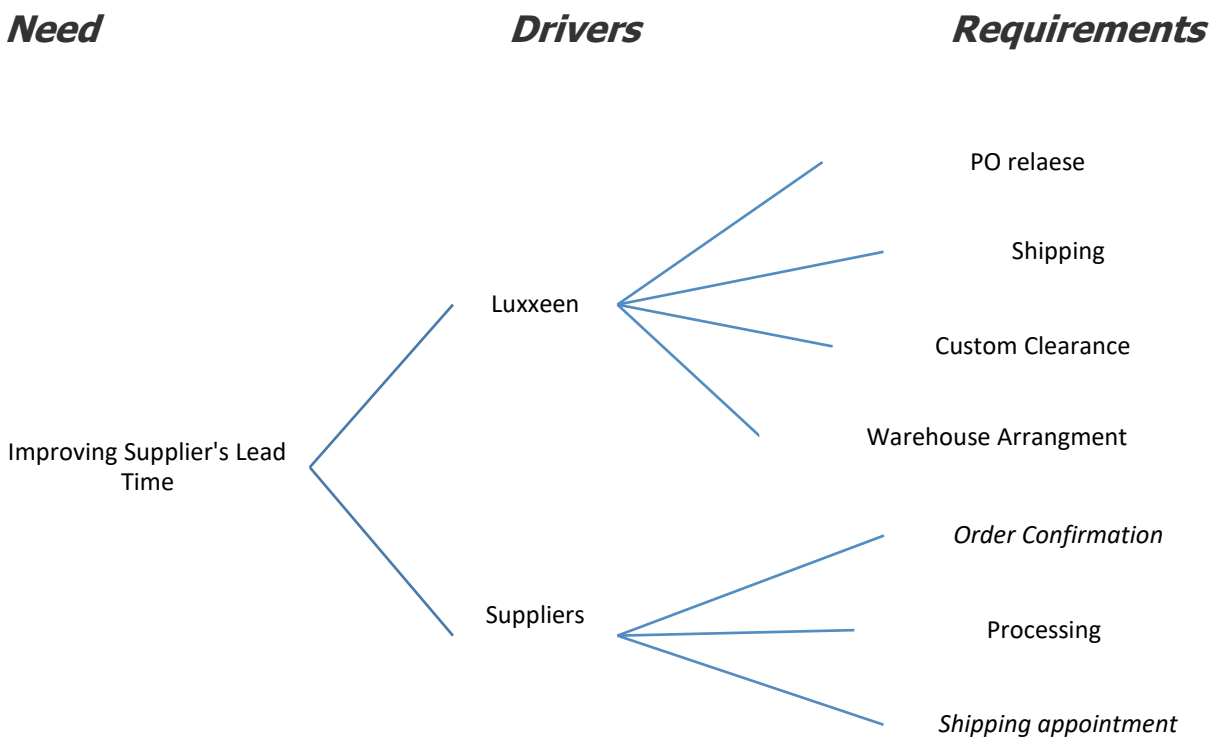


Figure 8: Critical to quality from external point of view

4.1.5. SIPOC

In order to create a Luxxeen SIPOC diagram, we need to first create the overall process in a breakdown step. Then we need to recognize process outputs, group who will receive the outputs, and essential inputs and suppliers for each process. The last step is to present the prepared plan to the management team to get the approval and confirmation.

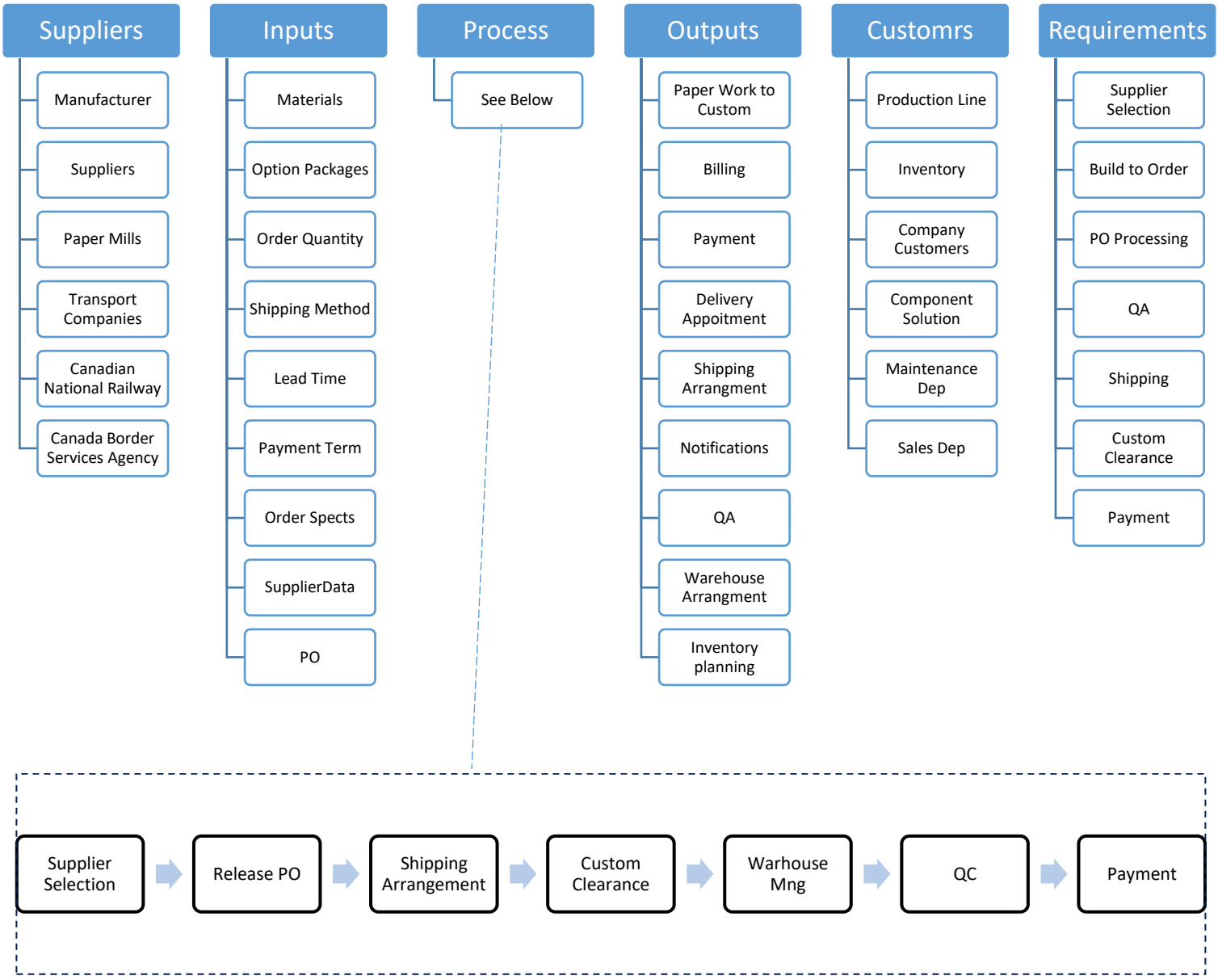


Figure 9: Luxxeen SIPOC diagram

As shown on the map above, the first step in the SIPOC business process is called "Suppliers". This initial step has several items that have to be considered to make us able to proceeds to the next steps. Manufacturers, Suppliers, Paper Mills, Transport Companies, Canadian National Railway, Canada Border Services Agency are standing by one another, and they all lead the category "Suppliers" to be created.

The second step, called "Inputs," includes nine subgroups. When it comes to "Input", materials are inevitable as nothing can be produced or manufactured without them. A clever business requires some factors to be considered and taken into account for a more efficient performance matching customers' needs. As an example, it is substantial to anticipate the order quantity and verify if the company has the capacity to produce the quantity maintaining its intended quality. The other vital factor could be "The lead time," meaning the time it takes to get the product ready for shipping. Indeed, some other items such as "Payment term", "Option Packages", "PO*", "Shipping Method," and so on are not pointless to be considered while talking about "Input". For instance, "Payment method" is different from one company to another, which increases its priority in a real business.

The third section, called "Process," is responsible for the happenings between inputs and outputs. It contains seven subsections that are represented in the chart above, respectively. The first item called Supplier selection, is our first step for this section. This will allow us to purchase our needs and have them processed in the next subsections. After the selection, it is required to place a PO, standing for the purchased order so that the supplier's company will prepare our order. Once the order gets ready, it is required to think of a way to have them delivered to our place/company. So

it comes to the shipping method. In the meanwhile, the order should be done the clearance. Then a warehouse has to be booked to get the order stored and finally the payment has to be made.

The next step, clearly, is said to be “Outputs”. It also consists of several subparts that have inevitable impacts which cannot be ignored. The parts which stand next to one another and lead to a whole section are “Paperwork to custom”, “Bill”, “Payment”, “Delivery appointment”, “Shipping process”, “and Notification”, “QA, Warehouse Arrangement” and “Inventory management”. The proportion of every single item in this section is important and might positively or negatively affect its neighbors based on its place and the sort of the business.

While heading to the end of these sections/ steps, we face the second-to-last one called “Customers”. This also includes a couple of subparts. “Production line”, “Inventory”, “Company customers”, “Component solution”, “Maintenance dep”, “Sales dep”.

The last but not the least part in terms of importance is called “Requirements”. It also is created by some factors, which are as follows: “Supplier selection”, “Build to order”, “Po processing”, “QA”, “Shipping”, “Customs clearance”, “Payment”.

4.2 Measure supplier delay risks

In our research, the company's executives approved that project might go wrong without a systematic technique to measure risk, specifically in a supply chain section. Investigating the risk connected with supply chain management is a quite new perception, and almost nothing has been done to support managers with this process. However, the main objective, which is certain is recording and analyzing supply chain risk, which must be a crucial part of continuous

improvement. So, Failure mode and effects analysis (FMEA) could be an important element to better understanding techniques to categorize and manage risk in your supply chain.

FMEA worksheet										
Function	**Potential failure mode**	**Potential Effect(s)**	**Failure Local effects**	**Higher level effect**	**System Effect**	**(P) Probability**	**(D) Failure Indicator**	**Level of Risk**	**Activities for detailed Investigation**	**Requirements and Mitigation**
Delay on Delivery	A: Transportation problem B: Production problem	a) Transport company didn't make the appointment) b) Machinery damage during production	Decreased pressure to deliver the orders	Running out of products	Severely Reduced sales Partial loss of customer. Risk of reputations damages	Occasional	using backup products from warehouse	Unacceptable	Check the production status and keep warehouse level in specific level and check probability of failure	Require backup products and/or Require backup transportation system

Table 10: FMEA table for Reducing Suppliers Delay Time

4.2.1. Data Collection Plan

The primarily stage before generating a Data Collection Plan is make sure the data that we are selected is accurate and also is relevant to the project. The whole reason for having a DMAIC project is to improve a process that is improving lead time of main Luxxeen suppliers, so as a guide line and practical tool to have better view on detailed corporations process, we can use

the SIPOC diagram in order to collect our data. In this project, we are using the SIPOC diagram from the phase of define.

4.2.2 Pareto chart

Considering different Luxxeen suppliers' categories, we need to find out which category is playing the main roles and has the highest level of propriety, so we are using Pareto Char to choose the most important category of suppliers. Pareto chart emphasis on mutually on bars and line graph by presenting the detailed values in descending sequence by bars and also the line which represents the collective total. The left vertical data is the frequency of buying that specific category. The right side of data on the chart is the increasing percentage of the total number of incidences based on accumulating values which is increasing.

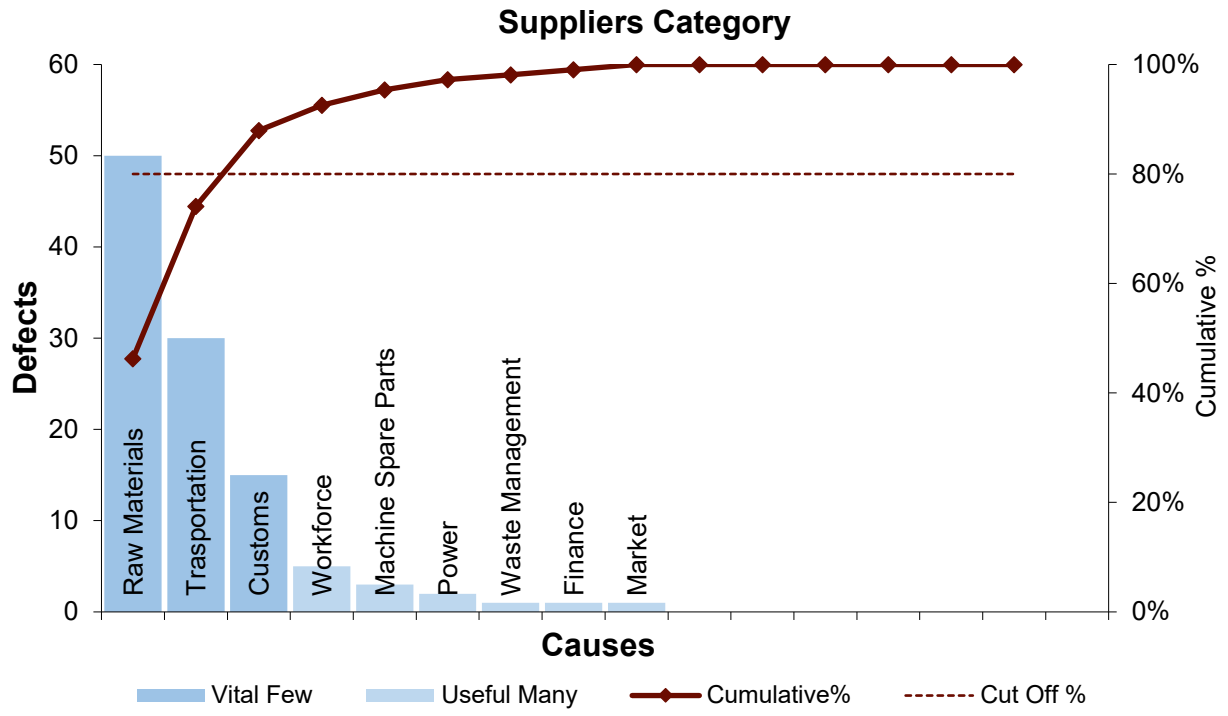


Figure 10: Luxxeen suppliers category Pareto Chart

Technically, the first three causes, raw materials, transportation, and customs, cover, 96 percent of the overall defects. The Pareto chart demonstrate the most significant highlighted issues among a set of factors based on the Luxxeen data. The raw materials supplier category is the main cause of delays. After that transport category and customs category are other categories for delays.

4.2.3. Measurement System Analysis

To have a measurement system analysis, we need to categorize and recognize the modules of variation and depending on the data type, use the suitable tool for analysis.

With measurement system analysis we assess our measurement process which typically consists of a particularly designed experiment that recognizes the components of variation in that measurement process. Measurement system analysis evaluates a group of equipment, operations, procedures, software, and staff that affects a measurement characteristic.

A measurement systems analysis considers the following:

· Choosing the correct measurement and approach

· Evaluating the measuring device

· Evaluating procedures and operators

· Evaluating any measurement interactions

· Manipulative the measurement uncertainty of different measurement devices or systems

In the following table, we have a list of different Luxxeen suppliers, including their expected and real delivery times. Out of the current selected suppliers, five main and essential suppliers directly impact the business.

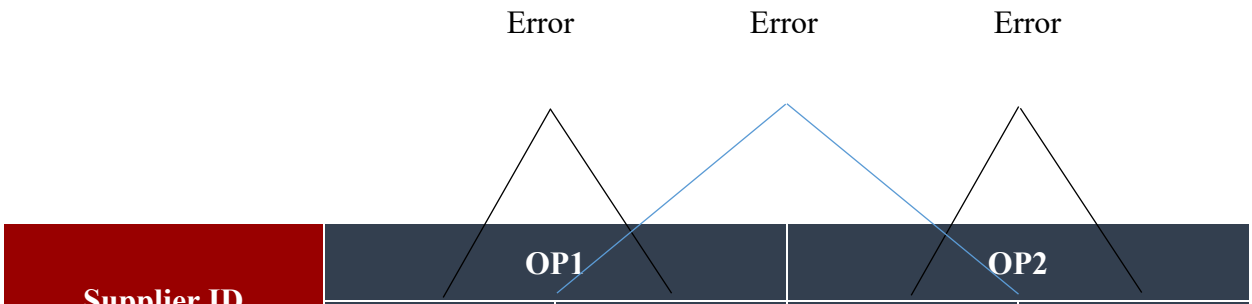
Supplier ID	JAN		Feb		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real	EXP	Real
LUX253	3	5	4	4.5	3	5	3	4	6	4	3	5	3	5	4	3	6	5	6	3	3	6	5	5
LUX265	6	2	2	2	3	2	4	4	6	4	6	6	4	3	5	4	5	2	3	3	6	2	3	4
LUX353	2	4	2	4	6	4	4	5	4	4	3	6	2	3	4	6	4	3	3	3	6	6	2	5
LUX666	4	4	2	1	4	4	5	5	4	3	4	3	4	5	4	1	4	4	4	5	4	4	4	3
LUX656	3	6	5	5.5	6	6.5	4	3	4	4	6	4	6	6	3	5	4	3	3	3	4	5	5	3
LUX785	4	5	4	5	3	5	6	3	5	4	3	4	5	5	5	4	3	2	4	3	6	6	2	5
LUX656	4	2	5	2	6	2	4	4	3	6	5	3	4	3	3	6	6	4	6	2	5	2	2	3
LUX885	2	3	3.5	3	2.5	3	4	2	4	2	6	2	4	3	5	5	6	2	6	6	6	4	4	6
LUX555	1	2	2	2	2.5	3	4.5	3	2	2	3	3	5	5	2	2	2	2	5	5	4	4	4	4
LUX122	2	6	6	6	4	6	5	3	2	6	4	5	3	3	6	2	6	5	3	6	5	3	6	3
LUX565	4	5	4	5	5	5	6	2	4	2	6	4	4	5	3	5	2	4	6	4	3	2	5	2
LUX888	2	4	2	4	5	4	2	6	5	2	2	2	5	5	2	3	6	6	3	3	2	5	6	5
LUX896	5	2	4	2	6	2	4	3	3	5	5	5	5	3	5	2	3	3	3	6	5	2	6	5
LUX544	4	3	2	3	4	3	6	5	4	6	5	6	2	2	3	4	3	5	6	3	6	2	4	2
LUX444	2	5	6	5	4.5	5	2.5	4	4	4	5	3	2	2	3	4	3	3	2	4	3	2	3	6
LUX656	3	2	4	2	4	2	2	2	6	2	3	3	2	5	2	6	3	4	3	5	5	6	3	4
LUX821	4	3	3	3	4	3	4	5	2	5	2	5	6	4	2	2	4	3	4	5	6	6	5	5
LUX452	3	4	6	4	5.5	4	4.5	4	6	5	6	2	5	6	5	5	4	2	4	2	3	5	5	4
LUX459	4	3	5	3	5	3	6	2	6	2	4	3	6	2	3	4	5	2	3	4	4	6	6	6
LUX259	4	2	3	2	2	2	2	6	4	5	2	3	3	4	4	4	4	3	5	2	3	5	5	2
LUX777	2	3	4	3	5.5	3	2.5	5	2	2	6	2	6	6	2	5	5	3	6	5	6	4	6	2
LUX458	6	3	2	3	4	3	3	3	2	2	2	2	3	6	3	3	2	4	5	2	4	3	3	6
LUX623	8	2	3	2	5	2	4	4	4	3	5	5	6	5	3	2	2	5	4	5	2	5	2	2
LUX545	4	6	2	6	5	6	5.5	6	5	6	5	5	6	3	3	6	5	6	4	2	5	5	2	4
LUX844	3	3	4	3	6	3	6	5	4	3	2	6	2	3	6	3	2	6	5	5	6	5	3	5
LUX687	2	4	5	4	3	4	3	6	5	6	2	3	5	6	2	3	6	6	4	4	3	2	6	6
LUX963	1	4	2	4	3	4	5	2	5	4	2	4	5	4	4	3	6	6	4	4	2	2	5	2
LUX455	1	4	2	4	4	4	3	3	6	2	2	3	3	5	2	6	6	3	4	3	5	4	5	2

Table 11: FMEA table for Reducing Suppliers Delay Time

First step to implement the measurement system analysis is selection 10 suppliers. In this stage we have chosen them randomly and we can't preselect them either good one or bad one in order to

have precise measurement system.

Our measurement system consists of a machine, method, components which are suppliers, environment and in our case is Luxxeen and employee how is conducting this test. Now we are going to select suppliers with their delivery time in obviously random order and our measurement system will make a judgment. Then we will do the same measurement system to measure the supplier delivery time again in different period. The main important factor for this section is; the measurement should be blind and 100 percent randomly and not selective.



Supplier ID	OP1		OP2	
	Jan	March	Jun	Sep
LUX253	35	32	35	28
LUX265	14	17	13	25
LUX353	25	27	28	35
LUX666	28	7	28	35
LUX656	42	39	46	21
LUX785	35	33	37	21
LUX656	14	12	13	28
LUX885	19	21	23	14
LUX555	14	13	21	21
LUX122	41	44	43	21

Table 12: Random measuring suppliers' delivery Time

After measuring random suppliers' delivery in two different months by two different operators, the difference in delivery time for suppliers in each period is called ERROE. The error between 2

months for one operator called Within system and error between operators called Between. Within system error usually called Repeatability and Between system error usually called Reproducibility. Minitab calculates the following results.

ANOVA gauge repeatability and reproducibility

ANOVA including Interaction

Source	DF	SS	MS	F	P
Parts	9	2329.22	258.803	4.61942	0.016
Operators	1	60.02	60.025	1.07140	0.328
Parts * Operators	9	504.23	56.025	0.94917	0.507
Repeatability	20	1180.50	59.025		
Total	39	4073.97			

α to remove interaction term = 0.05

Table 13: Two-Way ANOVA Table with Interaction

ANOVA without Interaction

Source	DF	SS	MS	F	P
Parts	9	2329.22	258.803	4.45490	0.001
Operators	1	60.02	60.025	1.03324	0.318
Repeatability	29	1684.72	58.094		
Total	39	4073.97			

Table 14: Two-Way ANOVA Table Without Interaction

Variance Components

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	58.191	53.70
Repeatability	58.094	53.61
Reproducibility	0.097	0.09
Operators	0.097	0.09
Part-To-Part	50.177	46.30
Total Variation	108.368	100.00

Table 15: Luxxeen Variance Components for supplier's delay

Gage Evaluation

Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	7.6283	45.7696	73.28
Repeatability	7.6219	45.7316	73.22
Reproducibility	0.3107	1.8644	2.98
Operators	0.3107	1.8644	2.98
Part-To-Part	7.0836	42.5015	68.05
Total Variation	10.4100	62.4599	100.00

Number of Distinct Categories = 1

Table 16: Luxxeen Gage Evaluation for suppliers' delivery Time

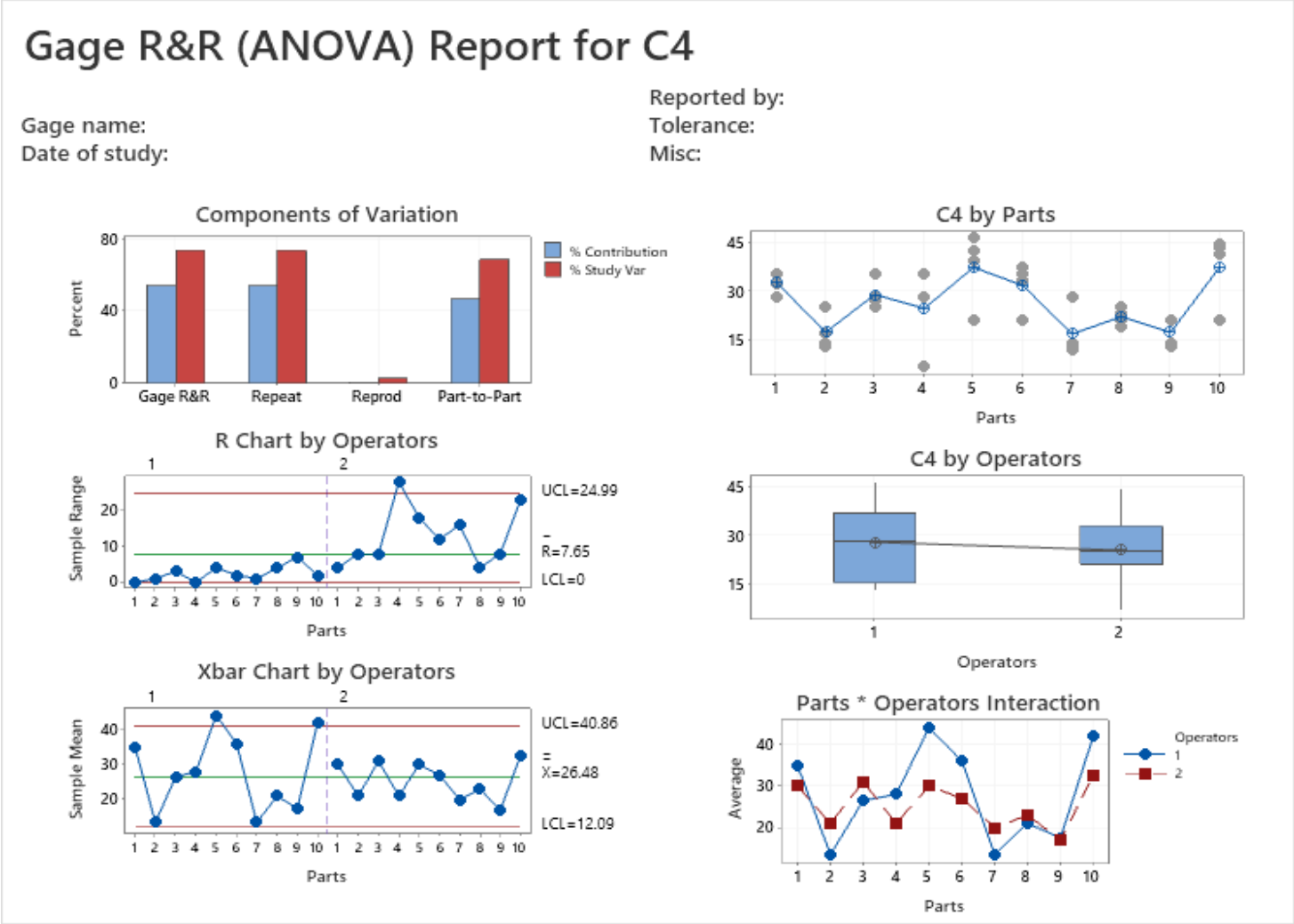


Figure 11: Luxxeen Gage R&R Report

Technically the Measurement System Analysis (MSA) try to answer tree main question:

1- Is my measurement system good and efficient? if our answer is NO, that means there is a problem and we need to answer next question.

2- Where the problem coming from?

3- What we need to do an what is our plan about the problem?

Bases on the result that we got, the Total Gage R&R is %73.28 which is not acceptable and it need be around %10 and repeatability problem is much bigger than reproducibility problem which our problem is within system that we call repeatability and as an answer of second question.

4.2.4. Sigma Level calculation

Following table shows the current sigma level based on the Luxxeen supplier data. We consider 3 different suppliers from the list of Luxxeen suppliers. The number of defects refer to number of delay time for each supplier. Also, number of units refer to total times that Luxxeen used that specific supplier. The following results show that the existing DPMO is 41,096.

	Supplier A	Supplier B	Supplier C	Total
Enter Number of Defects:	2	4	-	6
Enter Number of Units:	55	48	43	146
Enter Number of Opportunities Per Unit:	1	1	1	1
Defects Per Million Opportunities:	36,364	83,333	-	41,096
			Sigma Level	3.2

Table 17: Six sigma value for selected suppliers

Based on the current defects per million opportunities (DPMO) that we calculated, the current

sigma level is 3.2

Six Sigma Table:

1	690,000
2	308,000
3	66,800
4	6,210
5	320
6	3.4

Table 18: Six level for selected suppliers

4.3 Analyze supplier delay risks

A supplier risk analyzes is a process in order to validate and verify the suppliers' processes, strategies and economic situation. This process shows and regulates the level of the collaborating risk with the supplier and potential effects to the organization. Technically, the effective risk recognition methods concentrated on the root cause. Recognising the main parameter and causes of risk can helps in order to recognize the potential loss and elements of the organization is exposed. Classifying the root source can delivers useful guidelines about what stages and activity needs to be done to moderate risk most effectively and also recognising risk based on the consequence or outcome.

4.3.1. Classifying Possible Causes

Technically, there are three key classes of causes. The first one is potential causes, the second is likely causes, and the last category is root causes. During analysis phase, the project team can find out the problematic causes that needs enhancement and the possible solutions for reducing the gap between existing performance and the ideal stage of performance. Considering the Y=f(X) idea of Six Sigma, Analyze phase output and target is to calculate X's and to identify Xs and Y relationship. The analyses phase's main intention is the analyzing of the collected data in order to find and control the root causes of defects and enhancement opportunities.

Cause and effects Diagram. Which is also recognised Fishbone Diagram, for its typical shape, this type of diagram helps project group to identify the cause of the problem and not only the signs. This diagram helps a team to focus on the problem's content rather than team members' individual interests. Generally, the problem description is located on the right section of the figure and the team members concentrated to the other section by investigating the possible sources of problems like resources, individuals, and procedures.

Cause and Effect Diagram main significance

a) A cause-effect illustration is not able to find the root cause by itself. cause-effect diagram helps graphically some causes they are potentially contributing to the distinguished effect.

b) Graphical illustration of the characteristics that might helps to a practical effect that is being inspected.

c) The correlation among the potential causal factors is visibly shown. Also, one fundamental aspect may seem in several parts of the figure.

d) In general, the inter-collaboration is assumption and qualitative.

e) It emphasizes the consideration of all team members on the specific problem in a systematic way.

The main and significant reason of creating a cause-effect diagram is to have a clear view and understanding of the cause-effect connection. When we are completing the diagram for the Luxxeen supplier delays problem, we should be able to start at any endpoint and read the diagram as follows: delay on delivery from supplier side causes the delay in production and makes many problems for the company. The supplier delay causes loss of orders of the Luxxeen. Alternatively, we can start with the occurrence being explained and read it backward like this, sales orders of the Luxxeen were lost because of the suppliers' delays. The suppliers have delays because of their own problems. We might don't have enough evidence on which cause was essentially the key reason. However, the statement should make good sense.

All possible sources of causes should be measured. There are four classifications of causes defined that could be applied to supplier delay program for production of Luxxeen:

1. 1. Machines and materials as objects
2. Circumstances such as demand over a period of time, temperature, trend
3. Time sequence in the process: hierarchy of production or shift time (morning shift or night shift)
4. The place- related items like the loading dock, the distributor, or a specific warehouse branch.

4 Ws (When, Where, What, Why) are taken into the game and are being asked for purpose of explicitly. Plus, two other lists assist these several categories of causes to resolve the issue. The

lists are classifying as 5 Ms in this process and 5 Ps for services are mentioned in the following:

5 Ms

1. Manpower: (employees)

2. Materials: (supplies)

3. Methods: Procedures

4. Machines: (environment)

5. Measurements: (customers)

5 P's

1. People (employees)
2. Provisions (supplies)
3. Procedures
4. Place (environment)
5. Patrons (customers)

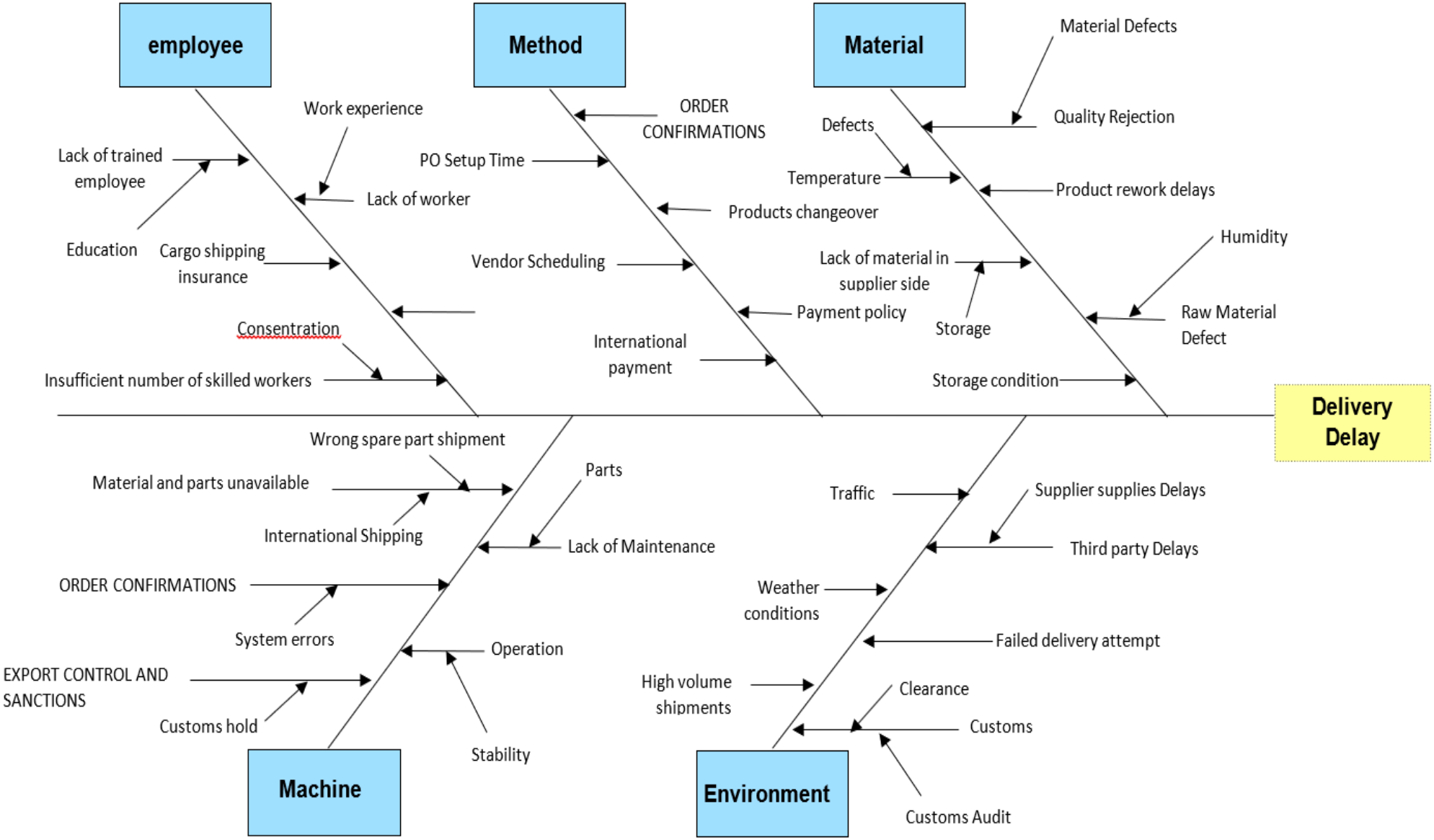


Figure 12: Delivery delays Cause and Effect Diagram

4.3.2. Orders and orders Confirmation

The Luxxeen PO's for the items may either be recorded as a hard copy or made by phone or email or any online framework. The provider will immediately affirm the request by a composed request affirmation for essential items for the provider's rundown of current items. Requests for items that will require adjustments or some other changes to their present details will be affirmed by the assessed time needed to satisfy the buyer's solicitation. Should the request confirmation be consistent with the Luxxeen buyer's structure, the buyer must inform the provider recorded as a hard copy within three days of receipt of the request affirmation. In the function, the buyer tells the supplier of such mistakes, the supplier will immediately send the company another and right request confirmation.

Weather conditions. For all transportation organizations, security should consistently be a need. With climate, street shut-downs wind up causing delays because of moderate travels. As unsolved as it might be for clients when climate conditions affect transport, there is just so much transport organizations can do to guarantee ideal transportation.

Traffic. Now, finding a city with no traffic is nearly inconceivable. Between development, accidents, significant barricades, and changes, it is getting regular to know about individuals encountering delays during their travel. Dispatch drivers can exploit course improvement programming. It can pinpoint the quickest course conceivable and update it progressively to evade delay-instigating functions.

High volume shipments. A rapid or surprising expansion in shipment transportation volumes can overpower a transportation organization that isn't outfitted with a satisfactory programming framework. This is generally regular during the Christmas season when the shopping spectacle starts. As online

requests soar, so does the prerequisite of a messenger the board programming, which can productively circulate the best possible volume to drivers through the most proficient courses.

Failed delivery attempt. Removing the attention from courier organizations, clients might be the behind transportation endeavor if there was nobody there to get the bundle. In the event that the transport company has delayed, the driver should proceed onward to forthcoming requests to maintain a strategic distance from delays. The truth of the matter is they normally have a fixed measure of time for delivery. Fortunately, this issue can be effectively understood with the correct track and follow the framework. This guarantees that clients are updated progressively and will know when they should get the order.

Customs. Moving to a worldwide point of view, as a transporter confronting customs, we should guarantee that all the necessary archives are available and filled to avoid any issues. Without the complete possible documentation, delays are unavoidable, and it can rapidly heighten to additional entanglements if specialists choose to review the freight.

In the situation when materials are stocked in border by customs for many different reasons like audit or congestion, business need to have a holdup strategy. Some portion of the back-up plan is organizations with solid messenger administrations which keep reports precise.

Export control and sanctions. Buyer recognizes that supplier is needed to follow relevant fare control laws and guidelines just as approvals law identifying with the deal, trade, import, move, task, removal, and utilization of the Items, including permit prerequisites. Buyer concurs that Items won't, whenever straightforwardly or in an indirect way, be utilized, sent out, imported, sold, moved, relegated, or in any case discarded in a way that will bring about resistance with any fare control laws and guidelines or with any authorizations law.

Third party Delays. When the supplier becomes aware that he won't have the option to deliver the Items at the concurred date of delivery, he will forthwith inform the Buyer thereof recorded as a hard copy. The warning will incorporate a portrayal of measures the provider thinks about proper to recuperate or restrict the deferral, assuming any, and another transport date.

Cargo shipping insurance. In the event that the deferral is a direct result of the vendor's action, and the item isn't shipped to the organization or has not left the distribution center or spot of capacity that is named in the protection strategy, the guarantor or insurance agency does not commit in light of the fact that the protection contract isn't compelling.

Delays for the international payment. Normally, the purchaser's principal essential commitment is the installment of the cost as given in the agreement of offer. Thinking about the current circumstance like COVID, delay in installment may happen in view of issues on the Purchasers' end, banks working days, the nation of starting point or constraints in administrative offices.

While each provider ought to take a stab at 100% on-time delivery, there are three primary reasons for late delivery. 1.Their suppliers are late. 2.They had a manufacturing issue. 3.They overcapacity. We should survey each of these and sort out countermeasures you can execute to help ensure you against late supply.

Their Suppliers Are Late. The simplest way to identify but then the hardest to get ready for is to find out how frequently you have been late to a client since one of your suppliers was late precisely. Furthermore, what could your clients do about it? So how might we ensure ourselves against this projection? Is that our supplier enough wellbeing stock to secure ourselves? The safety stock arrangement ensures us against every one of the three reasons that providers may be late; however, there's the conspicuous budgetary danger of holding an excessive amount of stock, after a supplier's late a result of

this explanation the first occasion when, we presently have influence over our company. Utilize the occasion to demand/request that they hold safety stocks. Their security stock arrangement ought to ensure us against our late Level II providers. Since the expense of their segment or crude material is far not exactly the expense of your stock, you can even go to money-related consent to pay for all or some portion of the security stock they're holding for you. What we can do about this issue depend on what tyoe of issue it is. On the off chance that it's a limit issue, they couldn't make your item since they didn't have an accessible creation limit – you might have the option to hold the limit early. You can do that by putting in a sweeping request in the event that you realize what your downstream interest will be. By submitting a sweeping request (say for half a year or a year of gracefully), your providers can't contend that they ran out of limit. In fact, that they should plan to make your stuff a half year or a year ahead of time. In the event that the creation issue isn't a limit issue – however rather is some sort of specialized assembling issue we can ensure you with safety stock (once more, held at the provider at a lower cost).

Excessive promise. Many suppliers when they receive the extra capacity orders, they don't reject them and try to handle the orders and it can be very annoying because most of the time they will face the delays to receive ethe order. Typically, if a provider over-promised, it implies that somebody realized they wouldn't have been ready to flexibly you on schedule. The most annoying part is that suppliers don't admit to this. They'll give us some rendition of one of the initial two reasons rather than reality. You may never realize that they are over-promised, yet here are a few signs. 1.They express that delivery will take a month and when you state "that is excessively long", they'll reveal to you they can convey in about fourteen days. 2.The individual who makes the promise isn't associated with creation however is boosted to make the deal. 3.The provider has a past filled with over-promising and under carrying. What would we able to do, most importantly, we should begin punishing supplier for late delivery. In the event that a provider is routinely late, we may need to begin asking for penalty paying of 3% or 5% or 10%. Finding substitute suppliers as reinforcement is consistently a smart thought. When our essential provider learns

we are doing this (particularly if the reinforcement is one of their rivals), that ought to likewise stand out enough to be noticed. The ideal approach to moderate late supplier delivery is to transport early, which gives the suppliers estimates or cover arranges to make sure about crude materials, parts, and manufacture limit. Furthermore, impart unmistakably is to ensure our suppliers know our prerequisites: amounts, dock dates, and quality particulars. The initial step to forestalling creation and shipment delays is to work with reliable and genuine suppliers from the beginning. However, at he beginning it is difficult and takes time to recognize the reliable ones. How might we guarantee your suppliers will remain on target of our manufacturing without working with them first? While there's no viable replacement for genuine encounters working with providers, we can take a couple of steps to vet providers before putting in a request.

Evaluate supplier's processes with an ISO 9001 quality audit. Not everything shippers can visit their supplier's office face to face before submitting a request. Furthermore, regardless of whether we can visit, we probably won't realize how to successfully assess manufacturing measures. For example, on the off chance that we visit a supplier introducing it as a furniture processing plant, you can undoubtedly affirm whether that supplier is, in reality, a purchasing office. However, shouldn't something be said about a provider's quality records, manufacturing plants, and other more modern cycles? These issues can be more enthusiastically for the normal shipper to recognize during a short visit. That is the place where an outsider quality review can help. Most quality review structures depend on the ISO 9001, a global norm for quality administration frameworks. Confirming your possible providers against this norm before manufacturing starts can help us maintain a strategic distance from muddled providers who are inclined to flighty manufacturing delays. Some problems which quality review can help to find them are:

• Insufficient in-line manufacturing quality controls to forestall and recognize quality issues before transportation

• Insufficient manufacturing limit concerning our request, proposing they may be redistributing all or some portion of our request to sub-providers

• No provider hazard evaluation framework to forestall the deficiency of key materials

• Lacking a point-by-point manufacturing plan that incorporates creation limit, orders, stock, item type, and creation lead times

• No alternate courses of action to fulfill client prerequisites in case of a crisis, such as utility interferences, work deficiencies, key gear disappointments, or field returns. Investigate our request all through manufacturing

4.3.3 Process Map Analysis

Process Mapping Analysis, which is called PMA too for Luxxeen manufacturing process, shows the actions elaborated in defining what Luxxeen does, responsibilities of teams, the standard or a process that needs to be completed, the measurement process and the way the accomplishment of a production procedure can be determined.

This process mapping's main function is to better help Luxxeen in becoming more efficient, less complex, and wasteful. The same time the strong and comprehensive process map letting stakeholders to have better understanding of the whole process in order to decide whether or not the improvements can be performed to the existing process.

The main objective of the process mapping analysis PMA for Luxxeen is trying to evaluate and measure the supplier delay's objective combined with the entire organization's purposes to make sure that all procedures are aligned with the corporation abilities and potential. Process mapping analysis, which is called process diagrams too, become more popular, useful, and standard tool in the business environments recently. The process map of the Luxxeen productions is following the real details step

and stage of business procedures for every section of the business. The main critical steps of Luxxeen process mapping are as follow:

1. **Procedure documentation**—Observing complete corporation steps and process
2. **Data collection** —Recognising steps, risks, components and crucial elements in a process
3. **Consultation and mapping**—Talk to individuals to considerate their point of view of in the process to designing precise and real based maps
4. **Analysis**—By using appropriate tools and methods, design or change the process in order to improve it more efficient and effect.

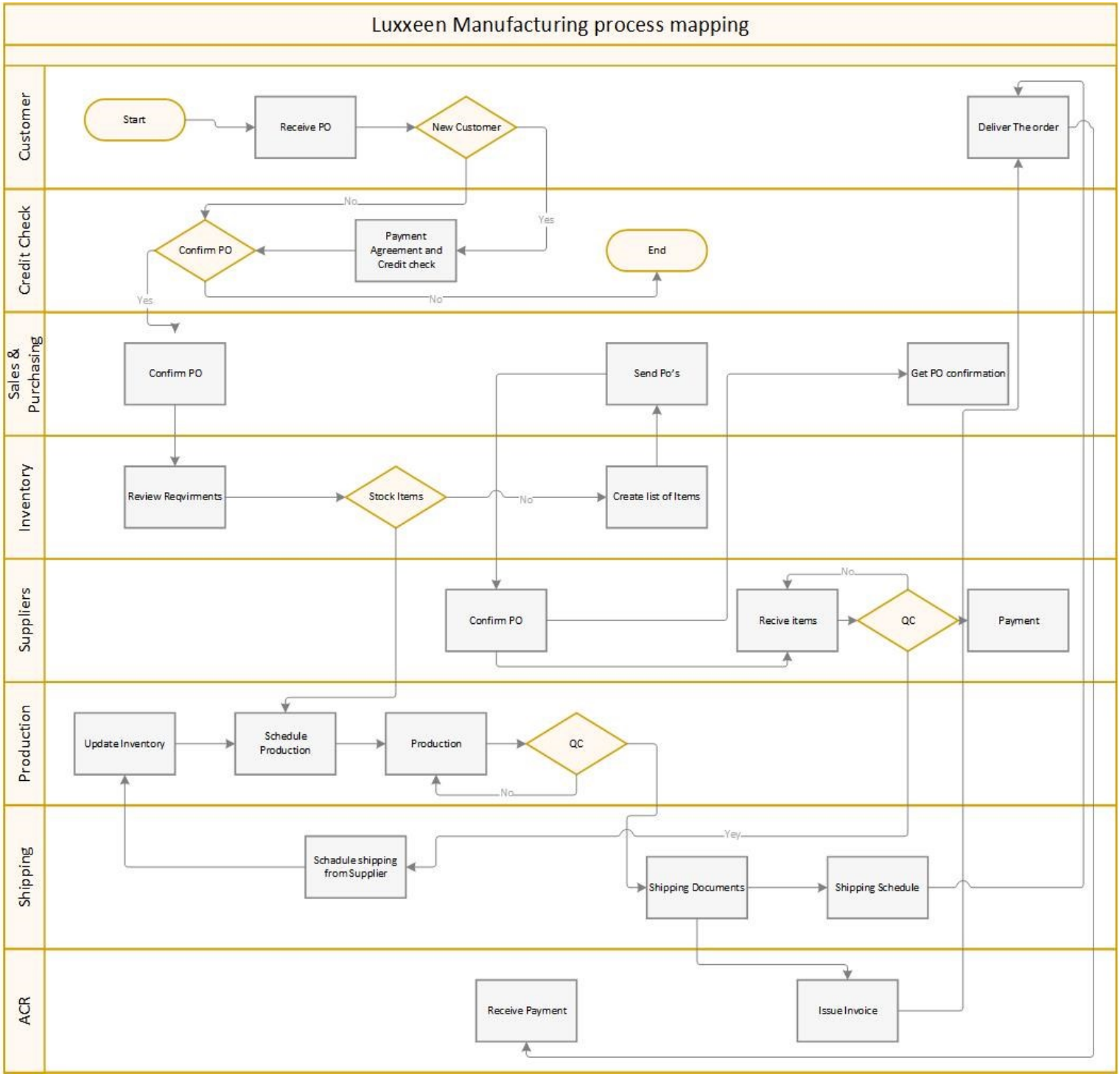


Figure 13: Manufacturing process map for Luxxeen

Luxxeen manufacturing process map starts with receiving the PO from clients. After we will check either this Po belong to new customer or excising customer. If the Po coming from new customer,

company need to verify the credit and payment term. After approving the PO, we need to verify the inventory with BOM (Bill Of Material). In case of lack of materials in warehouse, production manager needs to provide the request to purchase department to fulfill the stock level.

Next step is planning for production based on the other orders line and type of product, in some case we need to changeover the production line which needs more time and also need to match with other orders.

After Production, logistic need to arrange the shipping with buyer and also with transport company in order to deliver it on time. Last step is billing and payment process.

4.3.4. Finding the Root Cause.

As soon as the project group has recognised a potential cause then they need to verify to make sure if they find the right source of the problem. Six Sigma methodology employ many different tools in order to make sure the attitude that find in the production process is the source of a product defect. The analysis of variance (ANOVA) is tools to decide if there are any critical differences among the different independent supplier groups. The ANOVA considers the means between the Luxxeen preselected supplier groups and find outs if any of those means are significantly different from each other. Generally, ANOVA precisely tests null hypothesis:

$$H_0: \mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$$

In the equation μ is group mean and *k is* number of groups. The one-way ANOVA delivers a statistically significant result. In this stage, basically, with ANOVA we are testing different Luxxeen supplier groups to see if there's a difference between them.

Location	Size	Stock Contract	Shipping Method	Cost	Lead time
80	82	89	75	77	75
85	79	88	77	77	78
84	78	91	77	90	82
77	83	90	85	90	90
89	89	90	88	76	83
88	84	88	76	77	84
83	81	89	85	76	77
80	75	88	85	85	81
77	82	91	78	80	77
81	79	88	84	86	91
91	84	88	89	80	90
83	81	90	78	88	78
75	87	90	81	75	85
81	89	89	77	84	76
88	77	88	79	79	86
81	88	89	88	83	80
76	89	91	82	87	77
80	86	88	75	76	84

Table 19: ANOVA testing result for different suppliers

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Column 1	18	1479	82.16667	21.55882
Column 2	18	1493	82.94444	19.23203
Column 3	18	1605	89.16667	1.323529
Column 4	18	1459	81.05556	22.76144
Column 5	18	1466	81.44444	27.20261
Column 6	18	1474	81.88889	25.86928

Table 20: ANOVA result for different suppliers' group

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	829.5556	5	165.9111	8.439898	1.03E-06	2.303493
Within Groups	2005.111	102	19.65795			
Total	2834.667	107				

Table 21: ANOVA result table for group of suppliers

If F > F crit, then we reject the null hypothesis. In our case F= 8.439898 > F cirt =2.303 consequently, we refuse the null hypothesis. The means of the six different supplier groups are not all equivalent which means in any case one of the means is different. Nevertheless, the ANOVA doesn't state where the difference is.

4.3.5 Regression Analysis

Regression analysis is used in order to find trends in Luxxeen data. For instance, we might know that there's a relation between the quantity that we are buying materials and related profit, however regression analysis can assistance to quantify that. Regression analysis will deliver us with an equation for a graph so that we can predict about our data. For instance, based on the history of past last years extra profit or less, it can be predicted the lost and profit in next ten years' time in case of we continue the same way of business. It also can help us with statistics results like p-value and a correlation coefficient in order to find out the accuracy of the model . In following table, we have the Luxxeen data for cost of delays. The question is; what is the correlation between sales volume which is output and price and cost of delay as input. It means, we might be able to forecast sales volume if we know the price and also cost of delay.

Quantity Sold	Price	Cost of Delay
8500	$2	$2,800
4700	$5	$200
5800	$3	$400
7400	$2	$500
6200	$5	$3,200
7300	$3	$1,800
5600	$4	$900

Table 22: Luxxeen cost of delay for specific products

After we run a linear regression analysis in Excel, we can see and analyze the interpret of the summary output.

R Square. R Square is 0.962, it can be considered a very decent fit. 96% of the variation in sales volume is clarified by the independent variables delay costs and price. Whatever R Square is closer to 1it means it has the better the regression.

SUMMAR of OUTPUT	
Regression Statistics	
Multiple R	0.980681
R Square	0.961736
Adjusted R Square	0.942604
Standard Error	310.5239
Observations	7

Table 23: Summary of Regression Statistics

Significance F and P-values. To make sure if our findings are accurate (statistically significant), we need to check and verify the Significance F which in our case is 0.001. The significance F in order to be accepted need to be smaller than 0.05. Also, in case of we have significance F bigger than 0.05, it's possibly better to stop working with this kind of set of independent variables and we must delete a variable that they have bigger P-value of 0.05. After we need to repeat the regression while Significance F goes under 0.05. That means we need to have the most of P-values be under 0.05. In our data this is the case. (0.000, 0.001 and 0.005).

ANOVA
Table

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	9694299.568	4847150	50.26854	0.001464
Residual	4	385700.4318	96425.11		

Total	6 Group	10080000

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	8536.214	386.9117478	22.06243	2.5E-05	7461.975	9610.453	7461.975	9610.453
Price	-835.722	99.65304469	-8.38632	0.001106	-1112.4	-559.041	-1112.4	-559.041
Cost of Delays	0.592228	0.104346803	5.675579	0.004755	0.302515	0.881942	0.302515	0.881942

Table 24: ANOVA Result to check if our results are reliable

Coefficients. The regression is as follow y = Sales Volume = 8536.214 -835.722 * Price + 0.592 * Cost of delay. That means, for every item increase in price, sales volume decreases 835.722 units. For each unit add to Cost of delay, sales volume increases 0.592. This is valued information which we can also use these coefficients for forecasting. For instance, if unit price of one item is $4 and Cost of delay for that specific item is $3000, we are able to realize the sales volume which is 8536.214 -835.722 * 4 + 0.592 * 3000 = 6970.

Residuals. The residuals by using equation, demonstrate us the real data points are how far form the forecasted data points. For instance, the first product quantity sold is 8500. By considering the formula, the forecast data point is 8536.214 -835.722 * 2 + 0.592 * 2800 = 8523.009 and residual of 8500 - 8523.009 = -23.009.

Residual Results		
Remark	*Predicted Quantity Sold*	*Residuals*
1	8523.009	-23.00896712
2	4476.048	223.9521754
3	6265.938	-465.9382265
4	7160.883	239.1165726

5	6252.733	-52.73331119
6	7095.058	204.9418798
7	5726.33	-126.3301229

Table 25: Residual Output Table for the actual data and predicted data

And following is also a scatter plot of the presented residuals.

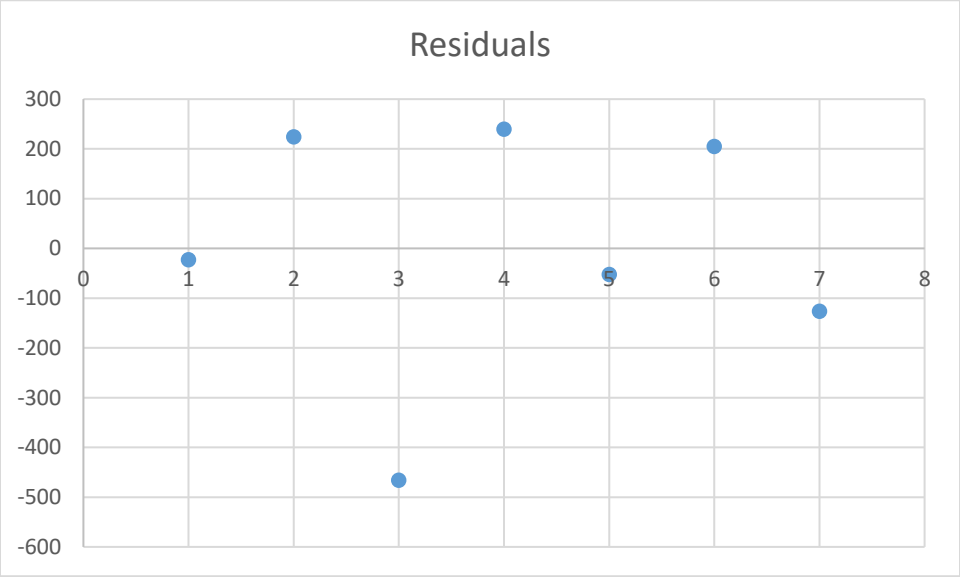


Table 26: Scatter plot of residuals

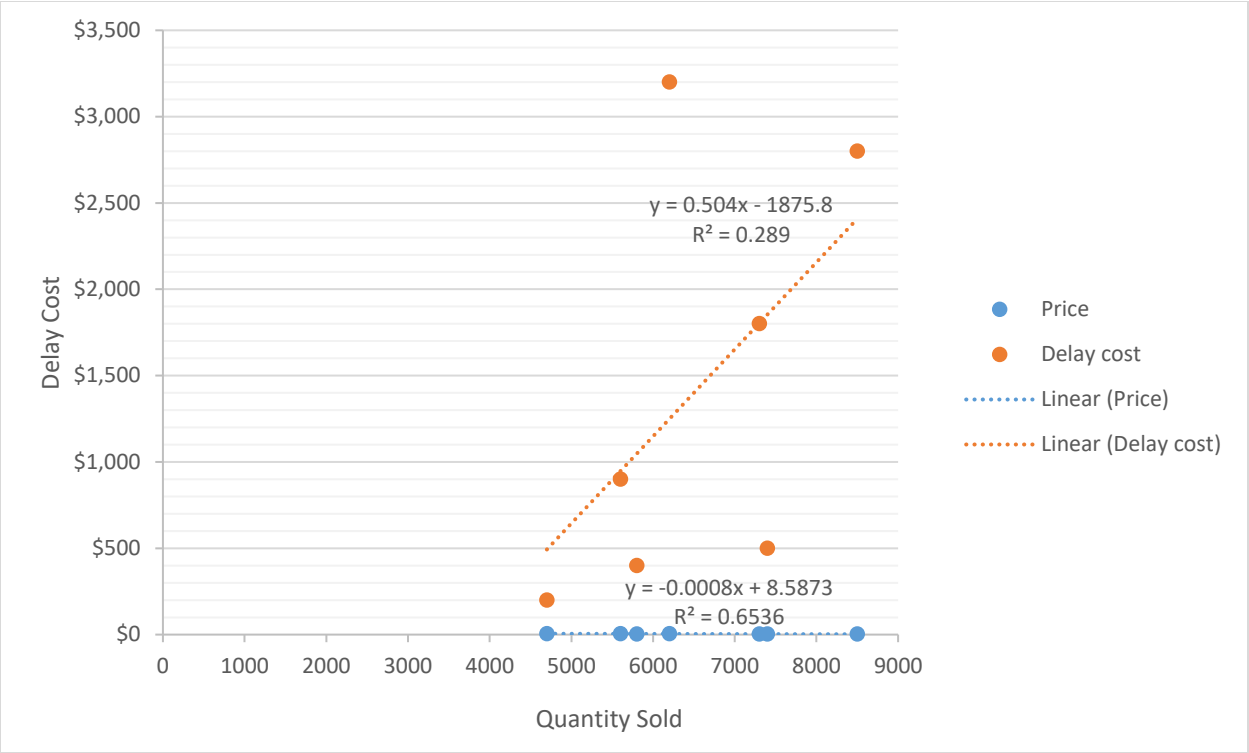


Figure 14: linear regression plot for the product defects

The structure of Six Sigma supports the project group to be able to analyze the process by creating models and considering individual and experimental process tools such as process maps and fishbone diagrams. After that Six Sigma can executes the Regression Analysis in order to verifying the theory of these probable causes which are responsible for the process or product defects.

4.4. Improve supplier lead time

With the analysis that we have done in the last section and the out data we have, now is the time to start making the improvements. Using any type of improvement management software can be very helpful at this stage which assists to perform the process constantly, achieve practical teamwork and run it much easier for the administration and executives to follow a specified DMAIC project.

4.4.1 Supplier Development

Supplier Development work together with all supplier dependents in order to advance and develop their processes, reliability, capabilities, manufacturing efficiency and quality. Supplier information and their related operational technology for the product or service they supply can be leveraged over supplier development to decrease cost and risk of the project. Originally, the main reason we do supplier development is; suppliers' competences and ability are not good enough to meet current necessities or upcoming expectations, but switching costs may be high, or the supplier has great potential. Second, Joint efforts may accelerate supplier improvement and third mutual benefits of company and supplier. There is different kind of approaches related to supplier development. Supply management professionals and purchasing should select the most appropriate approach to adapting their relationship with the supplier they already selected for development. Based on the condition, supply flow, type of products or service and market situation there are many different kinds of approaches for supplier development.

4.4.2 Different supplier development approaches

• Associating

• Inspections

• Assessment

• Solo or Double Sourcing

• Screens or Certification and Qualification Programs

A project of supplier development may be include to developing and improving a supplier's business, for instance helping them to estimate and redesign their business strategy in order to make the alignment of the relationship between the supplier and buyer .

In such a situation, both buyer and supplier organizations need to share a mutual understanding, obligation, and wish to achieve the supplier development project's points.

An essential pre-requisite for supplier development and supply management strategy is purchasing and supply management professionals should analyze and evaluate their own organization's objectives and business needs. The supplier development programs provide assistance to the procurement and supply management strategy and also help the corporation strategy. In order to have a reliable and solid supplier development, organisations need to have specific methodological percurrent skills as well as ability of project management and contract management. From other side supplier development also needs outstanding abilities to communicate with others as it is a key and crucial operative way of communication with suppliers and the companies. In supplier development, it is important that the corporations must recognize and acknowledge the supplier's situation and the influence on their corporate of the development process.

The Process of Supplier Selection Supplier selection is main and critical element of to all buyers' work and perhaps the greatest significant function in purchasing [36]. There are a variety of reasons why there is a need to find and pick a new supplier. For instance, formerly used source may have gone because of bankruptcy, in another cases the price of supplier may increased for no reason or also the quality may be unsustainable, and it may move to unexpected levels. Normally, the selection process for finding the best option which is fit based on company expectation, is complicated and important. First step of supplier selection usually is the scan and study of supplier information and their sources and eventually terminate with the list of approved selected suppliers. The supply management team need to have access to many information sources of supplier information like; financial sources, operational and capacity, personal contacts and also internal data [37]. In next stage the procurement manager uses the important selection criteria as a input for selection process. The selection process needs to be complete and consist of the necessary abilities, expertise and experience of suppliers. This meant that a potential supplier [38];

· In terms of economically, technically, and production-wise over the time need to be steady;

· Need to contribute and attend for product design stage and development as a business partner;

· Need to provide related information and the necessities of the products or services like quality goals and price;

· Need to be aligned with saving cost of production and process improvement;

· Need to provide a prototype and be capable to required capacity;

To be more precise in supplier development process, the following factors need to be considered as a main and critical element of suppliers' development.

- Supplier Evaluation
- Early Supplier Involvement
- Supplier Training
- Communication

4.4.3 Obstacles and Issues in supplier development

Supplier development can be valuable for both corporations and suppliers, specially for manufacturing sectors the success of operation can directly connected to the abilities and performance of the suppliers [42]. In order to improve the capabilities of suppliers and have abetter performance for the company or cutting the costs and improving the quality, so many companies are investing in their suppliers to collaborate with them and implement the supplier development [43-45.] While supplier development brings so many advantages and profits for the company and suppliers and also whole supply chain, however it might have several matters and issues during the supplier development process. There are several factors and elements for the competitiveness of a company. Supplier development is crucial and key elements of any corporations in order to add them extra competitive benefits There are some obstructing elements in supplier development like resource limitations, unproductive feedback, weak communication, lack of trust, the supplier's self-satisfaction, legal issues, initiative fatigue, and misleading objectives to improve the supplier, confidentiality issues, and unbalance of power in the relationship. These obstacles block the effective execution of the supplier development and eventually

they will affect the corporate performance improvement [40,41]. Handfield et al. suggested and advanced the diagnosis for barriers to supplier development [46]. They recommended some explanations to dodge these boundaries and issues few arrangements are recommended. They partitioned supplier-specific and buyer-specific issues. Supplier-specific barriers are lack of technical skill, lack of commitment, and shortage of human resources. Need of commitment happens when buyers are incapable to depict clear instruction for required materials or services. Failures of operational resources for lake of assets in engineering, machinery, information systems, operative skills and training are usual barriers through supplier development process. The buying companies use supplier development practices to improve performance and fight back the barriers to supplier development [47].

Best Practices in Supplier Development. **S**upply chain management consist of some main components, one of these important components is supplier development practices which play a vital role in improvement of company performance. In process of supplier development, supply chain management needs to study and concentrate across industries and focus on supplier capabilities if the outsourcing is a significant proportion of the operations. Supplier development practices which is normally performs by corporations are includes; official assessment of supplier, motivations of supplier, competitive environment leverage and direct participation in improving suppliers performance over training and other related activities. Essentially, the approaches and procedures of supplier development, which is used across industries, can be uncertain because of differences in complexity and operation between products and service-based organisation [48,49.]

Supplier development practices can be classified as competitive pressure, supplier incentives, supplier assessment, and direct involvement activities. Competitive advantage technique can use various suppliers if applicable and substituting the suppliers if needed. Supplier incentives also can be defined as an ability of increasing current volume or promising better condition for future business and credit and rewards for

better performance. Assessment of supplier comprised official valuation and certification. Direct involvement consists of regular visits of supplier's facility, investing on supplier training and knowledge improvement. Potential benefits included cost, quality, rework and scrap rates, production downtime, and problem resolution [50,51].

Part of the definitely best practices, procedures and actions which qualify the corporations to progress their quality, which has correlation with improving their supplier's product quality and on time delivery are;

- Allocation of specific members for supply development
- Providing guild line and instruction for supplier to continue after supplier development
- Concentration on primary sources for long cycle
- Evaluation & tracking unacceptable supplier quality costs
- Engage suppliers in development of new product or process
- Offer regular training programs and schedule for suppliers
- Supply instruction practical programs after training
- Manage enhancement focused seminars for suppliers
- Suggestion of necessary tools and high-level support to suppliers
- Prepare facility or center for supporting technically for suppliers
- Expand financial measurement systems to be able to measure improvements
- Invest the savings which is result of development to suppliers
- Inspire and help suppliers to improving processes at their supplier too
- Create feedback system loop in order to encourage suppliers
- Cost recovery
- Supplier Audit

By deploying these best practices, companies and manufacturers can impressively improve their supplier quality and implement these practices with the intention of accomplish their business objectives. Alternatively, best practice supplier development necessitates assigning resources to the supplier and the customer.

Supplier Development Enablers. There are so many enablers of supplier development. The most commonly used are focusing on eliminating waste and eliminating the performance barriers, conducting Value Engineering and value analyses, developing a supplier development project charter, implementing continuous improvement techniques using the PDCA cycle, and providing communication forums [52].

Elimination of Waste. A foundation of continuous improvement and just-in-time philosophies is the decrease and eventual elimination of waste. The common approach to assessing a supplier is that a supply manager should walk through a supplier's facility, discover problems, and decide whether suppliers should be based on measurable metrics. Honda corporation described the seven main wastes that straightly affect the efficiency of the manufacturing process. Nevertheless, the seven wastes can apply to service operations as well and from other side most of companies describe the Seven Wastes from their point of view. Generally, any action does not add value to the process or customer, it is considered waste.

Value Engineering/Value Analysis. Value engineering and value analysis are universal methods to improving products and processes. In both value engineering and value analysis, value is generally defined from the customer's point of view, which will use the product or process. Based on this main concept, the common question asked in all value-based analyses is, "Does this add value to the customer?" If the answer is no, then there is a high probability that this process or service is waste and can be reduced or eliminated, such as cost, action, part, step, feature, tolerance. Usually, the technique is applied commonly in manufacturing, will be used for value analysis to a broad range of activities from

the design of operating systems to the development of corporate reengineering projects, to the procurement of services and transportation [53].

Value Engineering. Value engineering happens in the design process before a product goes into production or a process has been implemented for the first time. Value engineering usually requires a scientific and systematic study of all phases of designing an item or process to the final product or process. Value engineering recognizes that the design process provides the greatest opportunity for reducing costs in the best method before the costs are applied to the actual product or process. Value engineering plays a key role in new product development.

Supplier Development Project Charter. The project charter for supplier development is an active document that is usually getting updated in a several stage including arrangement stage, performing stage and completion stage of supplier development project. The supplier development project charter usually contains the following parts: mission or vision, business case, situation and goals, project scope, and signatures.

■ *Mission and Vision***.** The mission of project should be defined to explain and specify what target development team is trying to get. The declaration of mission needs to be clear, summarised, and brief.

■ *Business Case***.** The business case is describing and explain the economical estimation of the current situation and after implementation of the project. In the phase of assessment, the supplier development team working on the estimated savings from the development project documentation and the related assumptions. Normally, the initial version of the estimation will never be entirely correct, that is why the estimate need be updated when new and more precise information becomes available.

■*Project scope and Goals***.** In the stage of project scope and goals, a qualitative and quantitative explanation of the existing condition and the goals for improvement are documented. In the early stage

of project, data need to collect on the calculable metrics and to be used to measure the progress in order to find out if they it follow project target. The offered documents need to be comprised describing the structure of tracking the improvements after implementation. Also, the development group needs to describe the project's scope. Explaining the project scope supports to make sure the project is in right direction the team members are concentrated the project focus to the activities required to complete the project.

■ *Schedule and Deliverables***.** A standard approach for scheduling is a Gantt chart in order to present the connections and time limit required to complete the project and also for to decreases future confusions and miscommunications.

■ *Assignments and Roles***.** This stage basically describes the team members responsibility and activities.

4.5 Control supplier delay risks - Identify control strategies/Audits

In the control phase, the best common tool is the Control Chart. The management team and project manager can control the advancement of the process over the control chart. It is also necessary that the project leader can understand the control chart so that the project group can generate a reference log signifying what the project leader should look for.

Different kind of tools in order to validate the parameters are within their limits are used. Also, to validate and regulate the movement of activities and documents, all the processes and the tasks are verified with the appropriate group or individual in Luxxeen. In other words, it is about ensuring the improvement delivers the real benefit over the longer term. In the control phase, the first step is to implement ongoing measurement. This step aims to the insurer is clear what we are going to measure after the project is closed and how it will measure it and how it will be monitor. The second step is about ensuring the solution that we have impalement becomes a standard solution. In other words, it necessities to turn out

to be a typical process inside the business. Thirdly, it is time to quantifying the improvement that we have made by comparing the new, improved performance against the original process. This also demonstrate the benefit of the new development. Finally, the last step of control is about closing the project to structure way and to be insured any lesson learned can be found in future to applied elsewhere in the business.

4.5.1 Six Steps to control Supplier Risks

The following six steps can be used to address these challenges and to establish a supplier risks control program;

Step 1- Develop a full enterprise view of suppliers and suppliers of suppliers.

An informed view of the company interactions with suppliers and suppliers of suppliers is not generally accessible for many organisations. To control suppliers, companies need to analyze their processes on an ongoing basis and recognize active suppliers. Furthermore, it is vital to study other crucial relationships such as suppliers, distributors, and others.

Step 2- Categorize the source base for risk management.

Businesses need to classify suppliers that have the greatest level of risk. They should know which suppliers have the greatest risk to the organization's major product or projects? Which suppliers might disrupt and affect constant operations in case their deliveries have a delay? Which suppliers have the highest risk to the company's reputation, brand, environment, health, and safety plans?

Step 3- Classify, progress, and find the right supplier risk data.

Companies must consider numerous wide ranges of data from diverse sources in order to understand the risk. These data include; supplier financials data, business continuity plans, information security plans, internal business requirements, internal risk, etc.

Step 4- Arrange constant data collection across the supply.

To collect the data, the company needs to join suppliers into a specific program and manage and gather different essential data, including internal and external information.

Step 5- Converting risk data into understanding and corporate data.

When risks are forecastable in advance and related to the type and size of the business, supplier risk management is easy. However, understanding risk in the business activities framework is critical for prioritizing the appropriate response.

Step 6- Creating company systematic tools for controlling supplier risk.

The company's crucial activities for risk mitigation should be recognized and formalized as a system for implementation. This control system should include precise action plans with repeatable activates, procedures, characters, tasks, and measures. On the other hand, these six steps also need an accurate foundation risk management's operating modeling.

In summary, the control phase is all about ensuring the improvement we have implemented will stick to business and continue to deliver real benefit to the business over the longer term. In Luxxeen production, the procurement department started improving the number of delivery days that suppliers have delays in delivering the orders. As the main measure of their process, we used a p-type Control Chart to find out the portion of deliveries which are not delivered on time. The following table and figure demonstrate the Suppliers delay's data and number of delays per days and Control Chart for the month. The percentage delays were further reduced in the next month by extending the contract and agreement to other suppliers.

Day of month	Delivery days	Number Delays (Days)	proportion Delays p	Control Line	LCL	UCL
1	24	2	0.08333333	0.05227785	0.2468367	-0.142281
2	35	0	0	0.05227785	0.2468367	-0.142281
3	27	3	0.11111111	0.05227785	0.2468367	-0.142281
4	23	0	0	0.05227785	0.2468367	-0.142281
5	19	0	0	0.05227785	0.2468367	-0.142281

6	22	3	0.13636364	0.05227785	0.2468367	-0.142281
7	31	1	0.03225806	0.05227785	0.2468367	-0.142281
10	25	0	0	0.05227785	0.2468367	-0.142281
11	22	0	0	0.05227785	0.2468367	-0.142281
12	17	0	0	0.05227785	0.2468367	-0.142281
13	26	5	0.19230769	0.05227785	0.2468367	-0.142281
14	30	4	0.13333333	0.05227785	0.2468367	-0.142281
17	21	0	0	0.05227785	0.2468367	-0.142281
18	35	0	0	0.05227785	0.2468367	-0.142281
19	24	0	0	0.05227785	0.2468367	-0.142281
20	31	3	0.09677419	0.05227785	0.2468367	-0.142281
21	31	3	0.09677419	0.05227785	0.2468367	-0.142281
24	32	4	0.125	0.05227785	0.2468367	-0.142281
25	27	0	0	0.05227785	0.2468367	-0.142281
26	15	0	0	0.05227785	0.2468367	-0.142281
27	31	0	0	0.05227785	0.2468367	-0.142281
28	28	4	0.14285714	0.05227785	0.2468367	-0.142281

Table 27: Suppliers delay's data and number of delays per days

Mean	0.052278
Standard Deviation	0.064853

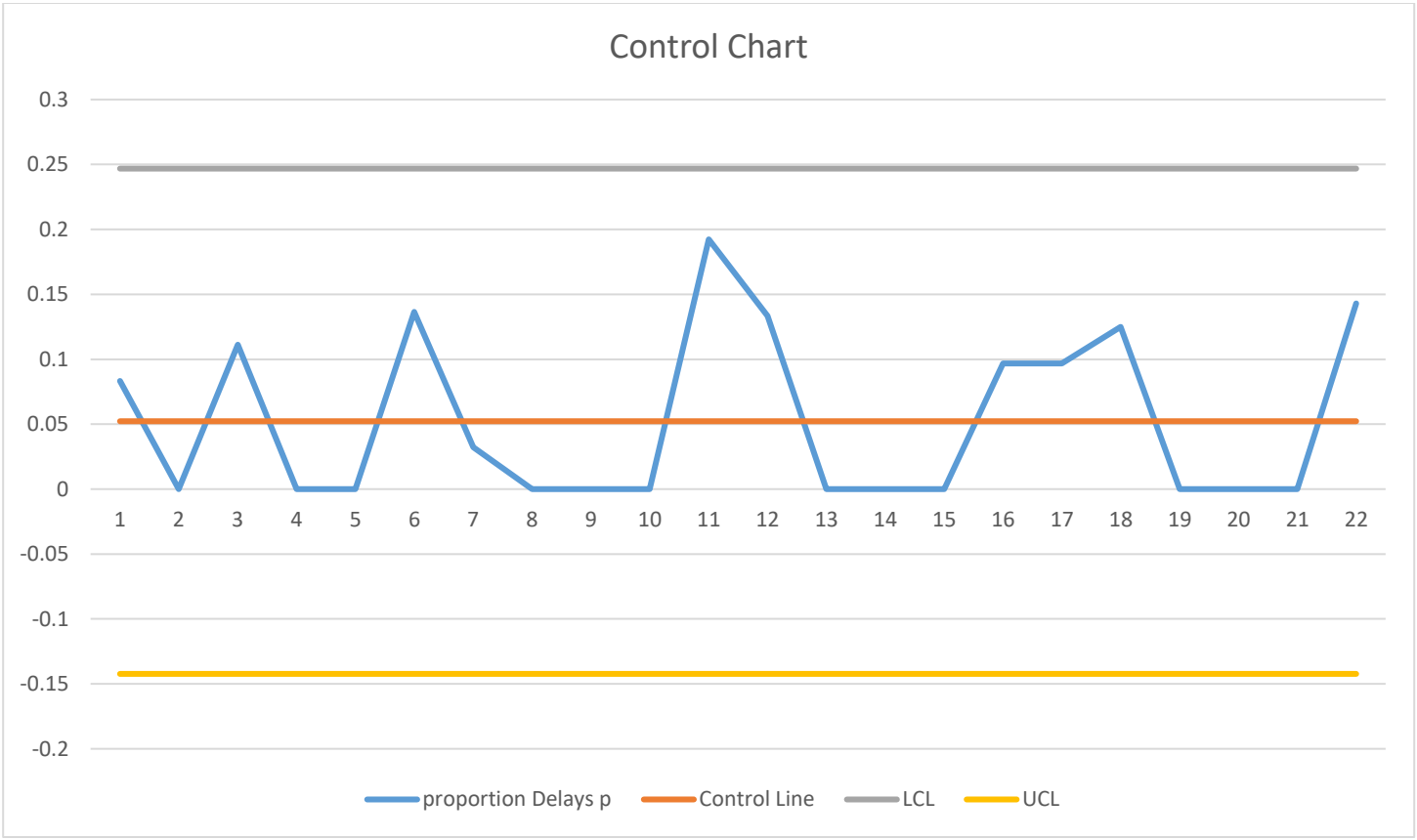


Figure 15: Control Chart for measure the percentage of delayed deliveries

Chapter 5

Supplier Selection based on AHP under disruption situation

Supplier selection and order allocation are two main parameters for reverse logistics and closed-loop supply chain networks, particularly with demand-supply difference risks. If businesses do not consider the potential uncertainties and risks in their supply chain and corresponding suitable actions are not taken to handle them; consequently, irrecoverable damages would be expected. In process of order allocation, four main elements that needs to consider are risk of disruption, demand uncertainties, market price and the volume of the returned products. Procuring from the backup suppliers and spot market needs to be considered to take suitable measures in uncertainties. We also need to investigate the changes in the strategic problem parameters that can distress the sourcing strategies.

`5.1 Multicriteria model

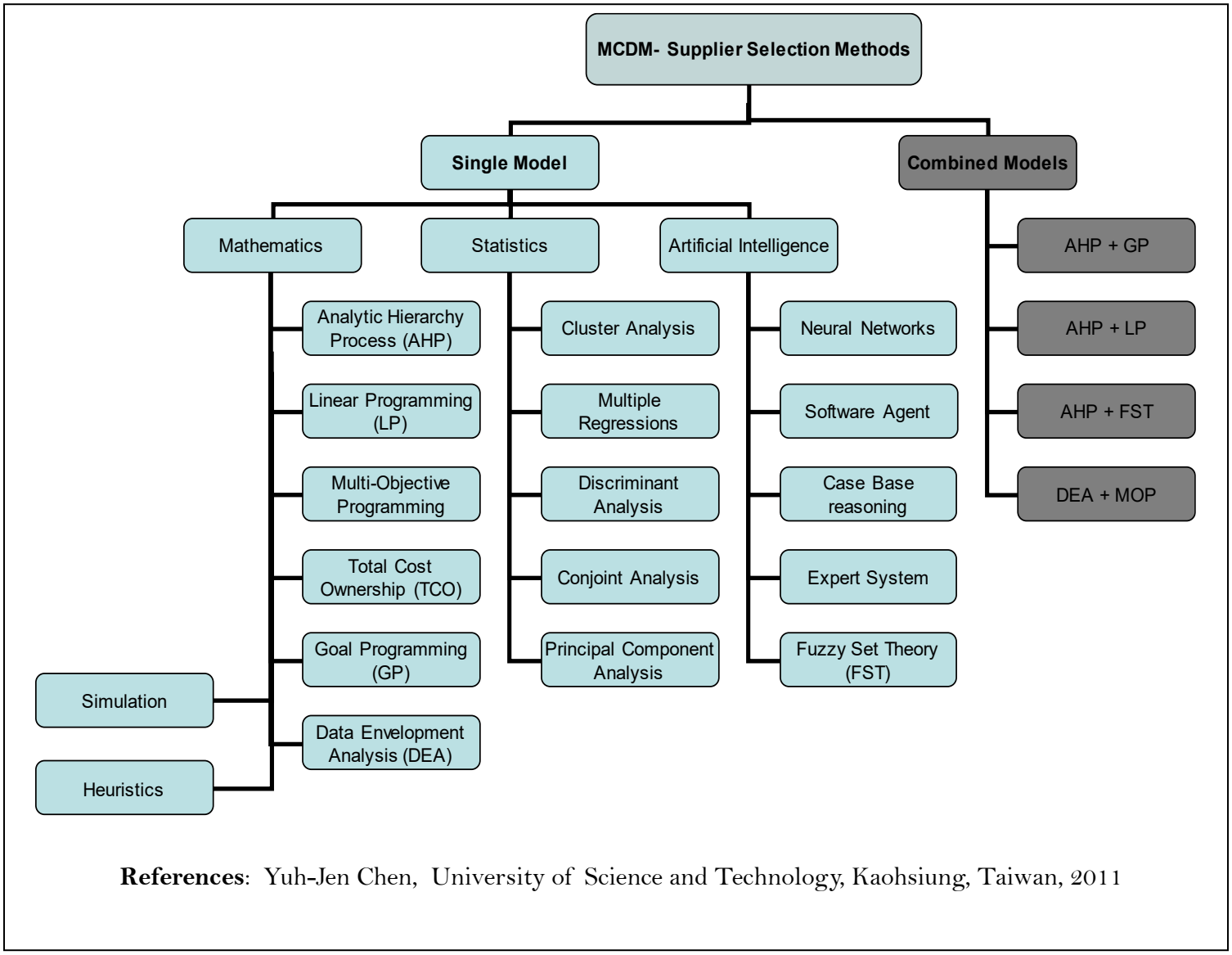
One of the key decision-making problems which many organizations are facing is the order allocation problem. It is a very tactical decision for companies to select supply sources, and it can successfully enable them to reduce their costs and improve profits. In order to answer the supplier assessment and selection problem, there are many studies which mainly used different multicriteria decision-making MCDM methods. In this chapter, we classify and analysis the various MCDM methodologies which is stated in the literature for resolving the supplier assessment and selection process. The presented methods for order allocation and supplier selection have been classified based on single or hybrid methods:

Single models are categories into three parts:

- Mathematics
- Statistics

- Artificial intelligence

Combined models are hybrid approaches combining mathematics, statistics, and artificial intelligence.



References: Yuh-Jen Chen, University of Science and Technology, Kaohsiung, Taiwan, 2011

Figure 16: Different multicriteria decision-making MCDM approaches

5.2 AHP Bases Method for Supplier Selection

Since introducing of Analytic Hierarchy Process by Saaty in 1980, AHP has been a practical and powerful tool to support the management group for multiple criteria decisions making and also researchers.

By considering the previous AHP researches and studies have been published, we can see they mostly are applications of AHP in a variety of fields like; selecting an alternative supplier, allocations of demand or resources, planning, resolution of conflict and as well as optimization. AHP is commonly functional for supplier selection because this method can classify the suppliers according to the relation rank of criteria.

In order to have correspondence data collection for AHP supplier selection model and also to have quantitative and qualitative information that could be practical by Luxxeen manufacturing company a four steps approach was executed to ensure effective implementation as follows:

5.2.1 Step1. Define criteria for supplier selection

Assessment and determination of suppliers is one of the ordinary multiple criteria decision-making problems which includes both qualitative and quantitative criteria. These criteria for design making strongly depending on the nature of considered product or service and also include many critical factors.

The several criteria those are significant for supplier selection in Luxxeen after discussions with 3 main experts, production manager, project managers and a purchasing manager in company are summarized in Figure18. With the intention of select the best and significant criteria, it was planned to accept the criteria that they have average of 7 and more. As a final point, the operational particularly important criteria like price, delivery time, quality, financial, location and management were selected for the level

of 2 out of detected 36 factors in Luxxeen for selection of right suppliers under disruption which the goals factor is in Level 1. Consistent and trustworthy suppliers helps Luxxeen manufacturers to expand product quality and decrease inventory costs. There are some main criteria to select supplier under disruption following as:

1. Delivery
2. Price
4. Service
5. Supply Capacity
6. Quality
7. Purchasing price
8. Flexibility
9. Performance History
10. Warranties and Claim Policies
11. Production Facilities and Capabilities
12. Net Price
13. Technical Capability
14. Financial Position
15. Bidding Procedural Compliance
16. Communication System
17. Status and Situation in Industry
18. Motivation for Business and improvement
19. Administration and Organization
20. Operational Technology and QA
21. Operational Maintenance Service

22. Business Attitude
23. Personation
24. Packaging Quality and Ability
25. Employment Relations History
26. Operation Physical Location
27. Volume of Past Business
28. Training systems
29. Corporation Arrangements
30. Defective parts
31. Collaboration with suppliers
32. Supplier and product designer's teamwork
33. Satisfy customer needs
34. Inventory management
35. Reliability
36. Risk

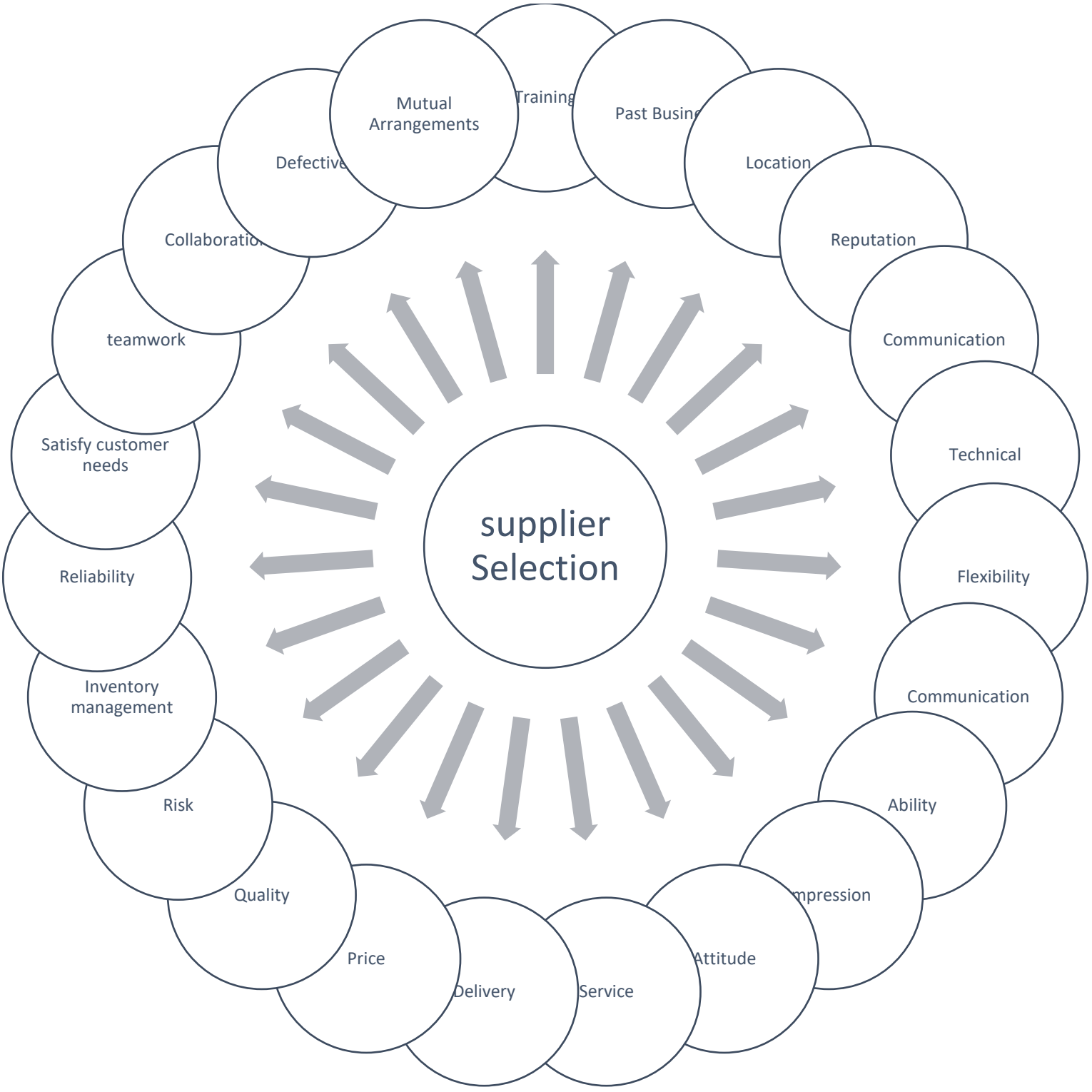


Figure 17: Luxxeen overall criterions for supplier selection

	Production	Project	Purchasing	Average
Cost	9	8	9	8.67
Quality	9	8	8	8.33
Location	6	7	6	6.33
Inventory	9	9	8	8.67
Financial	6	9	8	7.67
Management	5	7	6	6.00
Capacity	7	8	5	6.67
Delivery	8	5	6	6.33
Reliability	9	9	8	8.67
Responsivness	6	5	8	6.33

Figure 18: Different Criteria and their scores for decision-making in Luxxeen

5.2.2 Step 2: Describe sub criteria and sub-criteria of sub-criteria

In this stage, every criteria has higher average of 7 need to be break down to the sub criteria and sub sub-criteria for supplier selection. This stage is based on result of previous step which is five mains important criteria according to average scores of production manager, project manager and purchasing manager.

Structure and identifications of sub criteria and also sub sub-criteria are parallel to the first step with interviewing of managers in order to have a more detailed effected factors to the project. The interview with three related managers helps to find precise sub criteria's.

After receiving the feedback and the respondents form management team, the criteria were recognised which includes ten sub criteria and thirty-six sub sub-criteria for the levels 3 and 4 in supplier selection process.

5.2.3 Construction the hierarchical model

This stage of AHP comprises structure of AHP hierarchy method and also finding the weights for separate levels of supplier selection model. The presented AHP model is according to the recognised criteria and sub criteria and the goal as it shown in following figure for the supplier selection problem. The goal of our case study problem in selecting the right supplier for Luxxeen manufacturing company is defined in the first level. The following level (Level 2) consist; cost, quality, inventory, financial situation of supplier and reliability. The two next level of hierarchy which are third and fourth level comprise 32 sub criteria and sub sub-criteria which were recognized in previous stage.

The last level of the hierarchy consists of the different supplier that they need to be assessed in order to choose the most suitable supplier. The presented AHP model shown in following is largely applicable for the supplier selection problem of any other similar company and it can be use as a tool for supplier selection for any team that they wish to assess their suppliers based one defined criteria and sub sub-criteria.

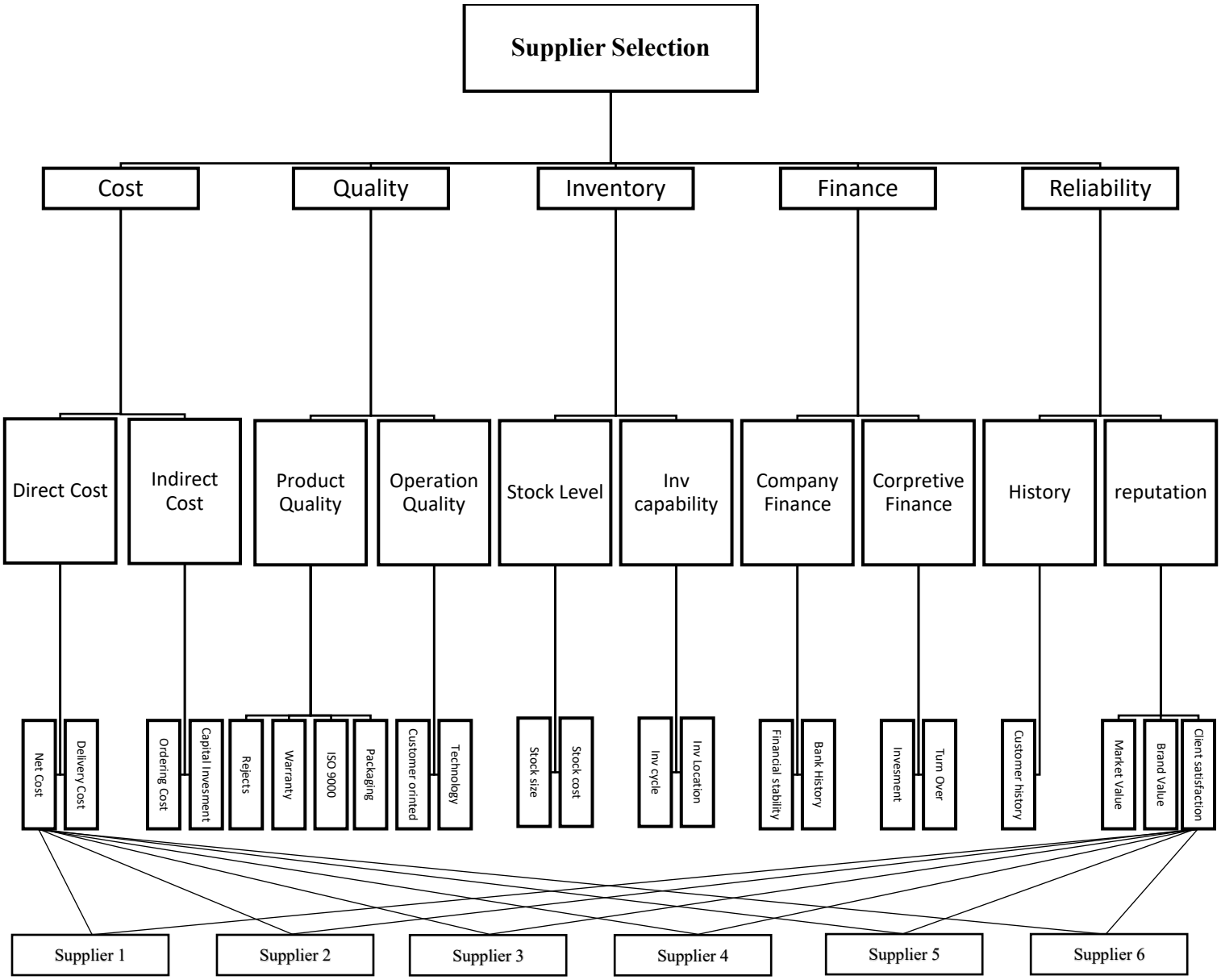


Figure 19: descriptive decision hierarchy for Luxxeen supplier selection

After construction of the practical hierarchy, the decision maker group can analytically evaluate the alternatives by creating the pair-wise comparisons for every proposed criteria. After creating all comparisons of criteria and also calculating the relation weights between every single criteria then, the numerical possibility of each alternative needs to be calculated. In order alternative have higher chance to

satisfy the goal, it needs to have higher probability. The goal of our problem is selecting the right supplier which is described in the first level.

The main reason of the pair-wise comparisons is to be recognising and classifying the relation and rank of the criteria and sub criteria. For this stage we are using the nine-point rank which is proposed by Saaty (1980). The level of importance is equal, moderate, strong, very strong and extreme which is presented by 1, 3, 5, 7, and 9, correspondingly and the intermediate values are represented by 2, 4, 6, and 8.

Measure	**Numerical Ranking**	**Reciprocal**
Extremely	9	1/9
Very Strong to Extremely	8	1/8
Very Strongly	7	1/7
Strongly to Very Strongly	6	1/6
Strongly	5	1/5
Moderately to Strongly	4	1/4
Moderately	3	1/3
Equality to Moderately	2	1/2
Equally	1	1

Table 27: The Saaty rating scale for criteria relations

The presented pair-wise comparison matrix demonstrates that relation of the fifth row and the fifth column shows the importance of that row's criterion comparative to the column's criterion as follow.

Supplier Selection	Cost	Quality	Inventory	Finance	Reliability
Cost	1	1	1/2	4	2
Quality	1	1	1/3	2	2
Inventory	2	3	1	5	5
Finance	1/4	1/2	1/5	1	1/3
Reliability	1/2	1/2	1/5	3	1

Table 28: The pair-wise comparison matrix

After finding the pair-wise ranks as in Table 28, the next phase is the calculation of a direction of importance or weighting of criteria in the matrix. In this regard we need to calculate the principal vector of the matrix through accumulation of the associates of each column toward finding the total. In the next step, we need to normalize each column to sum of 1.0 or either 100 percent and finally, adding the factors of each row and calculating the average.

Criteria	Cost	Quality	Inventory	Finance	Reliability	Row Total	Average
Cost	0.21	0.17	0.22	0.27	0.19	1.06	0.3539
Quality	0.21	0.17	0.15	0.13	0.19	0.85	0.1704
Inventory	0.42	0.50	0.45	0.33	0.48	2.19	0.4374
Finance	0.05	0.08	0.09	0.07	0.03	0.32	0.0649
Reliability	0.11	0.08	0.09	0.20	0.10	0.58	0.1150
Total	1	1	1	1	1		

Table 29: Standardized matrix of paired comparisons

In order to make sure about the judgments are consistent for the scoring, Saaty suggested Consistency Ratio. CR is an evaluation between Consistency Index and Random Consistency Index (RI)

CR = CI / RI.

As long as the rate of Consistency Ratio is smaller or equal to 10%, then the inconsistency is acceptable.

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 30: Random Consistency Index (RI) values

Supplier Selection	Cost	Quality	Inventory	Finance	Reliability	Weight	Eigen vector (λ)
Cost	1	1	1/2	4	2	0.2123	0.3337
Quality	1	1	1/3	2	2	0.1704	0.1704
Inventory	2	3	1	5	5	0.4374	0.4374
Finance	1/4	1/2	1/5	1	1/3	0.0649	0.0649
Reliability	1/2	1/2	1/5	3	1	0.1150	0.1150
Sum	4.75	6	2.23	15	10.33		

Table 31: Overall Preference Matrix

$$\lambda 1 = \frac{\left[(1 * 0.2123) + (1 * 0.1704) + \left(\frac{1}{2} * 0.4374\right) + (4 * 0.0649) + (2 * 0.1150)\right]}{0.2123} = 5.13$$

Similarly

$$\lambda 2 = \frac{\left[(1 * 0.2123) + (1 * 0.1704) + \left(\frac{1}{3} * 0.4374\right) + (2 * 0.0649) + (2 * 0.1150)\right]}{0.1704} = 5.20$$

$$\lambda 3 = \frac{[(2 * 0.2123) + (3 * 0.1704) + (1 * 0.4374) + (5 * 0.0649) + (5 * 0.1150)]}{0.4374} = 5.19$$

$$\lambda 4 = \frac{\left[\left(\frac{1}{4} * 0.2123\right) + \left(\frac{1}{2} * 0.1704\right) + \left(\frac{1}{5} * 0.4374\right) + (1 * 0.0649) + \left(\frac{1}{3} * 0.1150\right)\right]}{0.0649} = 5.07$$

$$\lambda 5 = \frac{\left[\left(\frac{1}{2} * 0.2123\right) + \left(\frac{1}{2} * 0.1704\right) + \left(\frac{1}{5} * 0.4374\right) + (3 * 0.0649) + (1 * 0.1150)\right]}{0.1150} = 5.12$$

λmax (Maximum eigen value) $= \frac{\lambda 1 + \lambda 2 + \lambda 3 + \lambda 4 + \lambda 5}{5} = 5.145$

CI (Consistency Index)$= \frac{\lambda max}{n-1}$

$= \frac{5.145-5}{5-1} = 0.0362$

Consistency Ratio (C.R.) = CI /RI = 0.0362/1.12 = 0.323

Normally CR higher than 0.9 means that the pair wise decisions are mostly random based and they are not completely reliable.

Supplier Selection	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Weight	Eigen vector (λ)
Supplier A	1	2	2	3	2	0.33	0.5210
Supplier B	1/2	1	1/3	1	2	0.14	0.1360
Supplier C	1/2	3	1	3	5	0.32	0.3211
Supplier D	1/3	1	1/3	1	2	0.12	0.1239
Supplier E	1/2	1/2	1/5	1/2	1	0.09	0.0875
Sum	2.83	7.5	3.86	8.5	12		

Table 32: Cost Comparison Matrix

λmax = 5.254

CI = 5.254 – 5 / 5-1 = 0.0635

CR = 0.0635 / 1.12 = 0.0567

Supplier Selection	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Weight	Eigen vector (λ)
Supplier A	1	1	2	2	1	0.24	0.3738
Supplier B	1	1	2	½	1/3	0.17	0.1704
Supplier C	1/2	½	1	2	3	0.21	0.2133
Supplier D	½	2	½	1	3	0.20	0.2018
Supplier E	1	3	1/3	1/3	1	0.18	0.1767
Sum	4	7.5	5.83	5.83	8.33		

Table 33: Quality Comparison Matrix

λmax = 6.112

CI = 6.112 – 5 / 5-1 = 0.278

CR = 0.278 / 1.12 = 0.248

Supplier Selection	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Weight	Eigen vector (λ)
Supplier A	1	2	1	4	1	0.26	0.4013
Supplier B	½	1	¼	½	1/3	0.08	0.0778
Supplier C	1	4	1	5	5	0.38	0.3846
Supplier D	¼	2	1/5	1	3	0.14	0.1383
Supplier E	1	3	1/5	1/3	1	0.14	0.1439
Sum	3.75	12	2.65	10.83	10.33		

Table 34: Inventory Comparison Matrix

λmax = 5.775

CI = 5.775 – 5 / 5-1 = 0.193

CR = 0.193 / 1.12 = 0.173

Supplier Selection	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Weight	Eigen vector (λ)
Supplier A	1	1/3	½	2	½	0.10	0.1574
Supplier B	3	1	2	1	4	0.33	0.3267
Supplier C	4	½	1	3	4	0.30	0.2975
Supplier D	½	1	1/3	1	¼	0.12	0.1150
Supplier E	2	½	1/4	4	1	0.16	0.1606
Sum	10.5	3.08	3.83	11	9.75		

Table 35: Finance Comparison Matrix

λmax = 5.950

CI = 5.950 – 5 / 5-1 = 0.237

CR = 0.237 / 1.12 = 0.212

Supplier Selection	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Weight	Eigen vector (λ)
Supplier A	1	4	3	2	1	0.32	0.5062

Supplier B	¼	1	1/3	1	¼	0.09	0.0885
Supplier C	1/3	3	1	½	4	0.21	0.2052
Supplier D	½	1	2	1	3	0.21	0.2149
Supplier E	1	4	1/4	1/3	1	0.17	0.1694
Sum	10.5	3.08	3.83	11	9.75		

Table 36: Reliability Comparison Matrix

λmax = 6.047

CI = 6.047 – 5 / 5-1 = 0.261

CR = 0.261 / 1.12 = 0.233

Supplier	Cost	Quality	Inventory	Finance	Reliability
Supplier A	0.5210	0.3738	0.4013	0.1574	0.5062
Supplier B	0.1360	0.1704	0.0778	0.3267	0.0885
Supplier C	0.3211	0.2133	0.3846	0.2975	0.2052
Supplier D	0.1239	0.2018	0.1383	0.1150	0.2149
Supplier E	0.0875	0.1767	0.1439	0.1606	0.1694

Table 37: Option Performance Matrix for suppliers

The table 37 shows that supplier A is in better than others in terms of cost, quality, timeliness and trust while supplier B has better financial position.

Total weight of Supplier A:

$$(0.212 * 0.521) + (0.170 * 0.373) + (0.437 * 0.401) + (0.064 * 0.157) + (0.115 * 0.506) = 0.418261$$

Total weight of Supplier B = 0.123319

Total weight of Supplier C = 0.315646

Total weight of Supplier D = 0.153360

Total weight of Supplier E = 0.141532

No.	Supplier	Priorities	Rank
1	A	0.4182	I
2	B	0.1233	IV
3	C	0.3156	II
4	D	0.1533	III
5	E	0.1415	V

Table 38: Option Performance Matrix for suppliers

Chapter 6

Conclusions and Future Work

The accurate and reliable selection of suppliers and allocation of demand among the selected suppliers is a critical issue for any buying firm. This issue becomes even more problematic when suppliers need to consider the possibility of disruptions and type of disruption for any individual suppliers that are exposed to the risks of failure due to disruptive events. This study consists of developing an analytical model and solution procedure for regulating the optimal relation and contract with suppliers and necessary requirement of supplier under the risks of supply disruption. This study considered different capacities, compensation possibilities, and disruption possibility for each supplier. The probability of loss costs due to the supplier(s) disruption is clearly considered in the model. The mixture of DMAIC and AHP methodology together has made the study more realistic, specially with the case study that we have in but, at the same time, more complex to solve.

The main objective of this thesis is to design and develop a framework based on Six sigma DMAIC method for supplier risks assessment and study about the supplier ability and type of contract in disruption situations and selecting suppliers and demand allocation under disruption risks. In this study we precisely study and addressed following problems. First, conduct a literature review on supply chain risks including supply, demand, price, network disruption and so on in order to find out the research gaps. Second, model for supplier risks assessment bases on six sigma DIMAIC approach is presented with considering disruption situations. Third, multicriteria AHP based models for supplier selection under disruption risks is discussed and also as a validation and verification of the methodology a case study with Luxxeen Inc. is conducted.

In chapter 3, DMIAC based approach for supplier risk assessment is presented. The proposed model approach entirely relies on supplier ability and performance. The novelty of the presented method against other researches is primarily finding and explaining the supplier behaviour and their ability and collaboration level with related effects in disruption situation rather than improving the cost or time in supply chain.

The presented DMAIC approach comprises modeling of a supplier performance in manufacturing enterprises and also supplier selection based on AHP model for the enterprises that are expose to high or low levels of disruption in supply chain. The proposed model is a detailed approach and novel with considering the large set of effective parameters and manufacturing attributes in manufacturing and operational environment. The consider parameters includes: materials flow, storage condition, transportation conditions, operation and supply china environment, manufacturing methods, business regulations, employee, import and export condition and machinery capacity aw well as related cost constraints such as transportation costs, manufacturing and operational cost, maintenance cost, location, supplier size, type of contact, shipping method and Leadtime.

Several techniques in each step of DMAIC approach such as project charter, cost of delay, voice of customer, critical to quality, SIPOC, pareto chart, measurement system analysis, sigma level, root cause analysis, regression analysis and so on have been considered on the process of handling the supply chain disruption in supply chain condition of proposed approach.

Also, to determine the practicality and feasibility of the proposed method at the model design and operational levels, a case study with collaboration of Luxxeen Production and considering of real data in operation environment has been conducted to demonstrate the effects of the supplier contract type as well as stocking agreement effects on supply chain performance in disruption situation. The outcomes and

effects of stocking agreement with suppliers on the objective function value and reliability of suppliers has been investigated.

The supplier selection model based on AHP under disruption conditions in Chapter 5 proposes an integrated method towards the utilization of optimize strategy and supplier selection in manufacturing companies as a part of handling supply chain disruption strategy in order to make manufacturing organisations more sustainable.

The proposed AHP model for supplier selection offers a framework to have a productive decision in multiplex decision environments. AHP consider both qualitative and quantitative parameters for decision making and the advantage of AHP method is breakdown of complex situations in to a simple mechanism. The novelty of the chapter 5 which is supplier selection with AHP technique lies in the hybrid approach application in a real manufacturing case study where the output of supplier risk analysis is applied as a supplement for multi criteria supplier selection analysis. Considering the real case study on this research, concludes that the combining DIMAIC and AHP as a hybrid method has better and more reliable performance compare with other methods for supplier selection with consideration of disruption conditions.

6.1 Future Research

The suggested future research for this study can be classified as follows:

A. This research assumes that the buyer's has a pre-qualified suppliers and deterministic demand quantity, in the future, consideration of stochastic demand and assessment of other potential supplier outside of prequalified list will be an interesting extension of the proposed model.
B. The DIMAC approach model in Chapter 4 can be used as one of the key elements of enterprises in order to improve the management process which primary needs to focuses on improving global

management performance instead of considering only disruption situations, so the correlation of disruption condition with lean manufacturing can be considered for the future versions of this thesis.

C. Six Sigma technically works on current situation of processes and does not allow for the considering of a new tools or methods and from other side Six Sigma normally needs a complete dedication across all enterprise groups which makes it difficult to employ other process methodologies, so combination of DMAIC with Agile Methodology can be the guidelines for the future studies.

D. Design and development of comprehensive system similar to ERP (Enterprise Recourse Planning) for supply chain like Enterprise Supply Chain Planning is recommended for future works.

E. Additional future direction to this study can involve extending the proposed model for multi-product and multi-period under disruption and in normal condition settings.

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