Analysis and recommendations to improve the Request for Quotation process

The analysis for possibilities to improve the quotation process at Gits Mfg. Co., a CentroMotion company

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Bachelor Thesis

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"If you always do what you've always done, you'll always get what you've always got."

– Henry Ford

"Growth and improvement is about acknowledging weakness."

– Tony Frontier

ABSTRACT,

The purpose of this research is to find out if and how the RFQ process at Gits Mfg. Co. can be improved, by analysing previously executed quotation process. The current problem with the RFQ process at Gits Mfg. Co is that the lead time of the process is too long, on average. For competitive and internal strategical advantages the process is subject to improvement by eliminating waste in the process. These processes are manually worked on by employees of multiple departments, making these quotation processes multidisciplinary. Currently the process has an average Lead Time of 794.426 working hours, which is too long for the company. The data analysed is collected out of 16 executed quotation processes. From these collected data, calculation regarding averages and standard deviations were made to give a general overview of Lead Times for the different steps executed in the quotation process. The findings are based on completion dates of deliverables in the process and are not available in this document regarding confidentiality. To support the findings in this research, as well as the conclusion and the recommendations, literature research was conducted and references are listed. The improvement is realised by reducing time waste in the overall process, by also taking a closer look at the Lead Time of individual deliverables, specific solutions can be implemented at different locations in the total process. The company can improve their RFQ process by implementing the recommendations stated in chapter 5.2 of this report. In Chapter 6 the conclusion is stated that the company can improve their process by 148,5 – 247,6 working hours.

Keywords,

RFQ, quotation process, lean management, time waste, NPD processes, process improvement, process analysis.

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Preface

Dear reader,

This thesis is written to complete my bachelor thesis regarding Industrial Engineering and Management, part of the faculty of Behavioural, Management and Social Sciences at the University of Twente. During the time I worked on this thesis, I had the privilege of working at Gits Mfg. Co. (Gits Manufacturing Company), located in Oldenzaal and Urbandale, Iowa, USA. Here I learned a lot about the process of quotation, the subject on which this thesis is based. I want to mention that it is essential and without help of the people at Gits Mfg. Co. it would not have been possible for me to finish this thesis sufficiently. Without their input of time, effort and expertise to support me while executing my research. I had a huge amount of freedom at the company to execute my research as I saw fit. Special thanks go out to Global Product Line Director Bart Kroeze and Global Sales Director Dennis van den Noort, who both helped and guided me in my research. Furthermore, I would like to thank Dr. Lin Xie from the University of Twente, who assisted and guided me through my research and gave proper feedback during the writing of this paper.

Finally, I would like to thank my family and friends for their support and interest in my research.

Colin Smit

List of Abbreviations

EBV:	Exhaust Brake/Backpressure Valves
EGR:	Exhaust Gas Recirculation
OEM:	Original Equipment Manufacturer
COE:	Centre Of Excellence.
QMS:	Quality Management Systems
ERP:	Enterprise Resource Planning
LOI:	Letter Of Intent
Project Charter:	A document in which the major details of the project are listed.
PFMEA:	Potential Failure Mode and Effect Analysis
Customer PO:	Customer Purchase Order
MOQ:	Minimum Order Quantities
RFQ:	Request For Quotation
RFI:	Request For Information
QD-174:	A financial document to make financial calculations for the project.
PM-07:	Program Management document 07. A quality document to ensure that program management can keep track of progress. This document also provides an overview of which tasks are executed by which department, who is supportive of which tasks and who approves the different tasks/steps in the process.
LT:	Lead Time
QG:	Quality Gate
BOM:	Bill Of Materials
DV Plan:	Design and Validation Plan
PLM:	Product Line Management
NPD:	New Product Development
Gits Mfg. Co.:	Gits Manufacturing Company, also referred to as ‘the company’.
VSM:	Value Stream Map. Lean Management tool to schematically show value and non-value adding times for the steps of a process.

St. Dev.:	Standard Deviation. The expected difference of the difference between a random variable and its mean.
Avg.:	Average
NVA:	Non-Value-Adding
VA:	Value-Adding
Specs:	Specifications
SBU:	Strategic Business Unit
CFD:	Concurrent Function Deployment
CI:	Continuous Improvement

Executive Summary

Company and problem introduction

The company at which this research has been executed is Gits Mfg. Co., a company located with their COE (Centre Of Excellence) in Urbandale, Iowa, US and partly in Oldenzaal. The company focuses on EBV (Exhaust Backpressure/Brake Valve) and EGR (Exhaust Gas Recirculation) valves for medium to heavy-duty commercial vehicles. Currently, their RFQ (Request For Quotation) process takes too long and the problem stated was to gain insight and a recommendation on how to improve/optimize the current RFQ process. The problem was first stated since the company expects more RFQs in the coming time, due to European Emissions Regulation Laws. All major OEMs (Original Equipment Manufacturers) of commercial vehicles need to design a new engine that meets these new regulations. The valves that Gits Mfg. Co. produces help with the thermal management and emission regulation of these newly developed engines.

Analysis

To analyse the time waste or the NVA (Non-Value-Adding) time of the process, historical data was analysed. In this data, the store dates of deliverables are used. Because the process is fully executed manually and no automation is present, the data of the RFQ processes was unknowingly generated by various employees. Employees will not be connected to specific data, since anonymousness is of high importance.

Between the moment the RFQ is received and the RFQ is answered by the company, a lot of deliverables are provided to eventually calculate the costs and the associated price of the product. Products get designed to customer specifications and therefore the products are slightly different for each customer. To lower the risk of giving a price for a product that eventually deviates from the actual price needed for the product, all deliverables are completely executed in detail. Based on all these deliverables, the lead time of the process is subject to the execution effectiveness of these deliverables, taking into account the NVA time as well as the VA (Value-Adding) time. The most interesting is the NVA time for each of the deliverables and of the entire process, since this is subject to improvement and the VA time for the deliverables is out of the scope of this research. The VA times merely provide insight into the efficiency of the execution of the entire process, given in percentages.

Table 1: Overview of NVA time in the quotation process

Stage	Deliverable	NVA time
Quality Gate 1	Project Set Up	7.6 Hours
	Customer Requirements	273.6 Hours
	Bid/No-Bid	70.9 Hours
	Project Charter	206.9 Hours
	Gate Certificate Sign-Off	160.2 Hours
Quality Gate 2	Project Set Up	-
	Action Item List	227 Hours
	Project Schedule(s) - Optional	364.8 hours
	Develop Delta Requirements	248.3 Hours
	Concept Design/Tech. Risk	34.4 Hours
	Design Plan	-119.6 Hours

	Process Flow Chart	223.2 Hours
	Packaging	46.0 Hours
	DV Plan	46.0 Hours
	Supplier Launch Plan	-159.1 Hours
	Project Calculation	194.7 Hours
	4-Block	-
	Gate Certificate Sign-Off	-
Quality Gate 3	Quotation	-117.0 Hours
	Warranty Agreement	
	Negotiation	
	Nomination P.O.	
	Project Calculation Update	
	4-Block	
	Lessons Learned	
	Gate Certificate Sign-Off	

The red text is part of the third quality gate but is out of scope for this research. The quotation process is merely the development of the price that gets sent to the potential customer. To gain insight, and to calculate VA and NVA times, the lead time of the entire process and the individual deliverables is calculated. For each of the deliverables, average, standard deviation, VA time and NVA time were calculated. The VA times were collected from the QD-174, and with these times the NVA was calculated.

The ratio VA time against NVA time is about $3:8$. 37,66% VA time and 62,34% NVA time, both compared against 794.426 total working hours per quotation process on average. Total NVA time and VA time are about 495.3 and 299.2 hours per quotation process, on average, respectively.

Recommendations

- Implementation of Lean (Six) Sigma, to decrease time waste between different deliverables and to improve the throughput times, making those lower.
- Better monitor the workload of the employees regarding the capacity that is present to work on quotations.
- The idea of management not knowing where a process currently is, is even further confirmed by the lead times and the NVA time of the Project Charter. A document that has to be signed off by the management team to agree to invest resources in the project.
- To continue on the execution of the project and being guided towards a good outcome, the projects also benefit from execution that is standardized. The way of working should be consistent all the time, with the same values, same structure, same process and systems
- Regarding communication, more communication should be implemented at the company. This is necessary to implement pull in the system.
- Reduction in variation, work and capacity management and continuous improvement can decrease development times by 30-50%. This would, on average, mean a reduction of NVA times by 148,5-247,6 hours (or 18,56-30,95 working days)

- The execution of the entire process gives a low-risk outcome to the probability of giving a price that eventually deviates from the actual price. To prevent resources from being invested and to gain a target price for a product under development, a ballpark quote is a solution.
- Implementation of AI can help improve communication within the organisation. The implementation of AI or digitalized kanbans saves the employees from sending the kanbans towards other employees.

1 Introduction and Methodology

This chapter provides a global introduction to the company providing the bachelor assignment as well as an overview of the different steps of the research, research questions and the possible problem solving approaches.

1.1 Company Introduction

Gits Mfg. Co. has engineered an innovative line for commercial vehicles regarding thermal management solutions for engines. With Gits Mfg. Co. part of the CentroMotion Transportation Segment. The Gits Mfg. Co. Centre of Excellence is in Urbandale, Iowa, United States, and a part of the company is located in Oldenzaal, The Netherlands. The brand serves our global customers around the world from different manufacturing locations: China, India, Mexico, The Netherlands and the United States. The industries and applications include:

- On & Off-highway – Thermal Management and Emission Control Valves for commercial vehicles, work trucks, buses, construction, mining and agricultural vehicles.
- Marine – Thermal management and control valves for marine engines.

In 2050 all of the emissions have to be reduced to 0 g CO_2/km. In combination with the development of the euro 7 engines, which will be launched from 1st of July 2025. Since all major Original Equipment Manufacturers (OEMs) will have to develop new engines that meet the regulations, the request for quotations (RFQs) will be increasing as well. From this product line, other RFQs for similar products are submitted by our global customers. For Gits Mfg. Co. it is important to obtain as many customer requests, whereas for the customer a timely receipt of the commercial proposal is necessary. Receiving as many requests as possible is important for Lone Star Private Equity Funds since they bought the company and want to add value to it to be able to sell it with profit. If the company receives more RFQs and can complete RFQs faster, it is adding value to the company.

The current RFQ process contains multiple steps and actions by different departments of the company. This process is fixed and connected to automotive standards and requirements of the IATF. The execution of the process can be time-consuming, where sometimes time is not available and potential increased risk occurs by not having the possibility to assess all documents and execute all steps in full.

In the assignment, the exploration of the current RFQ process, specifically for the Thermal Management Product Line is the major topic. From this exploration, areas to improve will be identified where speed is related to risks. The shorter the time, the higher the risk. Possible deliverables are process maps, critical paths for each of the risk classifications, recommendations and a plan for improvements.

1.2 Action Problem and Problem Cluster

The company, Gits Mfg. Co. is aiming for a quicker and more reliable process to send quotes to their customers. There is a process in place with a fully documented and completely calculated, to reduce risks, quotation for a (newly developed) product, but the timelines and quality are very different between them. It is the assignment to explore the current request for quotation (RFQ) process, in special for the Thermal

Management Product Line. From this exploration, areas to improve will be identified. The shorter the time (steps need to be skipped), the higher the risk (when not all steps are executed in full).

For example: If a customer wants a validated product, then certain steps in the RFQ process possibly can be skipped and the process is finished earlier, without the increased risk of giving a wrong price on a quote. But if a product is not validated, or of high-risk classification, and steps in the process are skipped then the chances of giving a price that deviates from the eventual actual price, with calculation of costs and profits etc., will be increased. So, the risk of giving a price in which you deviate from the price you would give when following all the steps becomes bigger.

To define a possible action problem, let’s introduce the following table with variables:

Table 2: Action Problem Case Specifics

Variable	***Norm***	***Reality***	***Problem Owner***
RFQ Lead Time	*X* amount of time	*Y* amount of time	Gits Mfg. Co.

The action problem can be defined in detail as:

The RFQ process lead time should be reduced, from *Y* amount of time to *X* amount of time, for the RFQ process at Gits Mfg. Co. The reduction is not yet determined, because it depends on the unknown values of *X* and *Y*. The moment de values of *X* and *Y* become known, then the reduction can be determined with the following formula:

$$\frac{(X - Y)}{Y} * 100\% = Z\%$$

Equation 1: Formula to calculate Z%

The value of *Z*, in time, is the amount of time the process can be improved. The *Z* is based on the overall execution of the process and has to be realised by eliminating time waste, NVA time. *Z%* is calculated compared to the LT of the current state of the process, defined in hours. Z% therefore gives amount of time, in percentage, that the process could be improved compared against the current LT of the process.

The value of *X* will be determined by the company. If a potential customer wants a full quote within 1 month, and the company has a process to get quotes to the customer within 6 weeks, then the company is still too late. So, therefore, the company can provide a LT for the process depending on the risk classification. The value of *Y* will be determined by analysing completed RFQ processes. This will be done by evaluating the start and end date of the processes, as well as lead times towards certain milestones. The main problem is stated by the company that is providing the bachelor assignment, which is the lead time of the quotation process. To identify the core problem, which needs solving, a problem cluster can be of use. The detailed problem cluster can be found in Appendix A: Detailed Problem Cluster, since adding it here would make things indistinguishable and it would not be readable. A simple version of the problem cluster can be found in Figure 1: Problem Cluster. To understand the problem cluster, it must be clear that the arrows point in the direction of the main problem that needs solving, the action/main problem. The core problems can be identified by following the arrows downstream since the arrows show what is affected by a certain problem.

The problems in the problem cluster were found by talking to multiple employees spread over different departments of the company, these were not interviews but merely hallway conversations. The department where the employees are stationed all work with the QD-174 and the PM-07 quality documents, the main documents in the RFQ process. These documents are used in the product development and the project calculations for the company. Unfortunately, these documents are not distributable and therefore cannot be shared with the University of Twente without the consent of Gits Mfg. Co.

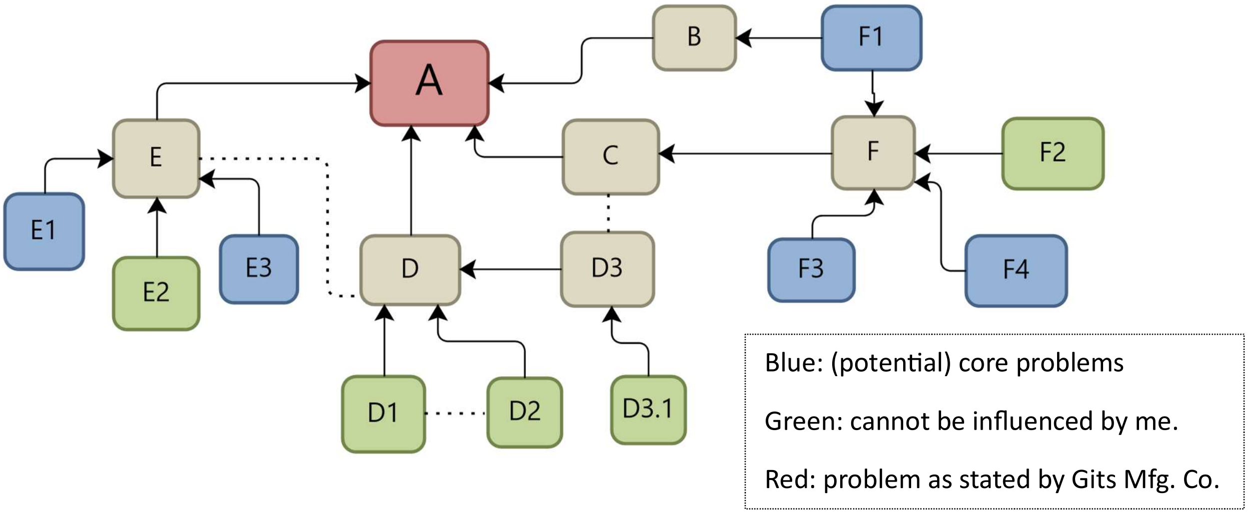


Figure 1: Problem Cluster

The letters represent the following problems:

A. Lead Time for the Quotation Process is too large.
B. An overview of all running quotations, and their status, is missing.
C. They execute the same task that was already executed.
D. The workload is too high to finish all tasks on time.
    1. Too few employees.
    2. Employees are not properly trained.
    3. Executing steps that eventually lead to nothing.
        1. Not clear if a possible project from a customer is interesting for the company.
E. Completing steps/tasks takes longer than anticipated.
    1. Unclear if the current project is “Alien”, “Major”, “Minor” or “Same As” and which complies with those risks.
    2. Information from suppliers takes a long to collect (external problem).
    3. Too many big tasks, which are a lot of smaller tasks.
F. A lot of people don’t trust the document, QD-174.
    1. Communication is not going smoothly; e-mail is not optimal.
    2. Excel documents are too complicated and need more clarification.
    3. Too many people work on the same document.
    4. Tasks, responsibilities and entitlements are unclear.

To find some core problems to solve we follow the arrows in the opposite direction, so possible core problems are: E2, D1, D2, D3.1, G1, G3, G4. This are quite a lot of core problems that can be solved to improve our main/action problem.

The dotted lines between problems, D & E, D1 & D2, C & D3, indicate a certain relationship between these problems. For D & E, if the workload is too high, then there is too much work for people to execute which automatically results in tasks that must be put on hold for a large amount of time because there is simply no time to immediately execute those. D is not a direct subproblem of E, but it does affect problem E. There is a positive correlation between D & E, if D increases then E increases as well. For D1 & D2, the correlation is negative. If employees are better trained, you would need fewer employees to execute the same number of tasks and if employees are less trained then you would need more employees to execute the same number of tasks. The productivity of the employees depends on the amount of training (and the quality of the training) they have had.

For C & D3, there is some overlap in the problem, since executing tasks that were already executed, don't add value to the process. Therefore, a part of subproblem C is also implemented in subproblem D3.

1.3 Problem-Solving Framework

The problem-solving approach is based on the MPSM (Managerial Problem-Solving Method), in which 7 phases are defined. According to Heerkens and Winden (2017), the phases are:

1) Defining the problem
2) Formulating the approach
3) Analysing the problem
4) Formulating (alternative) solutions
5) Choosing a solution
6) Implementing the solution
7) Evaluating the solution

Figure 2: Problem Solving Method Flowchart according to Heerkens, H. met Winden, A. van (2017). Solving

The steps described in the next section, Research , are based on the phases of the MPSM. Every phase of the MPSM has a specific aim to add to the method.

1.4 Research Design and Research Questions

1.4.1 Research Design

In phase 1, the problem is defined. Which means that we search for problems in separate ways. Interviews must be conducted, literature must be reviewed, observations must be made, and primary sources must be analysed. After this has been done a problem cluster can be constructed, in which all cause-and-effect relationships are visualized (the problem cluster can be found in Appendix A: Detailed Problem Cluster). When selecting the core problems in the cluster it is important to; leave out what is not known, leave out what can't be influenced (external factors and internal factors, like management choices) and take the most relevant of the remaining candidates. The action problem definition also must be stated, in which the gap between norm and reality is expressed in a variable, and the problem owner must be included as well. In this research, the action problem was stated by the company.

In phase 2, the problem-solving approach is described. The aim is to clarify the approach for the research. In which a Do, Discover and Decide is worked out to give an overview of steps. In Do, the step we are in now is designed to give an overview of everything that must be done to eventually conduct proper research. In Discover, we describe what information we need to gather to have all the knowledge necessary to execute the research. In this step, we also implement the research cycle, since we have a knowledge problem of not knowing something. A possible result is a list of research questions, we need answered to eventually answer the main research question. In Decide we select the key areas the research focuses on.

In phase 3, the problem analysis, we look for the details of the problems. We try to locate the bottlenecks, review our problem cluster and apply descriptive analysis (variables and research population). A process flow map can help give a clear overview, Bizagi modeller can be used. Bizagi Modeller is a software tool that allows you to create e.g., process flow charts. In phase 3 we also search for potential causes of the problem. We can find these by executing an explanatory analysis (variables, relationships and research population). The difference with the problem cluster is that we now look for variables and their relation, not the problems themselves, and possibly map it in a research model. The relationship in the explanatory analysis can be either qualitative (e.g., nominal, ordinal) or quantitative (e.g., interval, ratio). After potential causes have been identified it is time to start looking for known solutions, either by literature research, observations, communication and analysis of primary and secondary sources.

In phase 4, think of innovative solutions that can solve the problem. Brainstorming or mind maps may help generate workable solutions for the problems. The evaluation of the newly found solutions and choosing a solution is done in this step. We define the decision, define the decision-making process, establish criteria, scale criteria, weight criteria, generate scores and evaluate the options. This will be done by making a rubric, with criteria for the solutions and these criteria will be given a certain weight in cooperation with the problem owner to implement the importance of certain criteria.

In phase 5, the recommendation of one or multiple solutions, based on the integration of theory in Gits Mfg. Co.

In phase 6, the implementation of the solution. We can map the new process flow with our implemented solution to get a clear overview of the new process and think of different critical paths. By doing so we can also compare this with the old process. The organizational context can be considered, think of strategy (McKinsey 7S), culture (Kurt Lewin Change Model) and the process (as mentioned above). Further literature studies can also help to find more qualified frameworks.

In phase 7, the new solution is evaluated. Is the gap between the norm and reality gone, does the solution provide a solution to the action problem? Can we find topics to keep improving the current (new) process, with continuous improvement in mind? Evaluate all phases of the MPSM and perform a structured evaluation.

1.4.2 Solving Research Questions

Before work on the tasks stated earlier can start, there first must be knowledge about the details of the RFQ process. The process focuses on but is not limited to, the different steps that must be taken to complete the entire process, the departments executing these steps, the lead times of the steps, and the milestones, which then is used to calculate averages ($\bar{X}$) and standard deviation(σ). It is known that the total process takes *Y* amount of time, while the goal is *X* amount of time. The value of variable *Y* can be figured out by looking at previous RFQ processes and taking the average of those and the standard deviation. The value for *X* depends on company standards. Company standards will be gathered from the company and deadlines can be determined for each of the quotation processes, depending on their risk classifications. When both values are determined, we can calculate *Z* and *Z*%, so we know how much the process needs to be improved. To formally state the research question, these terms need to be combined, variable, norm, reality, problem owner and how we want to improve the process. By doing this it results in the following main research question:

> "*How can Gits Mfg. Co. improve the lead time of the RFQ process, from Y amount of time to X amount of time, by reducing time waste in the process*?"

To answer this question, the following sub-questions must be answered:

1. What is the current lead time of the RFQ process, making a distinction between the different risk classifications? (Current State/Reality)
   - To tackle this sub-question, the data that is documented for previously executed RFQs has to be analysed. With this data, the average lead time, as well as the standard deviation can be calculated. By doing so this indicates how long the process takes.
2. What critical path does each of the risk classifications generate?
   - Which steps must be executed for each of the risk classifications, in the current situation? Since some products are like previous products, then the data that was already generated can mostly be reused. This maps the steps that are executed for each risk classification.
3. Which tasks contribute to time waste in the total process?
   - By finding lead times to milestones, an analyse can be conducted regarding which tasks can be improved the most. The lead time of certain tasks is longer, therefore there is room for improvement by re-arranging certain tasks. If one task takes too long and all other tasks must wait till that particular task is completed, then that task generates a lot of waste for the rest of the process.
4. Which methods can be used to (further) improve the total process of quotation at Gits Mfg. Co?
   - Since we want to reduce the time wasted in the process, think of lean management and could this improve the process even further?
   - How can these methods be implemented to improve the process?
     Knowledge problems can be solved by literature research, in books or other scientific articles, in combination with the current situation.

1.4.3 Research Scope

The key area of the research is Gate 1, 2 and 3 of the PM-07 document, in which the deliverables for the 3 gates are being listed. The PM-07, together with the PM-07F1 and QD-174 are key documents for the RFQ process. Unfortunately, these documents are privileged to Gits Mfg. Co. and therefore cannot be distributed outside of the company without the company's approval. The research mainly focuses on the steps taken in Gate 1, 2 and 3 and the departments working on these deliverables. The process of quotation involves a lot of departments of the company. Every department has a certain responsibility towards their deliverables. Everything at the company outside of the scope described above is not part of the research.

1.4.4 Operationalization

The research that will be conducted is partly quantitative and partly qualitative, depending on the stage of the research. The differences between quantitative and qualitative research are displayed in exhibit 6-4 on page 128 of Business Research Methods Schindler (2019). Since averages and standard deviations will be used, the quantitative research is closest to the first stages of the research. In the first stage of the research, the company data will be assessed and calculations will be made to provide insight in the process. For later stages of the research, qualitative research is more applicable since then possible solutions and relations are being assessed. These possible solutions will be connected to literature to support the implementation of the solution. The data-gathering techniques that will be used are literature study, primary and secondary data and interviews. To be able to solve all the different sub-research questions, there has to be distinction between different approaches for all sub-research questions since some of those are quantitative and others are qualitative. By defining the approach for each sub-question, regarding a data collection method, a clear distinction can be made.

How to tackle the different sub-questions is stated in Solving Research Questions.

This is also defined in the critical paths in which some risk classifications can skip steps making the process quicker and equalling the total risks of the classifications because skipping steps increases the total risk of the process.

1.4.5 Reliability and Validity

According to Saunders, Lewis and Thornhill (2019), the definitions of reliability and validity are:

Reliability: "*Extend to which data collection techniques will yield consistent findings*."

Validity: "*Extent to which data collection method or methods accurately measure what they were intended to measure*."

The definition of reliability and validity are formulated differently by Schindler (2019):

"*Reliability is concerned with the degree to which a measurement is free of random or unstable error*."

"*Validity is the extent to which a chosen or developed scale (our measurement questions) measures what we wish to measure (our investigative questions)*."

To make sure the research is reliable and valid, the data collection methods have to measure what they should measure and that the findings will be consistent and free of randomness or unstable errors. Regarding validity for solving the sub-questions, the probability of getting invalid results is small. For the sub-questions, the data already exists, and it isn't a matter of measuring but more a matter of analysing and calculating. The probability of making an error in calculating is always present, but is not as much a matter of validity, as it is of reliability. To get reliable results the calculations and analysis must be correct every time one gets executed. To eventually get the right results, the calculations have to be done correctly, based on the correctly collected data. For finding information, the Systematic Literature Review comes in place by filtering and searching only for academic sources that are about the right topic. By doing so, the literature on which the answers are based, will be reliable as well and make sure that the conclusions are based on literature that connects to the research.

1.4.6 Inclusion and Exclusion of Data

Regarding the gathering of data and the selection of the data, the following gets taken into account:

- When accessing data from a Covid-19 period (March 2020 till May 2022) the data will be processed as normal. If eventually there is a clear correlation in longer lead times for RFQ processes executed during covid times, then this data will not be used for further research. If the lead time, of the process executed in covid time, lies within the borders of the standard deviations, it will be included in the data. Otherwise, it will be excluded from the data, since the lead time is so different from other data, this falsely influences the outcome of the average lead times.
- Data that is not accessible by the company drive, or that is missing, will be requested by the right person that was connected to the data. Note that it is not about who processed the data, merely about the exact date on the document.
- Data that can be found indirectly will be used for the research. To explain it by an example: If on step/task 1 the opening date is available, but the date end date is missing, but on step/task 2 the start date is given, then the start date of step/task 2 will be used as the end date for step/task 1 and vice versa. Step/task 2 might not be started immediately so the start date of step/task 2 is not the actual date that the execution of the step/task could be started. Unfortunately, this is the closest date found to the end date of the previous occupation.

Table 3: Quotation Processes Analyzed

###	RFQ Processes	RFQ start date
1	108054 Scania EBV CBE 1 Next Gen	12/9/2022
2	108065 DAIMLER H2 ITV	6/27/2023
3	108071 LIEBHERR H9xx H2 ITV	2/22/2023
4	108070 IVECO XC13 EUVII EGR 2023	6/26/2023
5	108069 IVECO NEF6 Euro 7 EBV 2023	6/28/2023
6	108068 IVECO NEF6 Euro 7 EGR 2023	6/27/2023
7	108067 SCANIA EBV DW5	6/26/2023
8	108066 CAT Methanol Electric WG	5/25/2023
9	108053 DAF MX14 ITV	10/4/2022
10	108002 EC1903 Navistar A26 ITV	12/4/2018
11	108050 ESP LLG	6/21/2022
12	108052 Komatsu HTPA Actuator	8/30/2022
13	108064 Navistar EBV J07	3/27/2023
14	108072 Scania DC16 V8 EBV	11/7/2023
15	108019 Caterpillar 13X EGR Valve	12/11/2019
16	108045 Caterpillar G3500 HR2.1 WG	3/31/2022
17	108032 Cummins 3-Way Ball Valve	2/4/2021

1 quotation process (marked red in Table 3) was excluded from the useable data due to very long lead times that were subject to the influence of the Covid-19 outbreak in 2020 and 2021. This quotation process would influence the averages and standard deviations of the other processes so much that the insight created with the calculations would give a wrong image of the actual averages and standard deviations. The total lead time of this process was so high that the average lead time would increase with 50%.

2 Description of the Current RFQ Process.

In this chapter the current quotation process, the process of answering the RFQ from a customer which is a full and binding quotation. This information is necessary to fully understand the coming chapters.

2.1 Quotation Process

The entire process of quotation is a process built out of three quality gates. These 3 gates are all focused on different aspects of NDP so that eventually a proper calculation of costs, investments and profit can be made. The process is made of these gates to ensure the highest quality before moving on to the next quality gate.

2.1.1 Quality Gate 1

In the first quality gate, the Bid/No-Bid phase, the company is focussed on the Bid/No-Bid in which the company decides if the RFQ from a customer is interesting enough for the company to develop a product and work on their RFQ. In this quality gate, the sales department of the company receives the RFQ from a potential customer and starts assessing the received RFQ. A project folder, located at the engineering drive of the company, is made by the sales department in which all the documents that are necessary to complete the RFQ will be stored. A risk assessment and a Project Charter are also made in this quality gate. To eventually decide to work on the RFQ or to drop the RFQ, the project manager organises a Bid/No-Bid meeting in which the Director of PLM (Product Line Management), Director of Sales and Director of Engineering have to approve to continue working on the RFQ, so the outcome of the meeting has to be 'Bid'. If all this is done, a quality engineer, together with the project manager, checks the deliverables of this first gate and if everything is of high quality and complete then the quality engineer will sign off the quality gate. The company executes the Bid/No-Bid meeting the lower the risk of working on a project that eventually is not even interesting for the company. The RFQ is the input for this phase and the signed charter is the output. An overview of deliverables for this quality gate can be found in Figure 3.

Activi	Deliverables Description	QMS Document
1	Request for Quote	SA-11
2	Project Set Up	MG-10
3	Customer Requirements	
4	Bid-No Bid	SA-03F1
5	Project Charter	SA-14F1
6	Gate Certificate Sign Off	PM-08F1

Figure 3: Deliverables for quality gate 1 and their supporting documents

2.1.2 Quality Gate 2

In the second quality gate, the feasibility phase, the goal is to develop and review the technical and financial feasibility of the project to assess the commitment to drive the project to completion. In this phase, the technical requirements of the customer are being analysed and from the analysis, a document called 'delta requirements' is made. In this document, the company and the customer discuss which aspects of the product can and cannot be met by the company. In this phase, they also make a design, a DV Plan (Design Validation Plan) and a supplier launch plan, as well as a process flow chart and they define the needs for the packaging of the product as well as the costs. All these plans and worked-out details are input for the QD-174 that is also being made in this phase. The business controller of the company has to sign off the financial sheet. When this is done, a quality engineer and the project manager check all the deliverables for this second quality gate and sign off the quality gate if everything is complete. The second quality gate is the gate that takes the longest in the quotation process. The approved Project Charter from quality gate 1 is the input for this second quality gate. The output for this quality gate is a signed-off QD-174 which is fundamental to sending a binding quote. An overview of deliverables for this quality gate can be found in Figure 4.

Act	Deliverables Description	QMS Document
7	Project Set Up	MG-10
8	Action Item List	PM-11F1
9	Project Schedule(s) - Optional	PM-14F1
10	Develop Delta Requirements	EN-48F1
11	Concept Design/Tech. Risk	EN-43/PM-15F1
12	Design Plan	
13	Finalize Delta Requirements	EN-48F1
14	Process Flow Chart	EN-50F1
15	Packaging	
16	DV Plan	EN-23
17	Supplier Launch Plan	PR-14F1
18	Project Calculation	QD-174
19	4 Block	MG-06
20	Gate Certificate Sign Off	PM-08F1

Figure 4: Deliverables for quality gate 2 and their supporting documents

2.1.3 Quality Gate 3

Quality gate 3 starts with sending the quote to the customer that sends the RFQ. This quote is based on the QD-174 finance sheet which contains all financial calculations to meet the company standards. The scope of the research ends the moment the quotation is sent, since then the customer is reviewing the quotation and negotiations start at this point. The fact that this is just two companies discussing the price of a product is a step in this process with very deviating lead times and is not directly influenceable by Gits Mfg. Co. The goal of this quality gate is to win the business from the customer that submitted the RFQ, the company is looking for a customer PO (Purchase Order) or other commitment to award the business to Gits Mfg. Co.. An overview of deliverables for this quality gate can be found in Figure 5. For the sake of the research, everything beneath the red line, in Figure 5, is out of the scope of this research.

Activi	Deliverables Description	QMS Document
21	Quotation	SA-11
22	Warranty Agreement	
23	Negotiation	
24	Nomination P.O.	
25	Project Calculation U	QD-174
26	4-Block	MG-06
27	Lessons Learned/CA	
28	Gate Certificate Sign (	PM-08F1

Figure 5: Deliverables for quality gate 3 and their supporting documents

2.2 Risk of Price Deviation

The reason that Gits Mfg. Co. has made such separate quality gates, which all have their review, to assure the quality of deliverables made and to reduce the risk of giving the customer the wrong price. If a price deviates from the agreement from the actual costs and price when the product is being produced, this simply costs money. To reduce this risk and to make sure that the company can send quotations that only have a deviation of about 5%, they designed this process. The security of giving a precise price makes sure that the process takes a long to complete since now all deliverables are worked out in full detail. If deliverables are not worked out as detailed, but sometimes the company would take a guess then the probability of giving a wrong price would increase but the total lead time of the company has the potential to decrease by a lot, depending on the amount of risk you are willing to take. The more risk you take, the higher the probability of giving a wrong price and the quicker the process can be finished and a quotation can be sent.

2.3 Risk of Time Waste

During the execution of the quotation process, a lot of departments of the company all work on different tasks. The execution of these tasks, and who is responsible for what task, is documented in the PM-07. A downside of all these departments working together is that a lot of communication and information flow occurs between the different departments and between the execution of different steps in the process. All this communication, and the fact that this mostly goes via Microsoft Teams or e-mail, causes long waiting times between the steps. Every time information gets transferred it takes time to start with the next step in the process. The process is manually monitored when different tasks are completed and progress is manually documented in the PM-07 document. To give an example, Employee A sends out a question to a colleague, employee B. The question was sent at day K in month L in year M, at time 4:30PM. The corresponding answer was received 20.9 working hours later, meaning a time waste of 20.9 hours. For the sake of privacy of the employees involved their names and the exact dates of the conversation have been anonymized.

3 Theoretical Framework

In this chapter, a theoretical framework is constructed that later is used to integrate into the company and on which the recommendations will be based. The theoretical framework contains multiple aspects of interest to the company.

3.1 Principles of Lean Management

The principle of lean management defines 3 major causes of waste, Muda, Mura and Muri. These are stated in Slack and Brandon-Jones (2019) and stand for; activities in a process that do not add value to the operation or the customer and therefore are wasteful, lack of consistency or unevenness that results in periodic overloading of equipment (or staff), and absurd or unreasonable, respectively. On the one hand side, we have the three causes of waste and on the other hand side, we have the types of waste. The types of waste are divided into various categories that apply to both service processes and manufacturing processes. According to Bertagnolli (2020); Sarkar (2007) there are eight types of waste defined:

Waste of overproduction: this is processing more or sooner than required.

Waste of motion: this is the movement of individuals that is unnecessary for completing a job/task in a process.

Waste of inventory: this is when there are items or supplies in the process over what is required for single-piece flow. In a service setting this would mean more supplies or items than required as single-piece flow is often not possible.

Waste of transportation: This refers to the movement of materials, which is more than just time in processing. Waste of transportation is the movement of materials and not people. Since unnecessary movement of people is a waste of motion.

Waste of waiting: this refers to individuals and items being idle between operations. This waste is quite evident in setups wherein the loads of process associates are not balanced.

Waste of underutilized people: not all abilities of associates/employees in a process are utilized to their fullest potential. Often the creativity of individuals is undermined.

Waste of defects: waste that is caused due to errors and not getting items or products right the first time out in a process. The errors cause the items to be reworked, something that is not necessary for items without a defect.

Waste of overprocessing: this means executing steps that do not add value for the customer.

There also are three different types of activities in a process:

- Value-Added steps, which contribute towards the value of the final product. This is what the customer is willing to pay for. These steps help to bring transformation to the product.
- Business-Value-Added steps, are those activities in a process the customer is not willing to pay for, but that cannot be avoided. These steps necessarily need to be in the process, and cannot be eliminated from the process. They are also called necessary non-value-adding steps and these are activities done for regulations, policies and quality assessments.

- Non-Value-Added steps are the activities in a process for which the customer is not willing to pay and that can and must be avoided. The focus should be to eliminate these activities/tasks.

Different tools/methods of lean management each have their characteristics and therefore focus on several types of waste (in which some overlap may occur).

The 5S tool helps companies to clean and to arrange the facility through five main steps. According to Naeemah and Wong (2023); Singh, Gandhi and Singh (2022); Slack and Brandon-Jones (2019) the five steps, that are Japanese of origin, are: shine (seiso), set orderly (seiton), sort (seiri), standardize (seiketsu) and sustain (shitsuke). The tool can be used to decrease superfluous movements, decrease setup time and reduce the duration of manufacturing preparation activities (Naeemah & Wong, 2023). The 5S technique is most important for manufacturing advancement, since it is the least complex and most effortless procedure to execute, as stated in Singh, Gandhi and Singh (2022).

Further improvement of the RFQ process can be realized by eliminating waste through a streamlined flow. The idea is that the route is changed to a more logical order so that products or documents don't see the same location twice. A perfect and well-known example to understand the flow is Value Stream Mapping (VSM). Soliman et al. (2022) and Slack and Brandon-Jones (2019) state that VSM is a simple and important tool for mapping the flow of materials and information throughout the entire value chain. It records the activities that directly add value as well as the activities that produce merely waste. It focuses on clearly distinguishing VA steps and waste-adding steps. This method can be of great value in paths since it focuses on steps that add value and that is exactly what the research needs to establish a clear VSM.

The use of kanbans, or simply signalling devices that can prevent accumulation of (material, customer and information) material, is implementable in the process. The idea is that the kanban controls the transfer of items between stations. Currently Gits Mfg. Co. mainly uses email, their QMS (Quality Management System) in SharePoint and a central drive which is accessible to employees. Automation could be of high value but must be further investigated. The system of kanbans is represented in the current process by the email they send or the phone calls they must use to contact other employees. Implementing AI into this can help improve and fortunately, Chen and Wang (2022) discuss this in their literature. They state that the implementation of digitalized kanbans saves the employees and the management of kanbans and frees the operators from thinking of sending the kanbans.

Within Six Sigma, the tool of VSM is already mentioned separately. Six Sigma is an advanced version of TQM (Total Quality Management) and Lean Sigma is a combination of Lean Management and Six Sigma (combining the best characteristics of them both). Slack and Brandon-Jones (2019); Vinod et al. (2015) both mention Lean Sigma, in which they both mention the elements of Lean Sigma that can be used to improve the process. The main characteristics of Lean Sigma are waste reduction, fast throughput time and the impact of Lean with the data-driven rigour and variation control of Six Sigma. Sometimes also Kaizen (or continuous improvement) is included in the concept. Tools of Six Sigma that can be of use are flow charts, cause-effect diagrams, fishbone diagrams and scatter diagrams. These tools can give insight into the correlation of data. These tools are mentioned in Vinod et al. (2015) and further elaborated on in Slack and Brandon-Jones (2019).

The dimensions of Lean improvement are eight variations of time calculations in a process. The lean principles distinguish time in a process depending on what the time is used for and over different stations in the process. Three of those time distinctions are already mentioned earlier, they are VA time, NVA time and Business-Value-Added time. The other 5 are more focused on the processing of the products and not on the actual time of adding value to the product. The cycle time is the time taken to execute a single step in a process. Wait time, is the time an activity is in a process is waiting to be worked on. This also includes individuals waiting for work. Transportation time is the time needed to move materials from location A to location B, in a process. Transportation time is also called travel time. Throughput time is the time a single product moves through the entire process. Lead time is the end-to-end time that is required to execute the process. This starts the moment the customer places the order and this ends the moment the customer receives the products or services the customer ordered.

3.2 NPD Processes

According to Harmancioglu et al. (2007), there is no general solution to design an NPD (New Product Development) process. Harmancioglu et al. (2007) state the following: "Organizational design is a critical problem for NPD processes because the design needs to enable effective coordination and conflict resolution and facilitate cross-functional sharing of resources. Influential organizational design elements include formally planned stages, senior-level involvement, business case preparation, customer input, and cross-functional integration". To manage production, managers should use stepwise approaches, and think of stage-gate processes, where required deliverables, the connected tasks, and the sequence of executing these tasks and performing departments are listed specifically and precisely. According to McDermott and O'connor (2002), stage-gate processes often result in lower-risk, immediate rewards and step-by-step projects. The supervision of senior employees may positively impact NPD by guiding the process. Simultaneously, a major possible downside is that the direct supervision of senior employees may decrease creativity in design and problem-solving, repressing the possibility of innovation (Miller, Dröge, & Toulouse, 1988). But with the current scientific and technological discoveries it would be of interest for companies to get young people in cross-functional teams, to develop innovative and technologically new products without, a senior employee sticking to the older technology, that might be outdated in comparison to the technology that competitors use (Gupta & Wilemon, 1990; Mintzberg, 1979). There are multiple ideas on how to design the ideal NPD process, taking into account the different departments of a company working on the NPD and taking into account that companies need to supervise processes for the sake of organizational structure. According to Tuli and Shankar (2015), a generic form of an NPD process is widely used in OEMs as well as other manufacturing companies. In the most general form, the supplier and the OEM operate as 2 separate operations, while actually, they are more connected than imaginable since both companies work on the development of the same end product but in different portions. Where suppliers are mostly focused on delivering a part of the final product and OEMs are focused on the complete final product. Collaboration, however, is present in the workflow of both companies. The information provided and communicated between both parties regarding feedback and technical requirements has quite some impact on the NPD process. Tuli and Shankar (2015) stated that NPD processes can be divided into three sequential phases:

- Planning and definition
- Product design and development
- Product validation

3.2.1 Lean NPD

The application of lean principles into product and process development has more and more important in NPD. Following the ideas of Morgan (2002), it is suggested that NPD performance, and their processes, can significantly benefit from lean principle variations, which were traditionally meant for manufacturing improvement. In the research on process development, by Adler et al. (1996), it got opined that traditional manufacturing improvements, thinking of work and capacity management, process improvement and reduction in variation can decrease development times by 30-50%, indicating possible implementation of lean principles, and tools, in the process management can also impact the development times drastically. Furthermore, applications implemented in the early stages of NPD can improve the implementations of lean in the later stages of the same NPD process. The goal of CI (Continuous Improvement) in NPD processes is hard to implement in these processes, according to Caffyn (1997) strategic capabilities can only be achieved in CI if a significant proportion of the organization is involved. Furthermore, will the full potential of CI not be realised until key behaviour is the norm in all areas and at all levels of the organization? In the paper of Liker and Morgan (2006), they made a clear distinction between the principles of Lean NPD in different aspects of product development. They argued that principles of lean can be implemented at the scope of the process, the people and the tools & technologies. The same distinction was made by León and Farris (2011), but in their paper, they also used multiple other papers to make an overview of different frameworks with the elements they are focused on and their description. By defining clear distinctions the principles can be implemented more precisely and more accurately depending on the goal that has to be achieved in the future state. In his research, Oppenheim (2004), suggests that the systematic coherent implementation of 5 lean principles eventually leads to less time waste in Lean NPD processes. The 5 implemented steps are: Define Value, Define Value Stream, Make the workflow, Implement Pull and pursuit perfection in the process. The last step, the pursuit of perfection in the process can be seen as an implementation of continuous improvement, a key element of lean. Key differences in the implementation of CI in the NPD process compared to manufacturing processes are listed in Table 4.

Table 4: Differences implementing CI in NPD compared to manufacturing implementation

Tangibility	NPD is a more tangible process than manufacturing processes
	On the shop floor creativity is about improving something that is already there.
	It is more difficult to define what the deliverable is.
Process characteristics	Longer time-scales in NPD
	NPD is an iterative process
	Culture in NPD is different from shop floor culture; two aspects: creative vs. structured
Evaluative frameworks	Difficult to measure 'quality' of the process
	Tendency to measure things that are easy to measure which may not necessarily lead to the desired result
	The problem in deciding what is the 'right' value to aim for with measurement.

Source: (Caffyn, 1997)

Sarkar (2007) states useful formulas to calculate variables of interest, for this research, are the formulas to calculate the Lead Time of the process, as well as the NVA time and VA time for each of the steps.

The formula for lead time is as follows:

Lead time = Value-Added time + Business-Value-Added time + Non-Value added time.

Equation 2: Calculation of Lead Time

The process efficiency, according to Sarkar (2007), can be calculated as well. To calculate this a simple formula can be used:

$$Process\ Efficiency = \frac{Value\text{-}Added\ time * 100}{total\ Lead\ Time}$$

Equation 3: Calculation of Process Efficiency

The outcome of the formula in Equation 3 is process efficiency in percentage, compared to the entire lead time of the process. The formula of Equation 3 looks very similar to the formula in Equation 1, which is used to calculate Z%. In Equation 1 the LT (Lead Time) of the future state process is subtracted from the LT of the current state process, to calculate the required improvement in percentage.

In the conclusion of their research, Caffyn (1997), Karlsson and Ahlström (1996), conclude that lean NPD consists of multiple interrelated techniques. Implementation of lean and CI into NPD processes is subject to the change of basic values and ideas. The implementation of lean is the beginning of the journey towards CI, the final destination towards the improvement of processes. CI capabilities are subject to challenges faced by companies, hindering and supporting factors. Ho and Lin (2009) state in their conclusion that their first stage, the project capture stage is the stage in which the company, formulates a proper response to the received RFQ of a potential OEM customer. Because the OEM customer will set a deadline to finish the response to the RFQ, it is a difficult and time-consuming process for suppliers to complete complex RFQs in the often short time given. Therefore, the use of a systematic, schematic and multidisciplinary method to respond to RFQs is necessary. The content of RFQs, as stated by Ho and Lin (2009), includes the following topics: product specifications, product development schedules, related costs, logistic plans, after-sales service plans, key component selection proposals and quality verification plans. The receiving company needs to review all product development topics to formulate their response to the RFQ accurately and in detail. To prevent responses to RFQs from being guesstimates, all related departments should participate in the discussion and development of the items in the RFQ to make sure that they are accurate. In the entire process, of developing the RFQ, the implementation of lean management starts with the management team. Caffyn (1997) states 3 major points for managers to make CI even possible to work. Stated is that managers must really understand what CI is about, and that CI is a set of key behaviours. Secondly, managers should recognize possible obstacles and delays, or disablers, that CI might face in their own NPD process. Lastly, managers should decide which enables them to support the implementation process of CI in NPD, to feed the key CI behaviours. To come back to Karlsson and Ahlström (1996), their statement about management having a crucial role in guiding the company towards CI, by implementing lean management, supports the findings of Caffyn. They add that ensuring a concurrent process is important, even so, is the new way of working. The new way of working should be consistent at all times and the same values, structures, processes and systems should be used to avoid stalemates in the NPD process.

3.3 Summary of Theory

Table 5: Overview of Theory

Paper	Method / Idea	Application Area	Location in RFQ
Naeemah and Wong (2023); Singh, Gandhi and Singh (2022); Slack and Brandon-Jones (2019)	5S	Decrease superfluous movements, decrease set-up time and reduce the duration of manufacturing preparation activities.	The decrease of superfluous movement can be mostly achieved between the exchange of information and documents.
Soliman et al. (2022) and Slack and Brandon-Jones (2019)	VSM	Define locations and tasks in the process that generate a lot of NVA time and therefore have room to be improved.	Provides an overview of the time waste in the entire process.
Slack and Brandon-Jones (2019)	Kanbans	To prevent accumulation of material.	Between the exchange of the deliverables and information.
Slack and Brandon-Jones (2019); Vinod et al. (2015)	Lean Sigma	Waste reduction, fast throughput time, data-driven rigour and variation control.	Standardize the execution of the process, based on the sequence of the execution of the steps.
Harmancioglu et al. (2007) McDermott and O'connor (2002)	Principles of process design.	Stepwise and Stage-Gate processes	The design of the process
Harmancioglu et al. (2007)	Separated stages in NPD processes.	List deliverables, connected tasks, sequence of tasks and the performing department	The design of the process
Tuli and Shankar (2015)	Lean principles and tools.	Divide NPD processes into three sequential stages.	The design of the process
Adler et al. (1996)	Lean principles and tools.	Work and capacity management, process improvement and reduction of variation.	

From the theoretical framework the most important definitions and tools that can be of major use later in this research will be mentioned in this section. To provide a clear overview of definitions that will be further used. The three different types of activities in a process, Value-Addes Steps, Business-Value-Added steps and Non-Value-Added steps are of importance in the continuation of this research. The input for a clear VSM are VA times, BVA times, NVA times, cycle times and throughput times. In this case the BVA times are included in the VA times and the cycle times and throughput times are not of interest since the scope is to eliminate time waste in the process. The 5S tool can help to clean the process by implementing 5 steps. Depending on the eventual locations of possible time waste reduction the ideas of this 5S can be logically implemented later to assure an improvement in the execution of the process. The implementation of a more streamlined flow, basically making sure that products of documents don't see the same location twice, might be hard to use later in the research. The scope is NPD process and since this process is a very iterative process it is usual that documents and products see the same location in the process multiple times. Although, VSM can still provide clear insight in the process to find major time waste in the process and find irregularities in the execution of the process. The use of kanbans, digitally, can be of interest to improve the communication between the completion and the start of the deliverables as well as between the different departments of the company. Improving communication and assuring immediate notifications can possibly speed up the process. AI might also be combined with this, since then the communication can be fully automated, depending on the precise AI environment.

The use of stepwise approaches, stage-gate processes, required deliverables, connected tasks, and the sequence of executing these tasks and performing departments are listed specifically and precisely is of high interest to improve the NPD process. Clearly documenting provides a good overview for all people involved in the process. The low-risk, immediate rewards and step-by-step projects come with these five ideas. The close guidance of senior employees can positively impact the execution of the process but simultaneously might decrease creativity. The NPD process can be divided into tree sequential stages, which have their own focus, that assure a valuable outcome with logical buildup.

The improvement of NPD processes can significantly benefit from the implementation of lean principle variations. Work and capacity management, process improvement and reduction in variation can decrease development times. The application implemented at the beginning of the NPD process can improve the implementations of lean in the later stages of the process. The systematic coherent implementation of 5 lean principles, as Oppenheim (2004) suggested, give clear overview of time waste and lead eventually to less time waste. The new way of working should be consistent, have the same values, structures, processes and systems to avoid stalemates in the NPD process.

4 Analysing the Current Process

This chapter provides output from the data analysis, in which LT, NVA and VA time are being calculated. The possible improvements per risk classification are calculated here as well. From the data analysis a general conclusion is drawn to elaborate on the data.

4.1 Data Collection and Calculation

During the first step of data analysis, the data has to be collected and documented in an Excel sheet, since the current quotation process is not very old, and recently was revised to improve it, the cases to analyse are limited. Most cases in the Excel document, which were not selected, missed a lot of steps or steps were not executed at all. The lack of this data was reason enough to leave these quotation processes out of the data analysis. Furthermore, 1 quotation process was excluded from the useable data due to very long lead times that were subject to the influence of the Covid-19 outbreak in 2020 and 2021. This quotation process would influence the averages and standard deviations of the other processes so much that the insight created with the calculations would give a wrong image of the actual averages and standard deviations. The exclusion of this quotation process is subject to the demands set before starting with the execution of this research, which can be found in the Inclusion and Exclusion of Data.

The actual collection of the data, used for the analysis of the quotation process, was collected from the engineering drive of the company. On this engineering drive, there are NPD folders regarding executed projects for potential customers who submitted an RFQ. From these folders the different dates were collected and noted in Excel, this was done for the milestones of the project. Together with the company supervisor Bart Kroeze, we came up with multiple milestones for the quotation process. The Bid/No-Bid meeting, the signatures on the Project Charter, the Delta Specs (Delta Specifications), the BOM (Bill Of Material), the QD-174 finance sheet and the actual date a binding quote is sent to the customer. For these milestones, the lead times were calculated using Excel. The exact formula that was used to calculate these lead times is as follows:

=NETWORKDAYS(Start_Date,End_Date,[Holidays])

This formula calculates the days between the milestones and could also exclude certain specified dates that were company holidays, such as the days between Christmas and New Year. The collective holidays of the company were requested from the Human Resources department and these dates we excluded from the net working days. After the different net working days were all calculated the milestones were swapped out for data regarding every individual step in the quotation process. By switching to each step in the quotation process instead of milestones, the calculation became more precise and long lead times were visible on individual tasks and not only for the execution of multiple tasks that led to the completion of milestones. To eventually calculate the NVA time for each of the steps, the VA time was collected from the QD-174. To work with these VA times, the formula that calculated the time between the steps was to be altered a little, the outcome of the formula has to be multiplied by eight to calculate net working hours instead of days. Therefore the new formula became:

*=NETWORKDAYS(Start_Date,End_Date,[Holidays]) * 8*

Now the NVA time could be calculated by extracting the value added times that were collected from the QD-174. With these VA and NVA times, a VSM was made that schematically shows the steps of the process with their times. As mentioned in Theoretical Framework, Sarkar (2007) made a formula (Equation 2) to calculate LT from NVA time and VA time:

LT = VA time + NVA time + Business-Value-Added Time

When rearranging the formula above a new formula was made to calculate the NVA time, the following was used to calculate the NVA times:

NVA time = LT – VA time – Business-Added-Value time

Currently, the Business-Added-Value time is taken within the VA time and therefore there is no Business-Added-Value time. Since we only have NVA time, LT and VA time, we are allowed to alter the formula and make it contain 2 known variables and 1 unknown variable:

NVA time = LT – VA time

4.2 Analysing Data for Each of the Steps in the RFQ Process

Data of the NVA time, so basically the amount of time the process is not being worked on, shows high variances in waiting times between the different steps. The VSM added in Appendix B: VSM Quotation Process, shows where waiting time is being added to the process. Note that all times in the VSM are working hours, so only office hours are used for calculation and therefore show more precise data. Also, it should be mentioned that data was collected in days, and not in hours, so all steps at least have some non-value added time, since the first day of the quotation process, when the RFQ gets submitted, is also counted as a day. To clarify this a little more, this is the reason why the task of Project Set Up has some NVA time but it can be a possibility that this gets done immediately after receiving the RFQ. The figures shown in this chapter, regarding the VA and NVA times, are parts of the complete VSM and in Figure 6 an example is shown. The triangles in these figures display the inventory and the time underneath therefore shows the NVA time. The blue and white blocks represent the task itself and the time beneath it shows the VA time for this process step. The times are in hours and the standard deviations (St. Dev.) and averages (Avg.) are calculated from multiple quotation processes. The calculations of steps in the process are made according to the project schedules that are generated in Excel by the company. The start date of one task is the end date of the previous task, but not in the first quality gate. The first quality gate is an exception since there is no schedule generated for this. Therefore the lead times of the steps of the first quality gate are all calculated from the moment the RFQ is officially received till the certain task is completed.

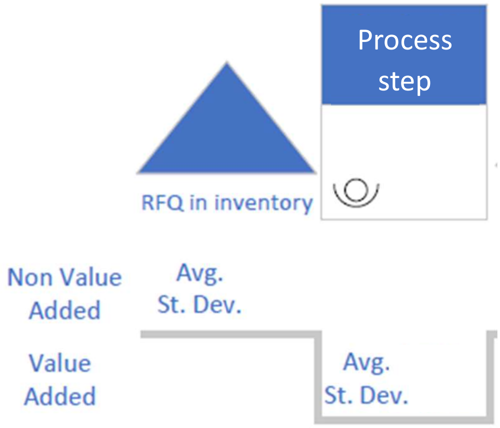


Figure 6: VSM, schematic view of 1 step of the quotation process.

4.2.1 Project Set Up

The NVA time and the VA time for the project set-up are displayed in Figure 7. As mentioned above, the NVA time for this step in the process can be logically explained. The waiting time, or inventory time for this step is present since the data collected is in days and to get working hours was multiplied by 8. By doing so this step automatically got waiting time since the execution of this step only takes 0.778 hours or 46.68 minutes, on average. The fact that the St. Dev. is higher than the Avg. means that the values in time for this step are spread widely. So, the differences in VA time for this step, which is used to make the calculations, are large. For this step, we can see that the most time is NVA time, to be precise, 90.67% of the total time is NVA time. The time wasted in this deliverable can be neglected, since the safe dates are in days and therefore this step doesn't necessarily produce 7.563 hours of time waste.

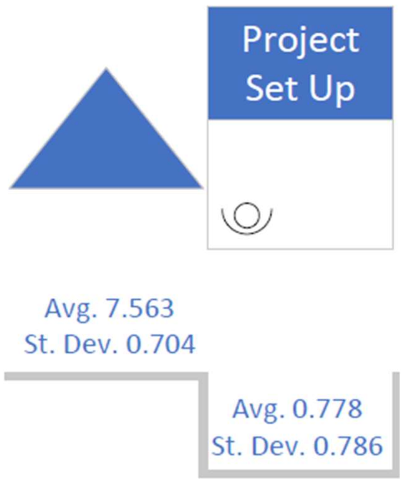


Figure 7: (N)VA times project set up

The average LT of this step is 8.000 working hours and the standard deviation of the LT is 0.000 working hours.

4.2.2 Customer Specs Available

For the step in which the customer specifications have to be collected, the VA and NVA times are shown in Figure 8. The long NVA times and their high St. Dev. can be explained logically. The moment the customer sends an RFQ and with it the customer specs, the NVA time will be 8 hours, since the NVA time is calculated by subtracting the VA times from the LT of this step. The actual collection of the customer's specifications has not been documented once in a QD-174 and therefore there is no VA time. Making the NVA time precisely eight hours, since one working day contains eight working hours. The high number of average NVA times is generated by customers who did not send their customer specifications together with their RFQ. Therefore these were not available to Gits Mfg. Co.. The fact that customers do not send their product specifications with their RFQ is something that can be seen as an external factor and therefore is not influenceable by Gits Mfg. Co. From a conversation with an employee, in which the process was discussed, the employee stated that the customer specs, the requirements for all aspects of the product that has to be developed are not always collected or available at the instant the RFQ is received. The fact that the specs of the customer are not available instantly is a cause for time waste in the overall process and in the completion of this deliverable/step. From the processes analysed, there are 3 processes that have a lead time for the customer specs that are above 500 working hours, most of the processes have the customer specs available within 2 weeks and some even have them available the same day. Making the time waste for this deliverable mostly caused by external factors. Note that the customers that had the specs available within a day are all the same customer.

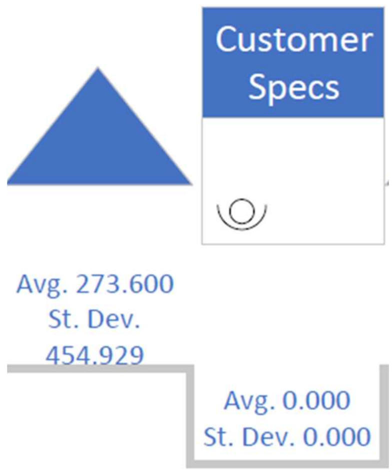


Figure 8: (N)VA times customer specifications

The average LT of this step is 273.600 working hours, and the standard deviation of the LT is 454.929 working hours. Unfortunately for the sake of process improvement, is this external time waste and not directly influenceable by the company.

4.2.3 Bid/No-Bid

The NVA time for the Bid/No-bid step and the VA times are displayed in Figure 9. The Bid/No-Bid is a meeting in which multiple employees from the company assess the different risks of taking on the submitted RFQ. Before doing so, a risk assessment document is filled in, this gives a graph as an outcome regarding the advice from the document. The document was made by the company and is merely a supporting tool for getting a clear comparison of all aspects of the RFQ. On average the Bid/No-Bid meeting and filling in the risk assessment document takes one hour. The average NVA time for this step is 70.867 working hours or 8.858 working days. The company scheduled Bid/No-Bid meetings on Monday evenings for a while now, since most of the time everybody is available on Mondays. One could reason that a work week has 40 working hours, on a full-time basis, and therefore the NVA time of the Bid/No-Bid should be 40 at maximum. If a meeting gets cancelled and the Bid/No-Bid gets postponed for a week, the process comes to a halt and the NVA time increases by 40 hours. The next Monday the Bid/No-Bid gets executed, one week delayed, and the process can continue again. The NVA time for this process step makes sense but can be decreased a lot if the company employees and the management/leadership team schedule these meetings more flexibly. It is good to make sure that everyone who has to be is indeed present, but this costs a lot of valuable time to realise. From this we can conclude that the inflexibility of the bid/no-bid meeting is the main reason that this deliverable produces time waste to the overall process.

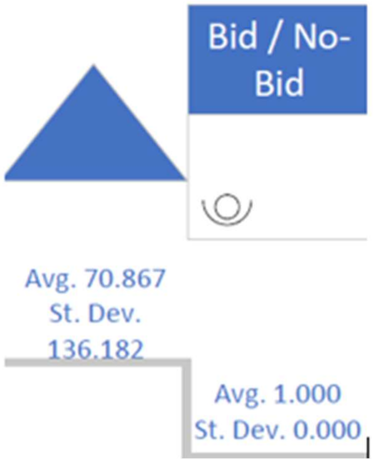


Figure 9: (N)VA time Bid/No-Bid

The average LT of this step is 71.467 working hours and the standard deviation of the LT is 136.218 working hours.

4.2.4 Project Charter

The Project Charter is a document in which important details to evaluate the project are written down. The Project Charter contains the project scope, technical definitions, design concept, BOM, cost target, manufacturing location, technical risks, countermeasures and project risk type. The incredibly high NVA time of the Project Charter, compared to the VA time, might be explained because the charter contains information from steps that are later in the process. The charter therefore is mostly a passive document in which information will be written down from time to time. The location of the charter, in the process, is also possibly subject to change. The NVA time of the charter is high because other tasks are being executed that must be put in the charter, tasks that belong to the second quality gate instead of the first quality gate, but this does not count towards VA time for the charter itself. Furthermore, it takes the management team a large amount of time to sign off the charter, while this doesn't have to take that long. During the risk assessment in the Bid/No-Bid step and the Bid/No-Bid meeting the company already has decided whether the project is of interest or not. Now the company is simply re-approving the project by signing the charter. The signatures that are required on the charter when it is finished also take a long time to collect. Multiple employees complained about this on the work floor when we were talking about the process. A Project Charter can be filled in, but the signatures of the management team might take multiple days or even weeks. For the calculations of the LT, and the statistics regarding the NVA time, the Bid/No-Bid meeting was chosen as the start date, since then the company has decided to continue with the RFQ and can start working on the required resources that are necessary. The main time waster for this deliverable is collecting the signatures from all required people, this can take days or even weeks.

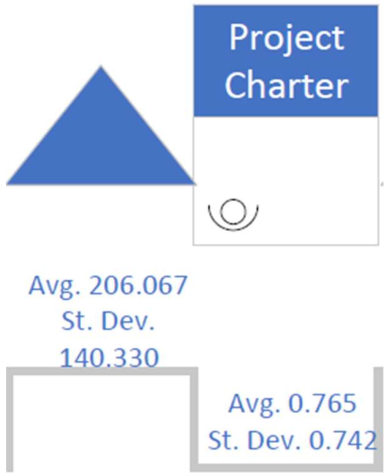


Figure 10: (N)VA times Project Charter

The average LT of this step is 206.933 working hours and the standard deviation of the LT is 140.061 working hours.

4.2.5 QG Sign-Off

The QG (Quality Gate) sign-off is a step to ensure that all the deliverables of the quality gate under review are of high quality, detailed and complete. The data for this step in the process is combined data from 2 QG sign-offs. They sign off quality gate 1 and quality gate 2 before the quotation gets sent to the customer, but they document this in the QD-174 under quality gate review, which then is combined data. The individual times for the first and second reviews are unknown, merely the reviews summed up. In Figure 11, the NVA and VA times of the QG sign-off can be found. On average, it takes 9.059 hours, or 1.132 days, to execute a review. Since the review can only take place after all the deliverables are completed, the lead time of the review starts when the Project Charter is finished. According to the process flow and the process design the process can continue with the second quality gate after the first quality gate has been signed off, but this is not always the case. Most of the time the quotation process continues with the second quality gate, even if the first quality gate has not yet been reviewed. A possible explanation for the high NVA time would be that there is no pressure to review the first gate. The process should, but does not stop when the first gate has not been signed off so for the management team there is also no pressure to correct a quality engineer when they do not or have not yet reviewed the deliverables of the first quality gate. As a result, the quality engineers can take all the time to review the quality gate and can postpone this until they have some spare time available.

After the 4-block, later in the process, another QG review and sign-off is conducted. As mentioned before in this paragraph the VA times are not separately documented in the QD-174 and therefore the determination of VA times is not possible for the individual QG review and sign-off, but only for the cumulative QG reviews. The major time waste for this step is not executing the QG Sign Off but merely starting with this step. Problem is that there is not enough overview or coordination for the Quality Engineers to start the step and to conduct the review. This means that this can be improved by improving the overview and insights in the processes and by improving the communication between the process owner and the person responsible for the review. The process owner is often also not clear and therefore the Quality Engineer doesn't know when to start, since no one will tell him/her.

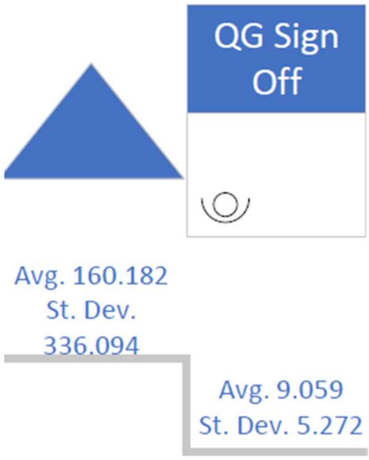


Figure 11: (N)VA times QG Sign Off

The average LT of this step is 170.182 working hours and the standard deviation of the LT is 336.105 working hours.

4.2.6 Action Item List

The action item list is the first task that contributes to time waste in the second quality gate. The action item list is made by the project manager to get an overview of the tasks that have to be executed, this is dependable on the project risk classification. A "Same As" risk classification requires fewer steps in the second quality gate since this product has similarities with previously executed projects. The project allows for the re-use of data, so these steps do not have to be fully executed again but merely require some finetuning. The lead time of the action item list starts the moment the Bid/No-Bid meeting is completed. If the lead time of the action item list is calculated from the moment the charter is signed or the QG sign-off has been done, the action item list would get unrealistic NVA and VA time values. The action item list is often finished before the previous quality gate has been reviewed and signed off. The Project Charter and the QG review are steps in the process that do not get pressure to be executed. Some of the NVA time of the action item list overlaps with the NVA time of the charter and has a complete overlap with the QG sign-off of the first quality gate since this starts the moment the Project Charter is finished and signed. The action item list is completed, 256.167 hours after the Bid/No-Bid meeting has been conducted, on average. The fact that the lead time would be negative if this started the moment the first quality gate has been signed off, means that the company does not follow its own designed process of quotation.

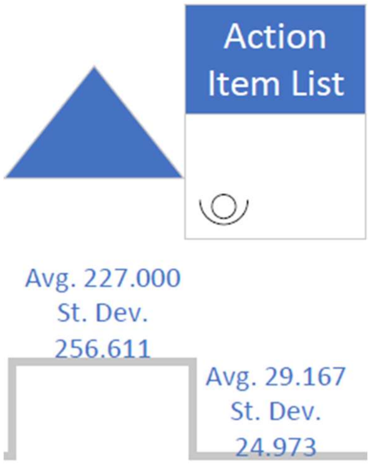


Figure 12: (N)VA times action item list

The average LT of this step is 252.000 working hours and the standard deviation of the LT is 246.127 working hours.

4.2.7 Project Schedule

The project schedule is subject to the schedule of the customer but the schedule gives clear guidelines for different parts of the quotation process and the production processes after the quotation has been sent and accepted. For example the production of A and/or B-samples. The project schedule is an optional deliverable and might only be made if the potential customer requests one. The lead times on this step in the process differ a lot and are most often made between the signing of the Project Charter and the action item list, sometimes even the schedule is finished before the Project Charter has been signed. Within this step the demands of the potential customer regarding their own timeframe is taken into account. Which means that the customer first has to have their own schedule before Gits Mfg. Co. can make a schedule for themselves that is in line with the schedule of the customer. Most of the times this schedule gets postponed to a later moment in the process. This deliverable is therefore under a lot of influence of external factors. The height of the St. Dev. and the Avg. shows that the data regarding the NVA times differ a lot and deviate substantially from the mean, if the St. Dev. is low, about 10, the data used to calculate the St. Dev. and also the Avg. would be much closer to each other. VSM overview of the VA time and the NVA time can be found in the figure below, Figure 13. The average LT of this step is 377.000 working hours and the standard deviation of the LT is 550.061 working hours.

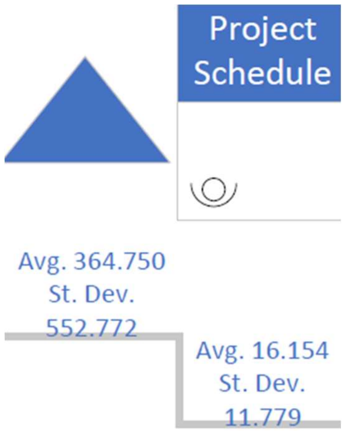


Figure 13: (N)VA times project schedule

4.2.8 Delta Specs

The process step in which an engineer reviews the technical and product specifications of the customer who submitted the RFQ is called Delta Specs Made. The outcome is a document, agreed upon Gits Mfg. Co. and the potential customer in which they accept or reject certain demands of the customer. From the data shown in Figure 14, the interpretation can be made that this step gets finished after the previous step in the process, since the Avg. NVA time is positive. Due to the high St. Dev. of the task the possibility of finishing his step before the previous step, is almost equal to the possibility of finishing this step after the previous step, as the process should be executed. On average the task takes 31.412 hours, or 3.927 working days to completely execute and finalize the delta specs. The times for these steps are calculated from the moment the first quality gate is signed off, since then officially the execution of this step is allowed to start. But, from the data, we see that sometimes the delta specs are finished before the first quality gate has been signed off. Within the time waste of this step is also the time the customers need to review the proposal of Gits Mfg. Co., making the delta specs is an iterative deliverable in which constant customer input and Gits Mfg. Co. input has to be compared to the specs of the customer and to the company capabilities. Furthermore, if the customer specs are not available the moment this step can be started according to the internal schedule, this also counts for time waste regarding this deliverable. The final outcome requires signatures and collecting signatures is time consuming process within the company.

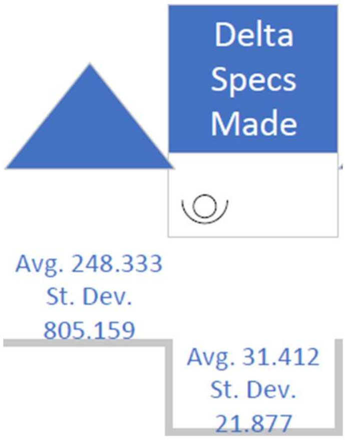


Figure 14: (N)VA times delta specs made

The average LT of this step is 280.889 working hours and the standard deviation of the LT is 795.100 working hours.

4.2.9 Concept Design/BOM

The concept design/BOM, is a step in the process that is a combination of multiple little tasks. This process step contains 5 subtasks which all count and support towards the completion of the composed task. The 5 subtasks, BOM, AutoCAD model, manufacturing plan, carry over vs. new components and the technical risk assessment are all part of the entire concept design. The VA times are not specifically for each of the subtasks but are the VA times of the composed task, and the same goes for the NVA time. A schematic overview of the NVA and VA times can be found in The VA times are documented in the QD-174, but since there are no loose dates available for each of the subtasks, the NVA time can only be calculated for the entire task. Unfortunately, this gives a less precise insight into possible time waste, but since all subtasks have to be completed before the concept design can be finished, the insight in the VA times and NVA times of the entire task is of more interest. The relatively low Avg. NVA time of this composed task, compared to other NVA times of tasks, shows that the tasks are started pretty quickly. The person that has to execute this task needs, on average, 4.295 working days to begin the task and about 10.772 working days to finish the task. The St. Dev. of the NVA time for this step, suggests that the NVA time varies a lot, even from quite large negative numbers to quite large positive numbers. Meaning that de data for this is spread widely and is not close to each other. The times calculated for this step start at the moment the second quality gate starts, so after the signing off of the first quality gate. This moment was chosen because the Delta Specs and the concept design both influence each other. If the delta specs change, the concept design changes as well and if the concept design cannot meet a demand from the delta specs, the delta specs have to be revised. The time waste for this deliverable are mostly connected to the external time waste when the delta specs are revised, this causes for changes in the concept design. The time waste for the concept design is, however, not very high and major improvements for the RFQ process are not in this step.

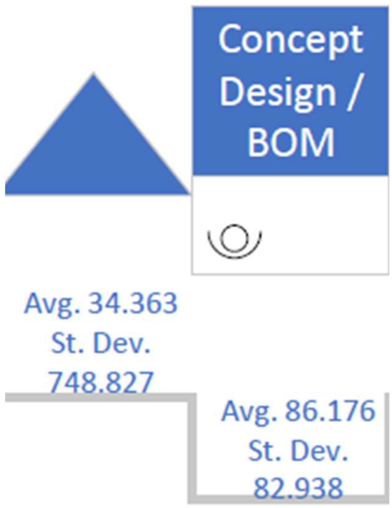


Figure 15: (N)VA times concept design/BOM

The average LT of this step is 141.818 working hours and the standard deviation of the LT is 733.609 working hours.

4.2.10 Design Plan

The design plan can start, according to the process execution schedule, the moment the concept design/BOM is finished. The NVA and VA time variables are schematically shown in Figure 16. The Avg. NVA time indicated that, on average, this step is finished before the concept design/BOM is finished, note that this is not always the case and the St. Dev. supports this finding. The St. Dev. shows that there are also cases in which the design plan was finished after the concept design/BOM and thus follows the process execution schedule made by the company.

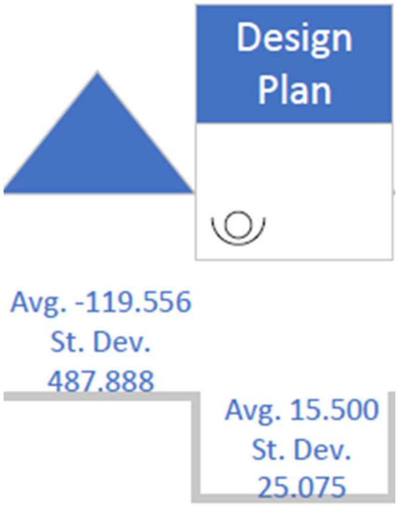


Figure 16: (N)VA times design plan

The average LT of this step is -106.667 working hours and the standard deviation of the LT is 489.157 working hours.

4.2.11 Process Flow Chart

After the design plan, concept design and delta specifications are finished, the process flow chart can be made. The calculated averages and standard deviations can be found in Figure 17, shown below. Since the design plan might be added to the delta specifications, that end date was used as the start date for the process flow chart. In the data gathered from the engineering drive, there was one LT that was significantly higher than the other LT's from the process flow chart. Indirectly, this can be seen in the high Avg. combined with the high St. Dev. of the NVA times for the process flow chart. The combination of the high Avg. and the even higher St. Dev. shows that this step gets finished after the design plan, concept design and delta specifications are finished, but also can be finished before the previous tasks are done. The NVA time of a certain case can also be negative. The process takes, on average, 33.059 working hours, or 4.132 working days, to complete. The average LT is 258.667 working hours.

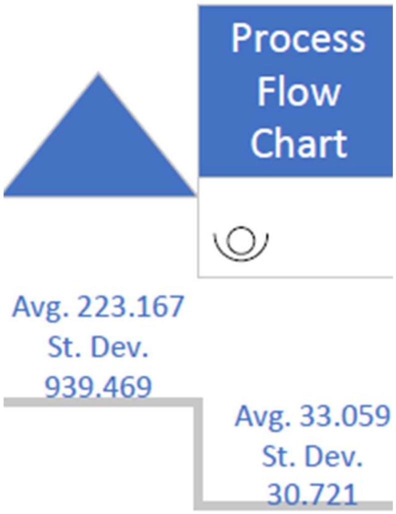


Figure 17: (N)VA times process flow chart

The average LT of this step is 258.667 working hours and the standard deviation of the LT is 931.656 working hours.

4.2.12 Packaging

For the packaging task, not a lot of data was available to calculate averages, standard deviations and NVA, VA and LT time. The cases that are documented differ from each other, as can be seen in the figure below, in Figure 18. The few cases, for which the packaging was documented separately, had very different LTs, but less spread VA times. The St. Dev. for VA times is almost as high as the Avg. for VA times, because in some cases 0 hours were registered for the packaging step of the process. These 0 hours were taken into account when making the calculations since they were also documented as 0 hours in the QD-174. If the 0 hours would not have been taken into account, the Avg. VA and St. Dev. VA times would become 14.111 and 8.569, respectively. Meaning that the averages increases and the spread of the VA times would become closer to the mean. By noticing that there are process with 0 hours of VA time for this deliverable, this means that this step uses solutions generated in the past to use for the new process as well. Since this deliverable is executed after the Process Flow Chart, DV Plan and Preliminary Supplier Launch Plan are finished, the deliverable is under certain demands of previous steps that determine together when this step can be executed. The problem in this is that communication has to be spot on to reduce the time waste in this step, the project owner has to pay close attention to the exact moment the three deliverables are finished so that the packaging can be executed. The problem is that this will be done the moment that in the next meeting the 3 departments responsible for the earlier steps, state that they are finished. By improving communication and improving the insight in the status of the process, the project owner can easier and more quickly switch the process to the next step and activate the department responsible for the packaging calculation.

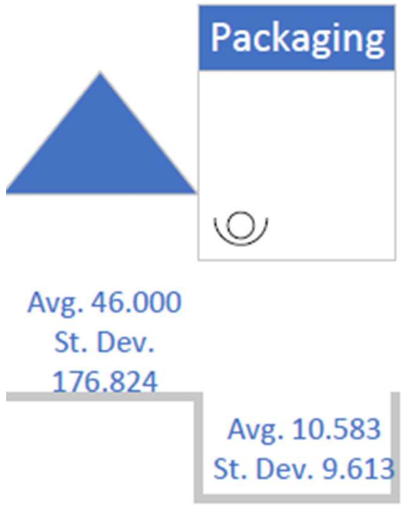


Figure 18: (N)VA times packaging

The average LT of this step is 53.333 working hours and the standard deviation of the LT is 171.622 working hours.

4.2.13 DV Plan

The design validation plan can start after the design is finished, it can start simultaneously with the process flow chart and supplier launch plan. Therefore the start date used for calculations is the end date of the delta specifications. In comparison to the tasks that should be executed simultaneously, according to the process schedule, the DV plan is finished. On average, the first task that gets completed is the preliminary supplier launch plan, which will be discussed shortly in the Preliminary Supply Launch Plan, secondly, the DV plan will be finished and lastly, the process flow chart will be finished. The DV plan requires a validation engineer and the Avg. VA and NVA times, as well as the St. Dev. VA and NVA times can be found below, in Figure 19. In general, this step gets executed after the previous step is finished, as scheduled, but there also are cases in which the DV plan is finished before the delta specs. Possibly meaning 2 things, the process is not executed as planned or the delta specs were updated after the DV plan was finished. On average the execution of this step, the making of the DV plan, takes 41.529 working hours, or 5.191 working days. Since on average, the DV Plan is finished before it's simultaneous task (Process Flow Chart), reducing the NVA time for this step doesn't affect the overall time waste of the process.

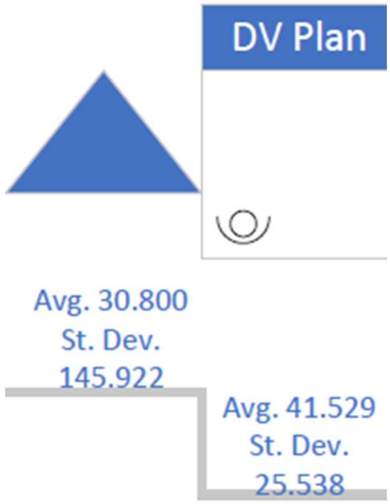


Figure 19: (N)VA times DV Plan

The average LT of this step is 73.600 working hours and the standard deviation of the LT is 129.234 working hours.

4.2.14 Preliminary Supply Launch Plan

As mentioned in the previous paragraph, the preliminary supplier launch plan can be executed simultaneously with 2 other steps and is finished first on average. In the preliminary launch plan, they use the information of the BOM to find suppliers for all the parts of the product that are designed for the customer, this includes costs. The employees from the sourcing/procurement department send out RFQs to suppliers to let them determine the costs of one or multiple parts of the final product. The output of this step in the process of quotation is a direct input for the QD-174, in which the financial calculations of the project will be made. We can see in Figure 20 what values are calculated for the Avg. VA and NVA times as well as for the corresponding standard deviations. Regarding the NVA times, we see a negative number, just as with the design plan and the delta specs, and know that the preliminary supplier launch plan is finished before the delta requirements are finished, on average. Which directly implements that the preliminary supplier launch plan is finished before the first quality gate has been signed off. The calculations however can also be a little misleading since we work with averages and averages can give clear insight over a global view, but are not specific for the cases that are taken into account. As a direct consequence, when looking at the data from the individual cases, there is only one case in which the preliminary supplier launch plan was finished before the delta specs were finished.

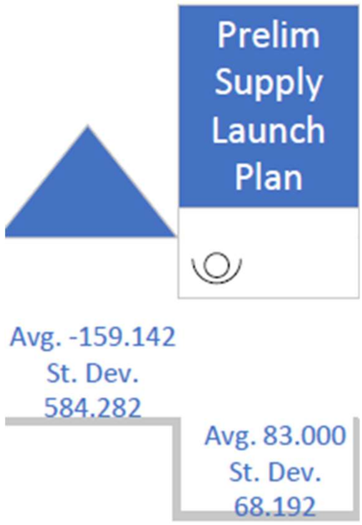


Figure 20: (N)VA times preliminary supply launch plan

The average LT of this step is -113.143 working hours and the standard deviation of the LT is 600.638 working hours.

4.2.15 QD-174

From the previous paragraphs, we know that some of the information gathered in those steps is input for the QD-174 document. To be more precise, the concept design/BOM, the process flow chart, packaging, DV plan and supplier launch plan are direct inputs for the QD-174. The output of this step is a signed-off QD-174, on which financial approvement is most important to continue working on the quotation process. The quotation that eventually gets sent to the customer is based on the financial sheet in the QD-174. In the calculation of the averages and standard deviations for this process step, the sign-off of the financial sheet or the latest save date of the QD-174 is taken as the end date for this step. The save date of the QD-174 was taken in cases where there was no signature on the financial sheet of the document, but there was a sign-off of the second quality gate, insinuating that they did not (wanted to) wait for the approval of the finance manager, the finance manager or even for someone of higher rank in the company. In Figure 21, the calculated averages and standard deviations are shown. Since there are multiple steps executed in parallel before the QD-174 can be filled in and signed off, the start date of the QD-174 step is set to be the first end date of the steps that were executed previously. To elaborate on this a little more, the following formula in Excel was used to determine the LT of the QD-174:

*=NETWORKDAYS(MIN[End_DateProcessFlowChart;End_DatePackaging;End_DateDVPlan;End_DatePrelimSupplyLaunchPlan],End_DateQD-174,[Holidays]) * 8*

This formula calculates the net working days between the end date of one of the previously completed steps and the end date of the QD-174. This was chosen since the project manager can start filling in the QD-174, the moment one of the previous tasks is finished. The financial departments only work on the finance sheet of the QD-174 once everything is filled in accordingly. If a MAX[] algorithm would be used then the latest end date would be selected and it would insinuate that the project manager cannot work on the QD-174 after all previous tasks are finished. The formula also subtracts holidays from the working days to get net working days and to transfer these to hours the outcome is multiplied by 8.

The long NVA time of the QD-174 is caused by waiting signatures. Filling in the QD-174 is not that much work and doesn't take a long time, most VA time gets added by the financial department making the calculations. The major time waster for the QD-174 is collecting signatures from management as well as making sure that the project meets the company standards regarding margin of profit. As stated by an employee, there is no clear moment when and by who the decisions are made. The lack of overview also makes it hard for management to schedule moments for the sign-off and the review of the project. This could be a cause for the long LT of collecting the signatures that are needed. Busy schedules make sure that management have to schedule the review or the sign-off in a far future, on average about 5 weeks in the future. Automatically meaning that the quote will not be send to the customer for the next 5 weeks, or that the quote will be send as a preliminary and not a binding quote, which is against internal company regulations.

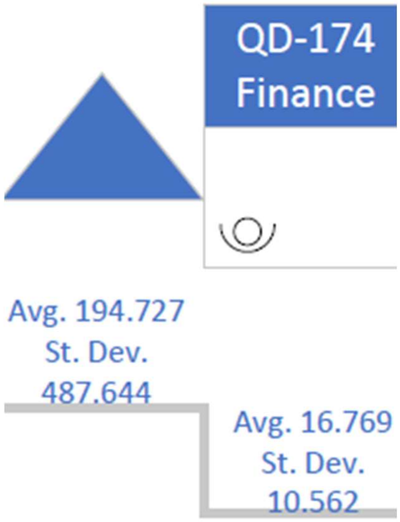


Figure 21: (N)VA times QD-174 finance

The average LT of this step is 208.727 working hours and the standard deviation of the LT is 484.289 working hours.

4.2.16 4-Block

The 4-block is a sheet in the PM-07 and in the NPD Dashboard, where the project schedule and the project Need-To-Know are located. For the 4-block are no NVA time calculations available since the 4-block is a sheet that keeps getting updated throughout quality gates 2 and 3. Meaning that the latest version of the 4-block might be after the quotation was submitted to the customer and false data would be used giving wrong insights. What is calculated, is the Avg. VA time and the St. Dev. VA time of the 4-block, which are 3.818 and 1.800 working hours, respectively.

4.2.17 Quotation

The quotation is the final step in the process of quotation. After the quote has been sent to the customer the company representatives, account manager and/or sales director, negotiate with the potential customer. After both parties come to an agreement they move on to warranty agreements, Customer PO, recalculation of the financial sheet in the QD-174, updating the 4-block, lessons learned and another QG sign-off are executed. As mentioned in the Research Scope, this is not within the scope of this research.

For the quotation step, the input is the signed-off QD-174, since the quote is based on the financial calculations desired to make sure the company meets their internal standards. The start date of the quotation step is set to be the end date of the QD-174 since you should have the approval of the company management. In Figure 22, the Avg. and St. Dev. of the NVA and VA times are shown. The Avg. VA time is 1 hour and the St. Dev. VA time is 0.000 hours, meaning that in no cases there was a deviation from the mean.

The NVA time average is calculated to be -117.000 hours or -14.625 working days. A possible reason for a negative average could be that the company sends quotes before the approval of the financial management or other higher-ranked employees. From all cases, 37.5% of quotes were sent with a negative lead time compared to the QD-174 document.

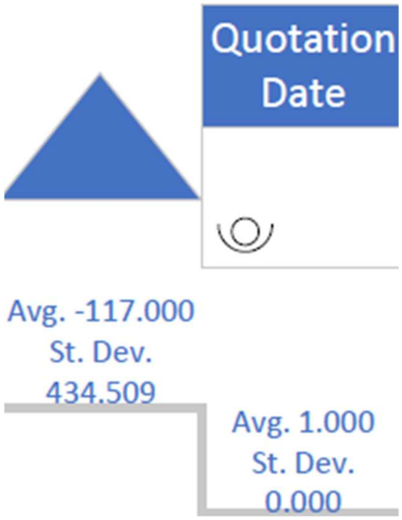


Figure 22: (N)VA times quotation

The average LT of this step is -102 working hours and the standard deviation of the LT is 408.289 working hours.

4.3 Critical Paths

For each of the four project risk classifications, “Alien”, “Major”, “Minor” and “Same As” the company has some differentiation in the critical paths for each of the classifications and has different lead times for the entire quotation process as well. The lead times are schematically shown in the table below:

Table 6: Lead Times for the different risk classifications

Risk type	Desired LT by Gits Mfg. Co.	Actual process LT	Desired Reduction of LT
“Alien”	560		
“Major”	320	221.3	$+44.6\%$
“Minor”	160	720	-77.78%
“Same As”	64	728	-91.21%

All values are given in working hours, unless expressed otherwise.

The different risk classifications all have different internal schedules and for the “Same As” classifications there a deliverables left out of the process, since the problem and the product can be mostly derived from earlier designed products, these steps don't have to be executed again to eventually come up with a details pricing and product. The 4 different schedules are displayed below:

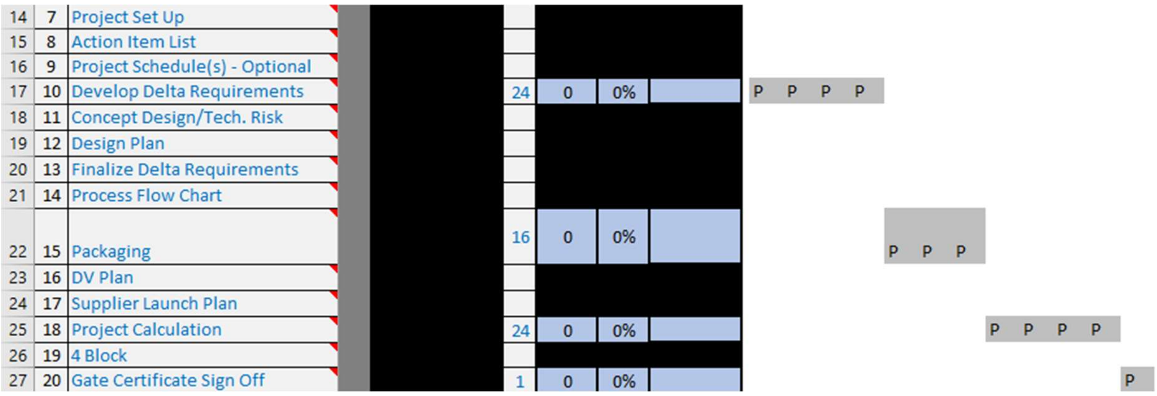


Figure 23: Schedule and deliverables "Same As"

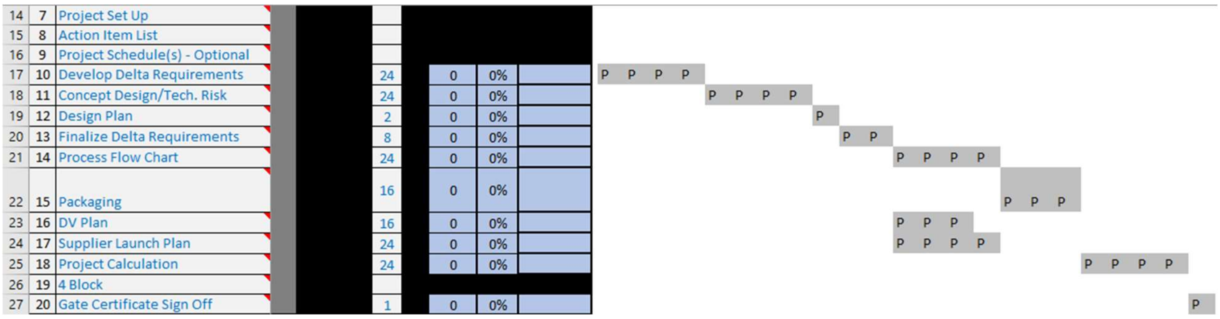


Figure 24: Schedule and deliverables "Minor"

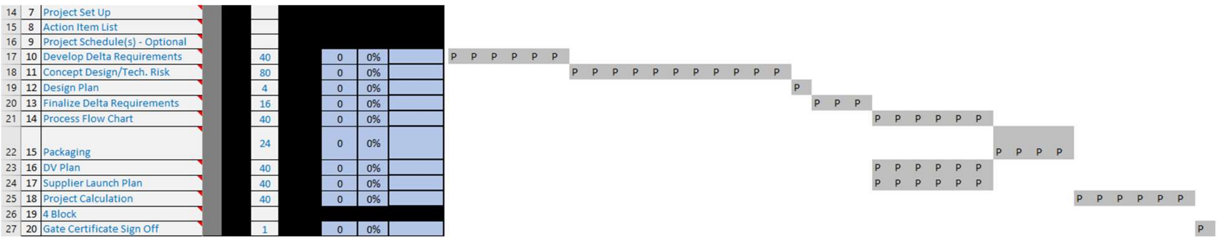


Figure 25: Schedule and deliverables "Major"

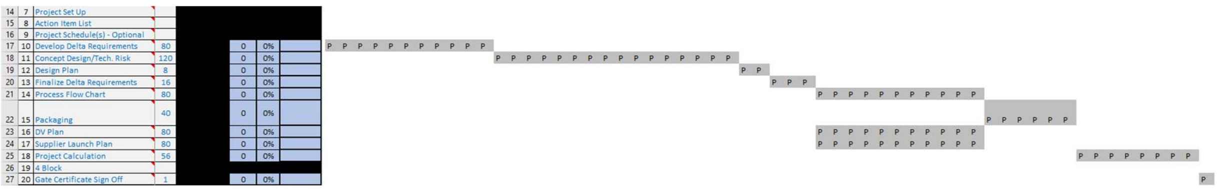


Figure 26: Schedule and deliverables "Alien"

As can be seen, the schedule for Alien is a lot longer than the schedule for “Same As” and for the “Same As” classification not all deliverables have to be completed. The first column after the stated deliverables gives the scheduled working hours per deliverable, which is the major input for the schedule provided in the images.

From Table 6, in combination with the total LT of different processes, the company was capable of meeting their deadline 21.43% of the time. The average number of days too late was calculated at 66.25 working days, which equals 530 working hours. To be able to meet their deadlines, the average quotation process has to be improved by 560 working hours for “Minor” projects and 664 working hours for the ”Same As” projects. The Major projects have an average days to late of -112 working hours, meaning that they are, on average, on time with submitting the quotation for those RFQ requests.

To calculate Z%, we use Equation 1:

$$\frac{(X - Y)}{Y} * 100\% = Z\%$$

For the “Same As” project, the average LT has to be reduced by 664 working hours, since the company is now 664 working hours late for their deadline. For the “Same As” projects, the average VA time is 344.500 working hours. Note that this would be 344 working hours if the entire process were executed in series and there would not be any parallel execution of tasks, this would not fit in the LT of the company of 64 working hours. The critical path of “Same As” projects can be found in Critical Path “Same As”.

The calculation of Z% gives the following value, for this risk classification: $X - Y = -664$ working hours and Y is defined at 728 working hours. This gives the value of $Z\% = \frac{-664}{728} = -91{,}21\%$.

For the “Minor” project, we found that the average LT has to be reduced by 560 working hours. “Minor” projects have an average of 157 hours VA time, which is less than VA time for “Same As” projects. Unlike “Same As” projects, this VA time fits in the LT of the company and the critical path might not be the major subject that has to change. The major improvements must be realised by reducing waiting time in these “Minor” project quotation processes. The critical path of “Minor” projects can be found in Critical Path “Alien”, “Minor” and “Major”.

The calculation of Z% gives the following value, for this risk classification: $X - Y = -560$ working hours and Y is defined at 720 working hours. This gives the value of $Z\% = \frac{-560}{720} = -77.78\%$.

For projects with the risk classification of “Major”, we have room to execute processes more slowly. However, the hours too late of -112 hours is an average and therefore there are also quotation processes executed that did not meet the company deadline. Giving us room for improvement, just not the ability to calculate the percentage that is needed. “Major” quotation processes require an average of 388.556 working hours of VA time to complete. The 388.556 working hours VA time only fits in the company LT if the process uses parallel execution and since they have an average of -112 hours too late, the company does this quite well. To further improve, the focus of improvement can be more on time waste reduction instead of process improvement. The critical path of “Major” projects can be found in Critical Path “Alien”, “Minor” and “Major”.

For Alien projects, there are no averages available, nor standard deviations, since there is only one properly documented Alien quotation process. The data from this process is therefore not comparable to other Alien processes and possible delays might be a singular event. Nevertheless, to mention this quotation process, it was 2104 working hours regarding the company deadline. Leaving an improvement of 1544 hours or 73.38%. The only executed Alien process however has a VA time of 388.000 hours. Even if the execution of this quotation process would have been done completely in series, and there would be no parallel execution of tasks, they would still be on time. The NVA time in this process is therefore so large that it suggests that external factors, like change in demand from the customer, change in technical aspects or failure to satisfy the customer would be logical. The critical path of Alien projects can be found in Critical Path "Alien", "Minor" and "Major". Calculating Z% based on 1 case, would not give reliable information and would be changed rapidly if a new Alien project would be executed.

4.4 Conclusion

From the data calculated for the different steps in the quotation process, there are multiple interesting aspects. The negative LTs for multiple steps in the process raise a question about the process itself, do the employees who handle the RFQ for the customers follow the quotation process or do they execute tasks a little differently than scheduled? Negative NVA calculated for a step most certainly were started before the ancestor task was finished and if the LT was also negative then we can also conclude that the step was finished before the previous step was finished. The averages give insight into the overall execution of the process but do not provide insight into current workflows or specific cases. To give a global overview of workflow and the usage of parallelisation in the process execution, the following chart was constructed. The calculated average VA and NVA time per executed process are schematically shown below, in Figure 27.

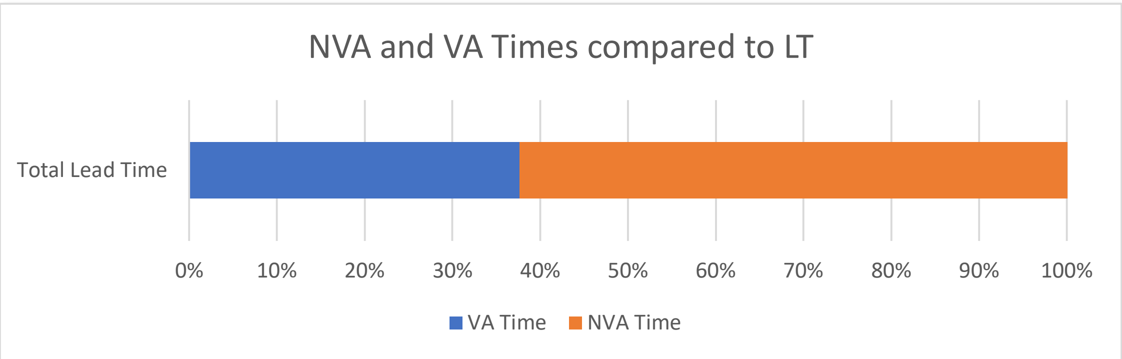


Figure 27: Average NVA and VA Times, in %, compared to LT

The ratio VA time against NVA time is about 3: 8. 37,66% VA time and 62,34% NVA time, both compared against 794.426 total working hours per quotation process on average. From the analysis of the data presented in Analysing the Current Process, the following conclusion can be drawn. Overall the process at Gits Mfg. Co. is a stretched process in which different departments form a multidisciplinary team to eventually come up with a details quotation for a product that satisfies the potential customer to the best of Gits Mfg. Co.'s ability. The target Lead Times, set by the company itself, is hard to meet and currently, the projects with the smallest risks do not meet the supposed deadline. Some tasks contribute a lot to the total NVA time, or time waste, of the total process. Resulting in a long LT for the processes, but also giving room to improve without changing the actual process they have established right now. Tasks that are currently adding a lot of time waste, are the Project Charter, QG sign-off, the making of the Delta Specs, the process flow chart and the calculations in the QD-174. Especially in “Same As” and “Minor” projects the Project Chart, Delta Specs and process flow chart take tremendous amounts of time, while the VAS time in these risk classes lower is than the average time spent on these tasks. The risk classifications do not give a general estimate of the lead times of the projects. The negative NVA times and the negative LT provide insight into how the process gets executed. In particular the negative NVA times and negative LT of the quotation step show that the final step doesn’t wait for management approval and that in some cases the quotation gets sent to the customer and approval gets collected afterwards. This perfectly fits with the hallway talk about the difficulty and time-consuming process of collecting signatures of the management team to approve the quotation.

5 Integration, recommendations and implementations

This chapter provides the integration of theory into the company, even as the recommendations and possible implementations are described here.

5.1 Integration of theory into Gits Mfg. Co.

Regarding the process design at Gits Mfg. Co., the new process design is based on lean principles from Ward and Sobek II (2014). The company invested a lot of resources and hours in the development of a new, improved and more professional process design that can easily be followed by everybody within the company.

As mentioned in Data Collection and Calculation, the company Business-Value-Added time is not separately defined. The Business-Value-Added time is included in the VA time. For the sake of calculation or determination of the LT and NVA times, the Business-Value-Added times do not have to be defined separately. These tasks are necessary to eventually develop a fully binding quotation that satisfies the customer as well as the company. Removal of these steps, the steps that only add Business-Value-Added time is therefore not possible. The Value-Added times calculated are derived from a document stored at the company drive. These VA times contribute towards the value of the final product, the full quotation that the customer receives, with all the details the customer requests. One could argue that since the quotation is not something the customer has to pay for, all executed tasks and all VA times are in fact NVA times. However, the company itself decides if they invest resources into the development of the quotation, in the Project Charter they estimate those required resources, and only at the nomination does the customer pay for used hours to make the quotation. Possible lean management tools, such as 5S, VSM, kanbans, TQM and Six Sigma (even better would be Lean Six Sigma) can help improve the quotation process even further. In the RFQ process at Gits Mfg. Co., 5S can be used to rearrange and further improve the process by reducing and sorting the different steps, by applying seiton, seiri and maybe even seiketsu and shitsuke. The implementation of Lean Six Sigma would focus on reducing waste, something that fits perfectly in the recommendations of this research. Besides waste reduction is Lean Six Sigma also very useful for increasing the throughput time and it would be useful to increase the impact of Lean with data-driven rigour and variation control of Six Sigma. Actual tools of Six Sigma that were used were flow charts, as well as VSM.

JIT, SMED and Heijunka, as stated in Holl, Pardo and Rama (2010), McIntosh et al. (2000) and Slack and Brandon-Jones (2019), respectively, won't be much of use for improving the process. JIT focuses on delivering just-in-time so that stocks stay low and SMED is focused on reducing start-up. Heijunka focuses on levelling the production to send smaller batches more frequently.

Time dimensions of lean improvement are used to provide insight into the process at Gits Mfg. Co.. The wait time is determined as the NVA time, the throughput time is the lead time of the process and cycle time is the time a single station, in this process a step, takes to be completed. The cycle time is calculated as the VA time of steps of the process.

The specific implementation of these tools makes it hard to apply at the company, also since it is not a manufacturing process in which these tool will be implemented. The process is a service process, in which people are the operators and there is no standardized production line that always operates with the same variables. The fact that this hardens the implementation of solutions is also mentioned by Caffyn (1997), who stated that implementing CI in NPD processes is more difficult than implementing lean methods in manufacturing processes. These differences are shown in Table 4.

The design of the process at Gits Mfg. Co. is in line with the findings of Harmancioglu et al. (2007), since the company uses a stage-gate process, requires deliverables at every task and the sequence of execution of these tasks, together with the responsible departments, are listed clearly. The goal of the company is to reduce the risk of giving a wrong price and according to McDermott and O'connor (2002), the stage-gate process results in this. Supervision of seniors is currently present at Gits Mfg. Co., guiding the process. This is stimulated by McDermott and O'connor (2002) but at the same time in contradiction with Miller, Dröge and Toulouse (1988), since they found that seniors may decrease the creativity in problem-solving and therefore repress the possibility to innovate. At the company they also use seniors but since the company has quite recently introduced a new NPD process together with a new QMS, the idea of repressing innovation by seniors does not apply.

The generic form of an NPD process, suggested by Tuli and Shankar (2015), is partly recognizable in the process at Gits Mfg. Co.. The first 2 gates show similarities with the planning and definition phase, but actual quotations are not in the generic form of Tuli and Shankar. Regarding the statements of Adler et al. (1996), the work and capacity management and reduction in variation do not apply to Gits Mfg. Co. at this moment. The company is not monitoring the work and capacity of the personnel. Besides this, there is also room to reduce the variation in the execution of the process, making sure that everybody executes the process according to schedule and does not execute steps before previous steps are executed, the development times can be reduced by 30-50% (Adler et al., 1996). An additional advantage is also the possibility of reducing the development times. From Table 4, the following differences apply to the process at Gits Mfg. Co., longer time scales, since the process takes a long time to fully execute. NPD is an iterative process, this is found back especially when the Delta Specs are made and simultaneously the Concept Design is made. The execution of these 2 steps often is at the same moment and eventually, the Delta Specs are finalized with the Concept Design and the Design Plan. Making this an iterative process as many deliverables are revised during the process. The quality in the process is also difficult to measure, when is a deliverable of high quality or when can the label of High Level be given to, for instance, a BOM? It is also hard to evaluate frameworks, how to measure possible improvements in the scope of quality is difficult and also the problem of measuring things that are not measurable. As brought up by Ho and Lin (2009), the schematic, systematic and multidisciplinary process is already present at Gits Mfg. Co., and so are the topics they suggested should be included. The suggestions by Caffyn (1997), regarding 3 major points for managers to make CI possible could be used as recommendations to further improve the process at the company. Finally mention Karlsson and Ahlström (1996) again, the major idea is to align everything always in the same order, same value, structures and processes should be placed at Gits Mfg. Co., to assure that there is a concurrent process all the time and by these standardizations, the process can be executed faster. The process at Gits Mfg. Co. can now better prevent stalemates since management better knows how far the execution of the process is.

5.2 Recommendations and Implementations

The coming recommendations will be based on that integration of theory. To evaluate possible improvements, the management of the company should keep a close eye on the execution of the process and should monitor LT of the coming executed processes. Note, that this might also be a topic for further research, see Limitations and Further Research.

Recommendations towards Gits Mfg. Co., regarding their Quotation process to answer RFQs:

A. Implementation of Lean (Six) Sigma, to decrease time waste between different deliverables and to improve the throughput times, making those lower. By using Lean Sigma, by making scatter diagrams, flow charts and cause effect diagrams, the company can provide itself with insight for possible improvements. Locations were improvements are possible since the data shows correlations between certain causes of time waste. The correlation between these areas can provide structure regarding the implementation of improvement tools. The implementation of this recommendation can get the company one step closer to continuous improvement, in which the process stays subject to change.
B. Better monitor the workload of the employees regarding the capacity that is present to work on quotations. It is clear that the company currently only has a global, and estimated idea of the workload and not a precise workload of the employees working with the process. Dividing tasks could therefore be improved and assigning tasks could be more equally spread to lower workload and to make sure that personnel can start working on deliverables earlier. By doing this the NVA times can be reduced, for example for the Delta Specs and/or the Project Charter. This could be done by keeping a spreadsheet of tasks for the employees working on RFQs. By doing so the management and the project manager can easily find and assess the workload of individual employees as well as the entire department. The moment an employee or a department is not fully occupied, the tasks can be assigned to employees with low occupancy. Making sure that the employee does have time to take on the tasks and execute the tasks fully, meeting the deadline set by the project manager or the management team. This require close collaboration between the management team and the project manager as well as the Human Resource Department to evaluate possibilities to hire new staff. This recommendation can be implemented for every deliverable in the entire process. All steps can profit from this recommendation since all the steps require human interaction to execute the deliverable.
C. The idea of management not knowing where a process currently is, is even further confirmed by the lead times and the NVA time of the Project Charter. A document that has to be signed by the management team to agree to invest resources in the project. Currently, the NVA time of the Project Charter is very high compared to the VA times, which are on average below an hour. The signing off, of a charter, does not take a lot of time and the signing does make sure that the process can be executed further. Therefore, the management team should be better informed by the project manager on the current status of projects. Or, management should better follow the development of the projects that are under their responsibility. Guidance can be better given when the management team is closely involved with the projects. By doing so, in which this can be combined with H, the management team gets frequent updates anytime a deliverable is finished and/or uploaded. Current status are therefore more frequently updated and can be assessed more often. This recommendation can reduce the time it takes to collect signatures from management, making sure the process won't come to a halt. This recommendation can reduce the time waste for the QG Sign-Off, Charter, Bid/No-Bid and QD-174.
D. To continue on the execution of the project and being guided towards a good outcome, the projects also benefits from execution that is standardized. The way of working should be consistent all the time, with the same values, same structure, same processes and systems. This is to avoid stalemates in the project and to ensure that everybody knows the sequence of steps that are executed. The owner of this possible improvement is the project manager, which has to keep a close eye on the execution of the process. The execution of steps that do not follow the

project schedule can be terminated immediately and resumed the moment the task is up for completion. Adler et al. (1996); Caffyn (1997); Oppenheim (2004) aim for structured workflow with little to no variation in the execution of the workflow, to reduce stalemates, LT and to improve efficiency and development of new products. The deviation of these steps should be communicated clearly. The standardization of the process is immediately in line with one S of the 5S tool. The Seiketsu, standardize, of the process would decrease superfluous movements. The other S's, sort, and set orderly can also be used to improve the process. But since the process and the deliverables are clearly scheduled and the information is stored orderly, these would not influence as much as Seiketsu. The hard part is that the entire RFQ process is very iterative and moves forward and backwards over the deliverables and the steps in the process. However, sticking to the project schedule and close management will improve the process overall.

E. Regarding communication, more direct communication should be implemented at the company. This is necessary to implement pull in the system. The current communication regarding the completion of deliverables is more oriented towards a push system. In which the project manager assigns tasks to certain individuals/departments to execute, by doing so the departments can execute these tasks when they have time available. Of course, the priorities within a department are not in the scope of this research but setting a reasonable deadline for a task, in collaboration with the executioner, would be more in line with a pull system. Then the project manager is pulling information from departments instead of pushing tasks towards them. This also connects to the possibility of knowing the workload of individuals since the deadline is set together. If a deadline cannot be met, the employee might be too busy or the timeframe is unrealistic. The last recommendation, regarding ideas to improve communication, is also highly connected to this pull in communication. This recommendation, can positively influence all the deliverables in the process. The communication whether the next step can be executed can be a game changer in the execution of the overall process. The weekly meetings are nice to keep a global eye on the progress of the process but the completion of step A should immediately lead to the start of step B. Quality Gate 2 will benefit most of this improved communication since this gate is the most iterative and requires the most time and resources.
F. Reduction in variation, work and capacity management and continuous improvement can decrease development times by 30-50%, based on literature from Adler et al. (1996). This would, on average, mean a reduction of NVA times by 148,5-247,6 hours (or 18,56-30,95 working days).
G. The execution of the entire process gives a low-risk outcome to the probability of giving a price that eventually deviates from the actual price. To prevent resources from being invested and to gain a target price for a product under development, a ballpark quote could be a solution. A ballpark quote is currently already present at the company, but has to implemented more and quicker. Most preliminary quotes are being send the moment the deadline approaches but there is no final quote available yet, at least not with full management approval. By sending a ballpark quote the customer can give a first line of feedback, when sending a price that is too high, the customer is forced to respond with a lower offer. Giving a clear indication of what price they are willing to pay, give or take 20% or so. If the price the customer suggests is impossible to realise, the company can decline the RFQ and no resources are invested. Ballpark quotes may also give the potential customer the possibility to continue their internal processes since they can get a rough indication of the price of the product.

H. Implementation of AI can help improve communication within the organisation. The implementation of AI or digitalized kanbans saves the employees from sending the kanbans towards other employees. The automation also gives the possibility to send pings to employees if their deliverables are late, or if their task can start since the previous task is completed. Traditionally the kanbans are used to monitor inventory level before a work station. In the process of quotation, at Gits Mfg. Co., the company could use these kanbans to communicate placing deliverables in inventory. Which is a direct result of executing a step in the process. When this is done, the next step can be executed. To automatically inform the project manager and the next person in line of the process, the digital kanban can be send to the corresponding employee. Giving them the information that otherwise would be send manually. The delay in communication between departments and/or employees can hereby be decreased. Functionality of AI can further be used to collect and analyse big data, data that would not be processable by humans since it is simply too much to handle. A tool that is available for this is Parashift, which is an AI Cloud IDP with OCR. Meaning that the AI is in a cloud-based environment, it is a Intelligent Document Processing platform which allows businesses to integrate AI into their architecture. Parashift has Optical Character Recognition to convert images of text to machine-readable text formats. A major solution that Parashift provides is that it can process forms in any format, automates communication as long as it is digital and the AI can process invoices, create them and send them. The logistics sector, in which Gits Mfg. Co. is present, benefits from Parashift by integrating document automation into the existing processes and applications of Gits Mfg. Co. Different possibilities for AI implementation are available, next to Parashift there is also V7, Nutanix and Microsoft Azure AI. Many AI-based cloud environments are currently available to automate, connect and analyse the data that is being processed.

6 Conclusion

This chapter provides answer to stated research question and its sub-questions.

To answer the main research question:

> "*How can Gits Mfg. Co. improve the lead time of the RFQ process, from Y amount of time to X amount of time, by reducing time waste in the process*?"

We first have to answer the sub-questions:

1. What is the current lead time of the RFQ process, making a distinction between the different risk classifications? (Current State/Reality)
2. What critical path does each of the risk classifications generate?
3. Which tasks contribute to time waste in the total process?
4. Which methods can be used to (further) improve the total process of quotation at Gits Mfg. Co?

The answer the first sub-question, this is mostly based on the data analysis of the previously executed RFQ process of the company. From the data analysis and the calculations conducted the average LT per risk classification can be found in the table below. The most interesting

Table 7: Average LT per risk classification

Risk type	**Actual process LT**	**NVA Time**
"Alien"	2664 working hours (based on 1 available process)	2276 working hours
"Major"	221.3 working hours	- 203 working hours
"Minor"	720 working hours	601 working hours
"Same As"	728 working hours	383.5 working hours

For the second sub-question the answer is based schedules in combination with the deliverables that each of the risk classifications demand. The deliverables and the schedules of the different risk classifications together come to a critical path in which the process should be executed according to the company norms for the process execution. As we can conclude the schedules of the company are not met, except for some "Major" projects that were finished on time. Most of the quotation process don't meet the internal deadline for the completion of the quote. This gets then solved by sending out a preliminary quote to the customer to stay in the race for nomination but the internal process is not completely finished on time. Regarding VA time the internal schedule of the company can be met, give or take a few hours. Implementing the NVA time in the schedules as well gives a more realistic and more current overview of the actual time needed to fully execute the process and give the customer a full binding quote. A realistic schedule, of an average process execution, can be found in Appendix D: Realistic Process Schedule.

The answer to the third sub-question is schematically displayed in Appendix B: VSM Quotation Process. Here all different deliverables of the entire process are shown with their NVA and VA times. The major time waste contributors for the process are the Customer Specs (external time waster), Bid/No-Bid, Project Charter, QG Sign-Off, Delta Specs Made, Process Flow Chart and the QD-174.

From Recommendations and Implementations, to answer sub-question four, we can conclude that the following methods, techniques and tools can be used to improve the RFQ process at Gits Mfg. Co.:

- Implementation of Lean (Six) Sigma, to decrease time waste between different deliverables and to improve the throughput times, making those lower.
- Better monitor the workload of the employees regarding the capacity that is present to work on quotations.
- The idea of management not knowing where a process currently is, is even further confirmed by the lead times and the NVA time of the Project Charter. A document that has to be signed off by the management team to agree to invest resources in the project.
- To continue on the execution of the project and being guided towards a good outcome, the projects also benefit from execution that is standardized. The way of working should be consistent all the time, with the same values, same structure, same process and systems
- Regarding communication, more communication should be implemented at the company. This is necessary to implement pull in the system.
- The execution of the entire process gives a low-risk outcome to the probability of giving a price that eventually deviates from the actual price. To prevent resources from being invested and to gain a target price for a product under development, a ballpark quote is a solution.
- Implementation of AI can help improve communication within the organisation. The implementation of AI or digitalized kanbans saves the employees from sending the kanbans towards other employees.
- Reduction in variation, work and capacity management and continuous improvement can decrease development times by 30-50%. This would, on average, mean a reduction of NVA times by 148,5-247,6 hours (or 18,56-30,95 working days)

By implementing these 8 recommendations, based on the Theoretical Framework, the overall NVA time of the process can be reduces drastically. The impact on “Minor” and “Major” processes will be the greatest since these processes have the longest LT. The “Alien” project requires such new technologies and such specific solutions that the company has never designed before that the outcome regarding the product is more important than having a quick quotation for the customer. The “Same As” projects require much fewer steps and therefore are much less influenced by changes.

To answer the main research question:

> “*How can Gits Mfg. Co. improve the lead time of the RFQ process, from Y amount of time to X amount of time, by reducing time waste in the process*?”

The company of Gits Mfg. Co. should implement as much recommendations as possible to reduce the overall NVA time of the total process. Some recommendations can be implemented throughout the entire process and some recommendations are more specific for certain problems occurring at certain points in the process. To meet the X, stated by Gits Mfg. Co., the process have to reduce by a lot of working hours. The − means that the process has to decrease the LT and the + means that the company has time left in the process and that they are actually quicker than desired.

Table 8: X and Y amount of time

Risk type	X amount of time	Y amount of time	Desired Reduction of time
“Alien”	560		
“Major”	320	221.3	$+98.7$
“Minor”	160	720	-560
“Same As”	64	728	-664

7 Limitations and Further Research

This chapter contains the limitations of the research and proposes bases for further research.

Regarding the limitations of this research and its reliability, there are certain points of concern. The selection of data might be taken into doubt, since at first only processes were selected that had enough documentation. Arguably the decision to include these processes, while not completely documented, or the opinion that they could give a better average regarding the averages of each step, could be argued upon. Furthermore, the recommendations are based on the analysed data of the process. Management of workload and other capabilities within the company are not included in the research since then the scope of the research would be too much. To fully know the workload and the pressure upon the employees and the departments, all internal and external processes have to be taken into account. Proper evaluation of workload is then possible, and proper management can then be conducted. Also, in the collection of data, the data was collected to the best of the researcher's ability. Knowing that it is an iterative process, store dates are subject to change and therefore the dates collected might not be the exact date the deliverable was finished.

For further research, the effectiveness of improvements could be measured against the current situation. Validating the effectiveness of the prescribed improvements. Within that new research, the concurrent and iterative process could be redesigned according to ideas of certain sources that have a general design for the NPD process, focussed on CI. Further research can also clarify the effect of management on the execution of the process, making sure that the process is properly guided during the execution.

The implementation of properly designed AI and other automation could be analysed. Regarding the effectiveness of AI in the new NPD process with CI.

Since Gits Mfg. Co. is currently working on improvement, by introducing validated building blocks, the effect of these blocks can be analysed against the current state. The implementation of these validated blocks would be a good development and on this development, the ballpark quotes could be based. Providing more guidance in making the estimates for these ballpark quotes.

8 References

Adler, P. S., Mandelbaum, A., Nguyen, V., & Schwerer, E. (1996). Getting the most out of your product development process. *Harvard business review*, *74*(2), 134-&.

Bertagnolli, F. (2020). *Lean Management Introduction and In-Depth Study of Japanese Management Philosophy*. Springer.

Caffyn, S. (1997). Extending continuous improvement to the new product development process. *R&D Management*, *27*(3), 253-267.

Chen, T.-C. T., & Wang, Y.-C. (2022). *Artificial intelligence and lean manufacturing*. Springer. https://doi.org/10.1007/978-3-031-04583-7

Gupta, A. K., & Wilemon, D. (1990). Improving R&D/marketing relations: R&D's perspective. *R&D Management*, *20*(4), 277-290.

Harmancioglu, N., McNally, R. C., Calantone, R. J., & Durmusoglu, S. S. (2007). Your new product development (NPD) is only as good as your process: an exploratory analysis of new NPD process design and implementation. *R&D Management*, *37*(5), 399-424. https://doi.org/https://doi.org/10.1111/j.1467-9310.2007.00486.x

Heerkens, H., & Winden, A. v. (2017). *Solving Managerial Problems Systematically*. Noordhoff Uitgevers.

Ho, Y.-C., & Lin, C.-H. (2009). A concurrent function deployment-based and concurrent engineering-based product development method for original design manufacturing companies. *Journal of Engineering Design*, *20*(1), 21-55.

Holl, A., Pardo, R., & Rama, R. (2010). Just-in-Time Manufacturing Systems, Subcontracting and Geographic Proximity. *Regional Studies*, *44*(5), 519-533. https://doi.org/10.1080/00343400902821626

Karlsson, C., & Ahlström, P. (1996). The difficult path to lean product development. *Journal of product innovation management*, *13*(4), 283-295.

León, H. C. M., & Farris, J. A. (2011). Lean product development research: Current state and future directions. *Engineering Management Journal*, *23*(1), 29-51.

Liker, J. K., & Morgan, J. M. (2006). The Toyota way in services: the case of lean product development. *Academy of management perspectives*, *20*(2), 5-20.

McDermott, C. M., & O'connor, G. C. (2002). Managing radical innovation: an overview of emergent strategy issues. *Journal of Product Innovation Management: an international publication of the product development & management association*, *19*(6), 424-438.

McIntosh, R. I., Culley, S. J., Mileham, A. R., & Owen, G. W. (2000). A critical evaluation of Shingo's 'SMED' (Single Minute Exchange of Die) methodology [Article]. *International Journal of Production Research*, *38*(11), 2377-2395. https://doi.org/10.1080/00207540050031823

Miller, D., Dröge, C., & Toulouse, J.-M. (1988). Strategic process and content as mediators between organizational context and structure. *Academy of Management Journal*, *31*(3), 544-569.

Mintzberg, H. (1979). The structuring of organizations. Engle-wood Cliffs. *J: Prentice-Hall*.

Morgan, J. (2002). Applying lean principles to product development. *SAE in Manufacturing*.

Naeemah, A. J., & Wong, K. Y. (2023). Selection methods of lean management tools: a review. *International Journal of Productivity and Performance Management*, *72*(4), 1077-1110. https://doi.org/10.1108/IJPPM-04-2021-0198

Oppenheim, B. W. (2004). Lean product development flow. *Systems engineering*, *7*(4), no-no.

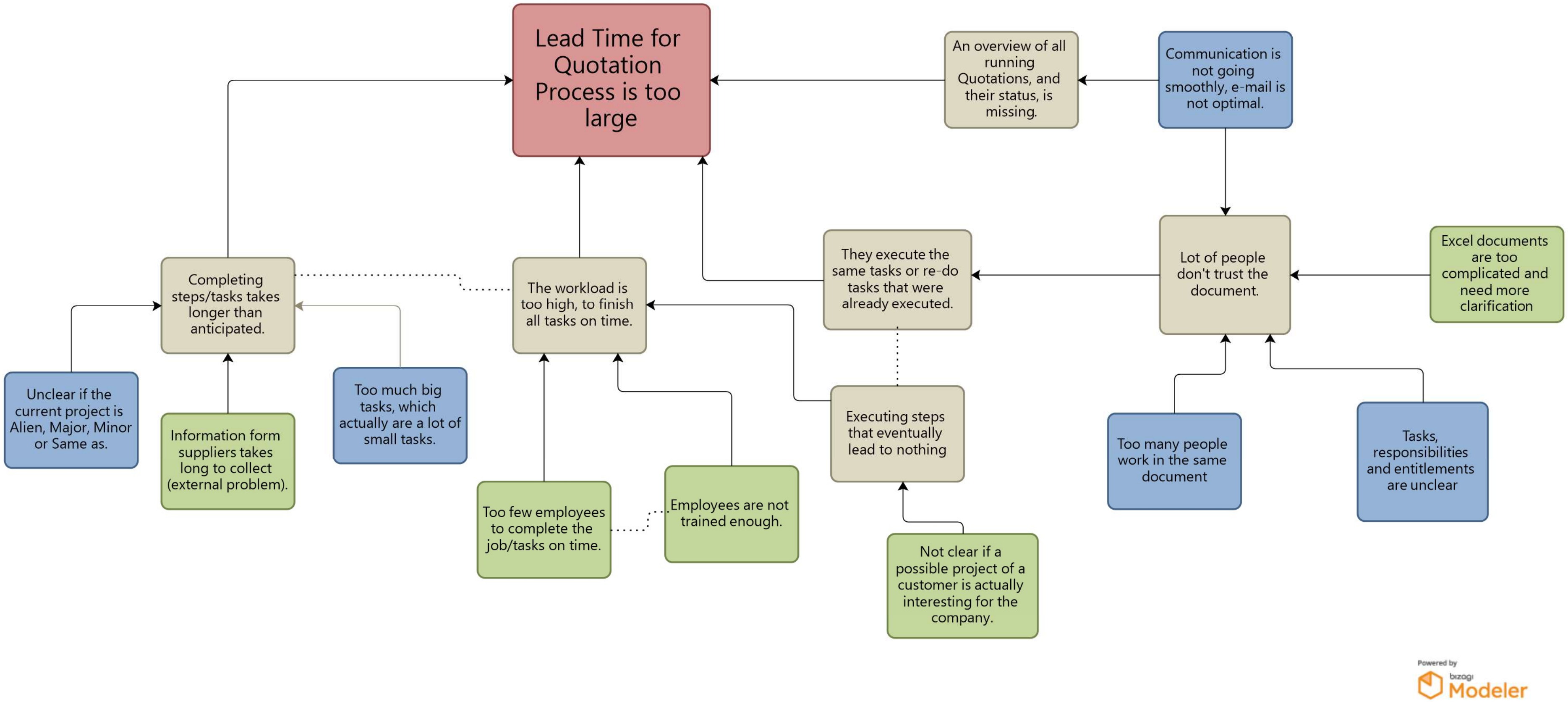
Sarkar, D. (2007). *Lean for service organizations and offices : a holistic approach for achieving operational excellence and improvements*. ASQ Quality Press Milwaukee, Wisconsin. http://site.ebrary.com/id/10929540

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research Methods for Business Students*. Pearson Education Limited.

Schindler, P. S. (2019). *Business Research Methods*. McGraw-Hill.
Singh, J., Gandhi, S. K., & Singh, H. (2022). 5S Concept Towards Performance Improvement: An Empirical Study [Article]. *IUP Journal of Operations Management*, *21*(4), 51-63. http://ezproxy2.utwente.nl/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=164034237&site=ehost-live
Slack, N., & Brandon-Jones, A. (2019). *Operations management* (Ninth edition ed.). Pearson Harlow, England.
Soliman, M., Oliveira Esteves, O., Trevisan, M., & Fogliarini Segatto, G. (2022). A tentative integration of value stream mapping (VSM) and BPMN for improved process mapping [Article]. *Knowledge & Process Management*, *29*(4), 371-382. https://doi.org/10.1002/kpm.1729
Tuli, P., & Shankar, R. (2015). Collaborative and lean new product development approach: a case study in the automotive product design. *International Journal of Production Research*, *53*(8), 2457-2471.
Vinod, M., Devadasan, S. R., Sunil, D. T., & Thilak, V. M. M. (2015). Six Sigma through Poka-Yoke: a navigation through literature arena. *The International Journal of Advanced Manufacturing Technology*, *81*(1-4), 315-327. https://doi.org/10.1007/s00170-015-7217-9
Ward, A. C., & Sobek II, D. K. (2014). *Lean product and process development*. Lean Enterprise Institute.

9 Appendix

9.1 Appendix A: Detailed Problem Cluster

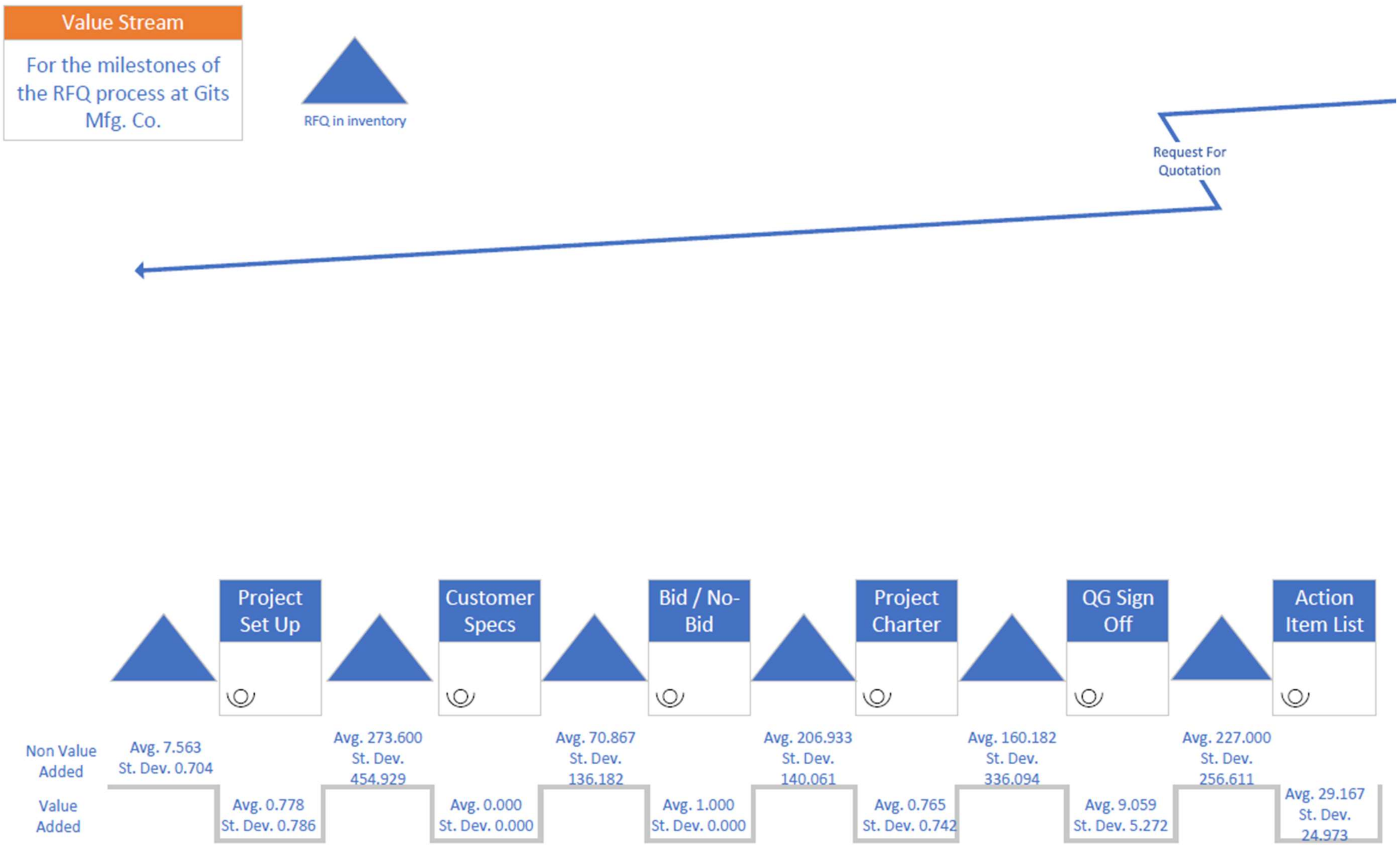


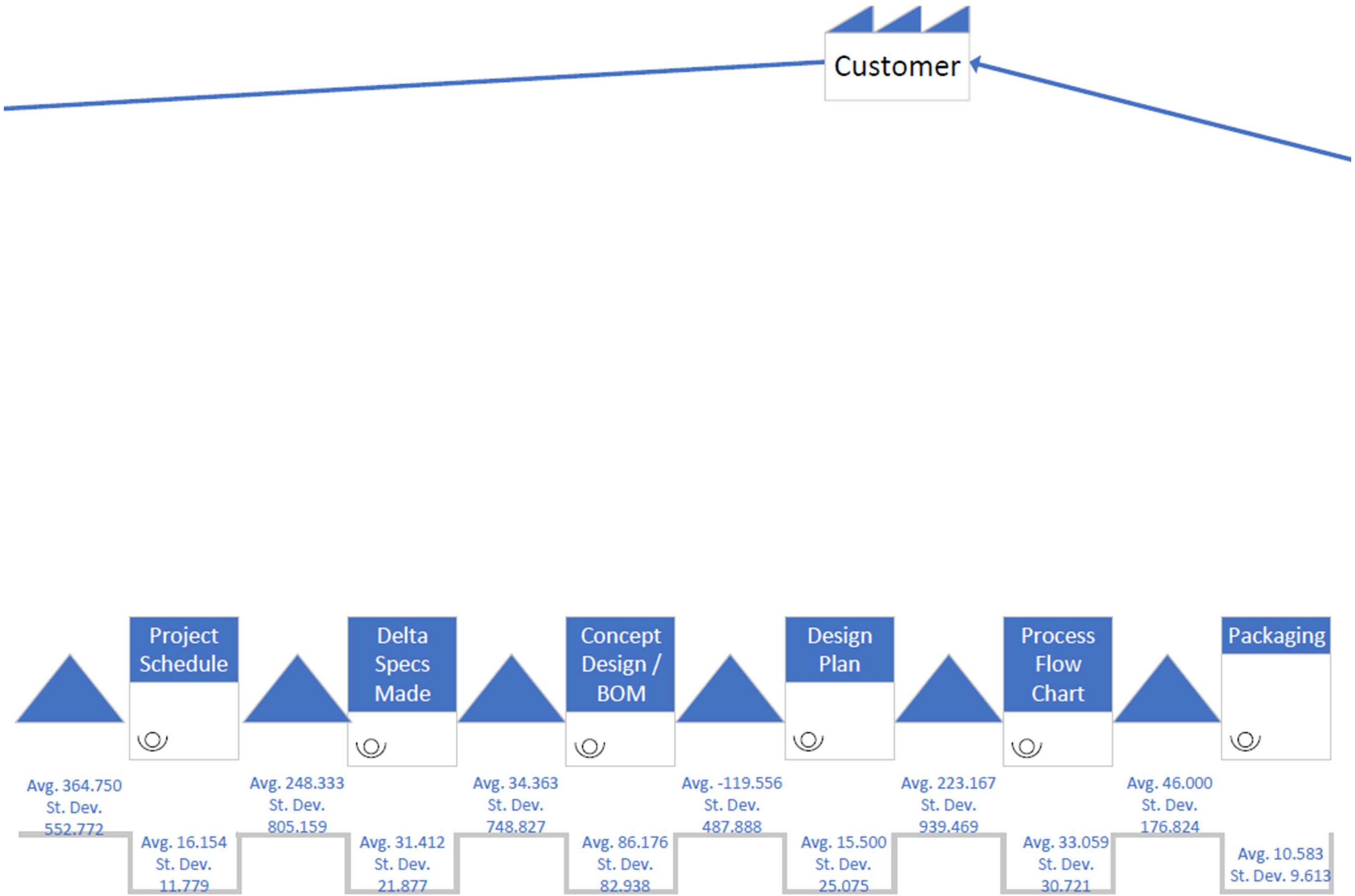
Blue: (potential) core problems

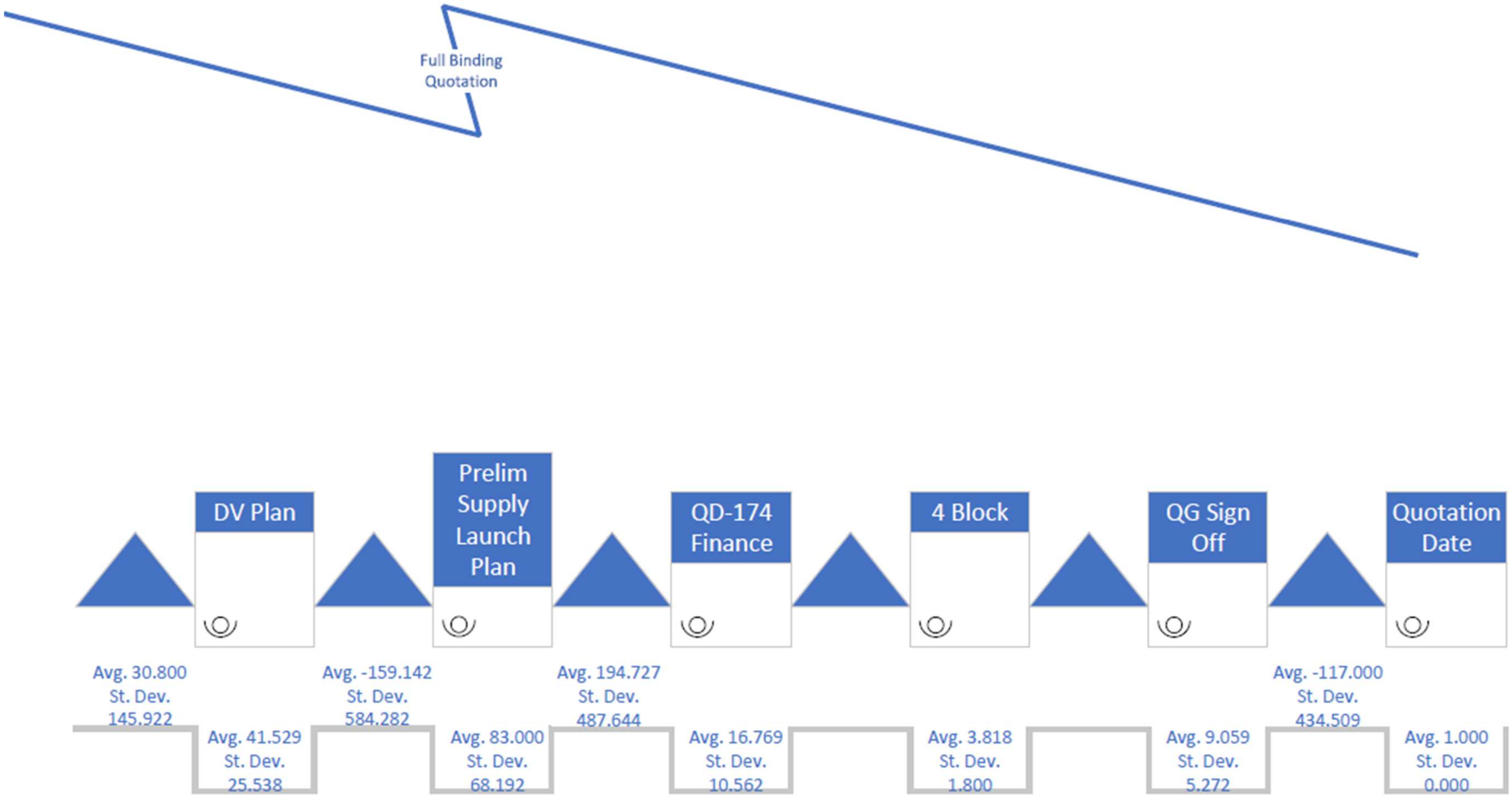
Green: cannot be influenced by me.

Red: problem as stated by Gits Mfg. Co.

9.2 Appendix B: VSM Quotation Process



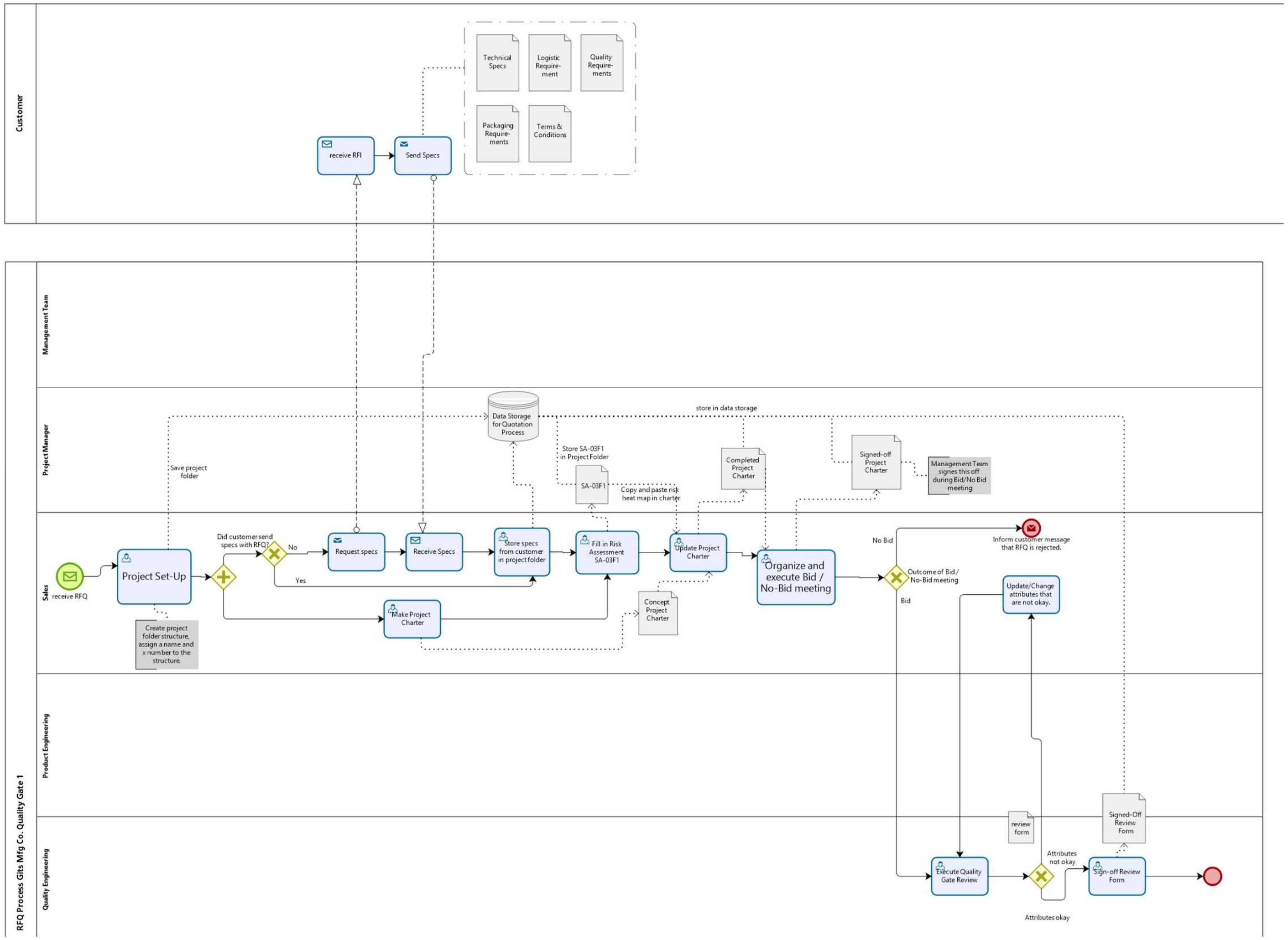

Customer
Project Schedule
Delta Specs Made
Concept Design / BOM
Design Plan
Process Flow Chart
Packaging
Avg. 364.750 St. Dev. 552.772
Avg. 16.154 St. Dev. 11.779
Avg. 248.333 St. Dev. 805.159
Avg. 31.412 St. Dev. 21.877
Avg. 34.363 St. Dev. 748.827
Avg. 86.176 St. Dev. 82.938
Avg. -119.556 St. Dev. 487.888
Avg. 15.500 St. Dev. 25.075
Avg. 223.167 St. Dev. 939.469
Avg. 33.059 St. Dev. 30.721
Avg. 46.000 St. Dev. 176.824
Avg. 10.583 St. Dev. 9.613


Full Binding Quotation
DV Plan
Prelim Supply Launch Plan
QD-174 Finance
4 Block
QG Sign Off
Quotation Date
Avg. 30.800 St. Dev. 145.922
Avg. -159.142 St. Dev. 584.282
Avg. 194.727 St. Dev. 487.644
Avg. -117.000 St. Dev. 434.509
Avg. 41.529 St. Dev. 25.538
Avg. 83.000 St. Dev. 68.192
Avg. 16.769 St. Dev. 10.562
Avg. 3.818 St. Dev. 1.800
Avg. 9.059 St. Dev. 5.272
Avg. 1.000 St. Dev. 0.000

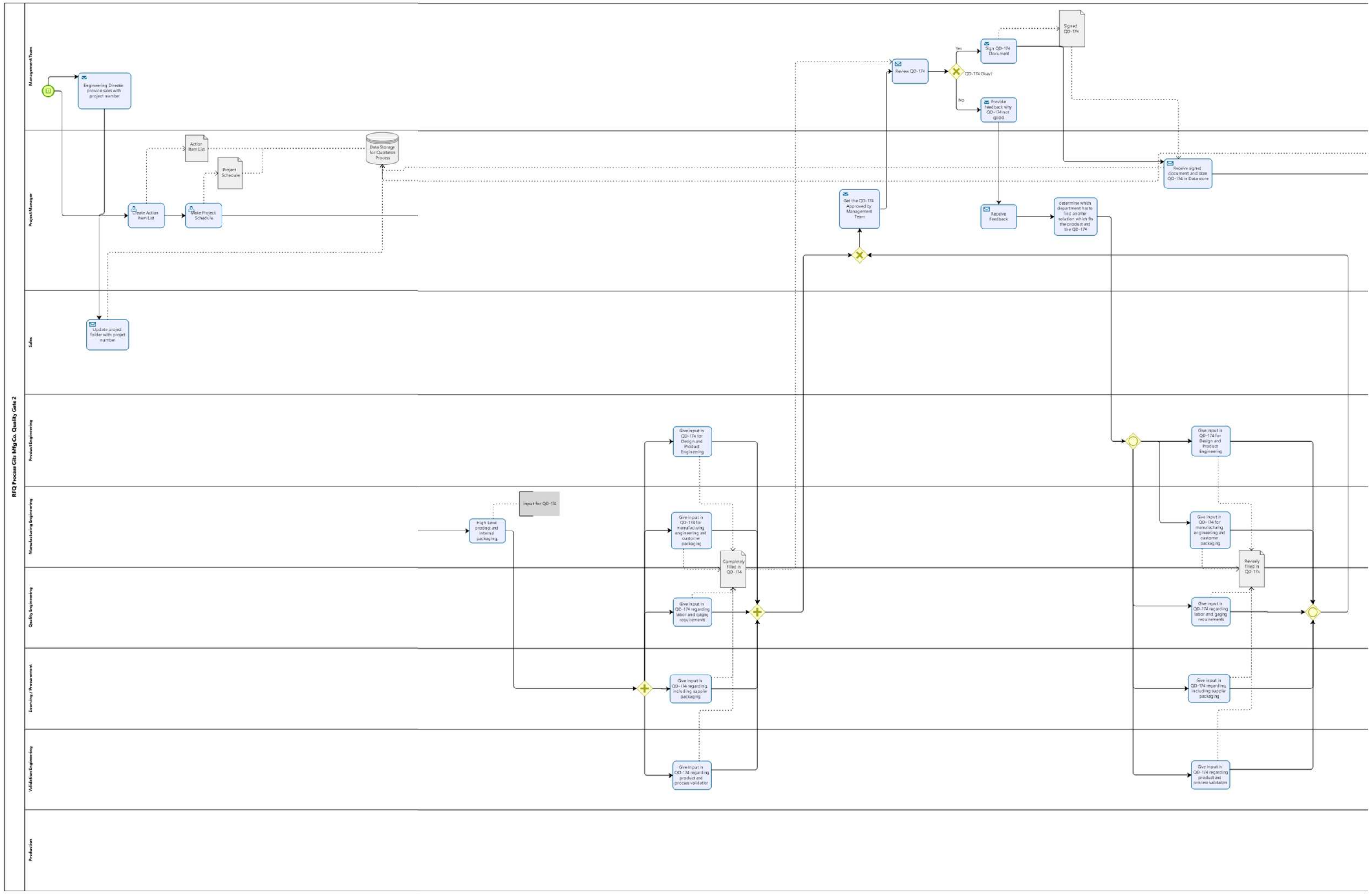
9.3 Appendix C: Critical Paths

9.3.1 Critical Path “Same As”

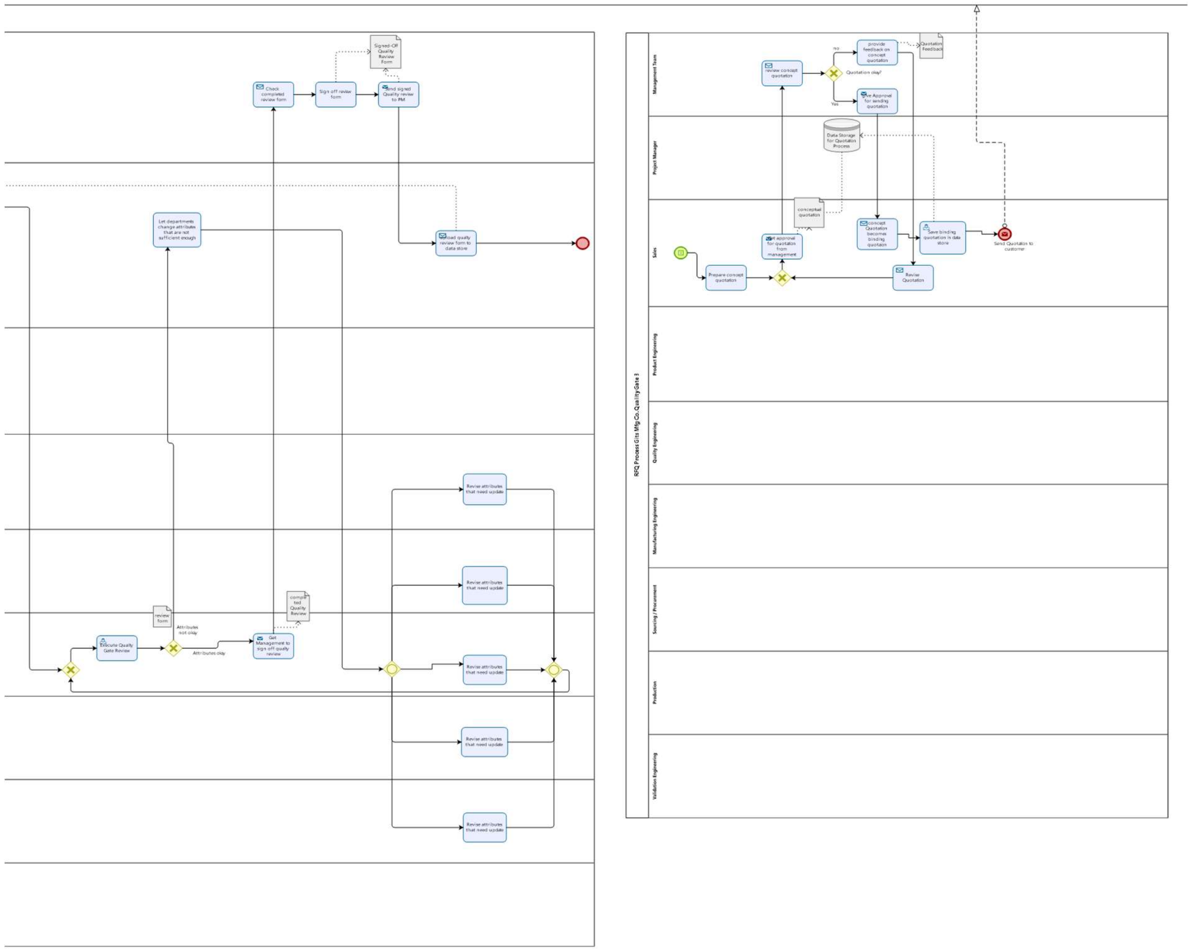
Quality Gate 1.



Beginning of Quality Gate 2

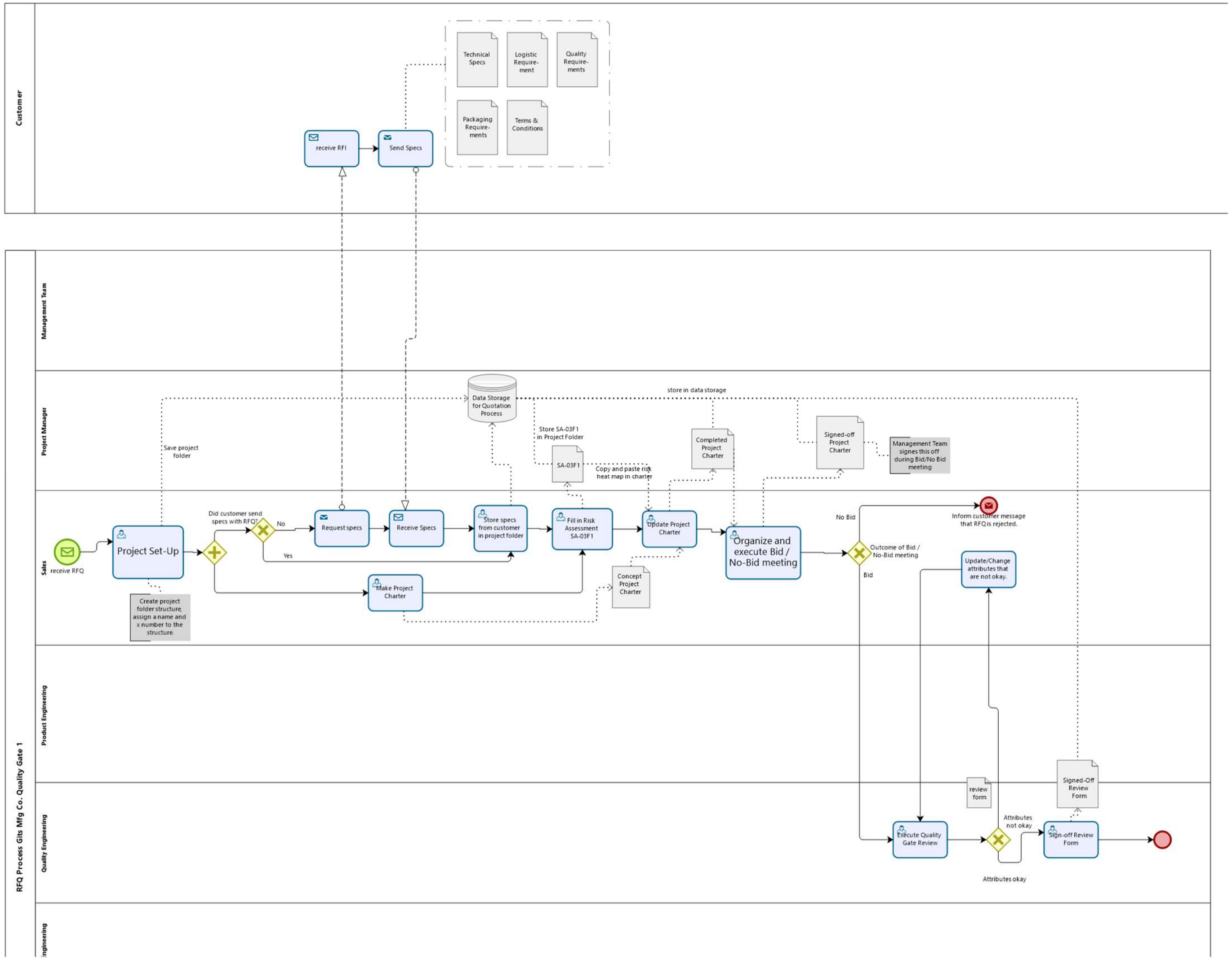


End of Quality Gate 2 and sending the quotation.

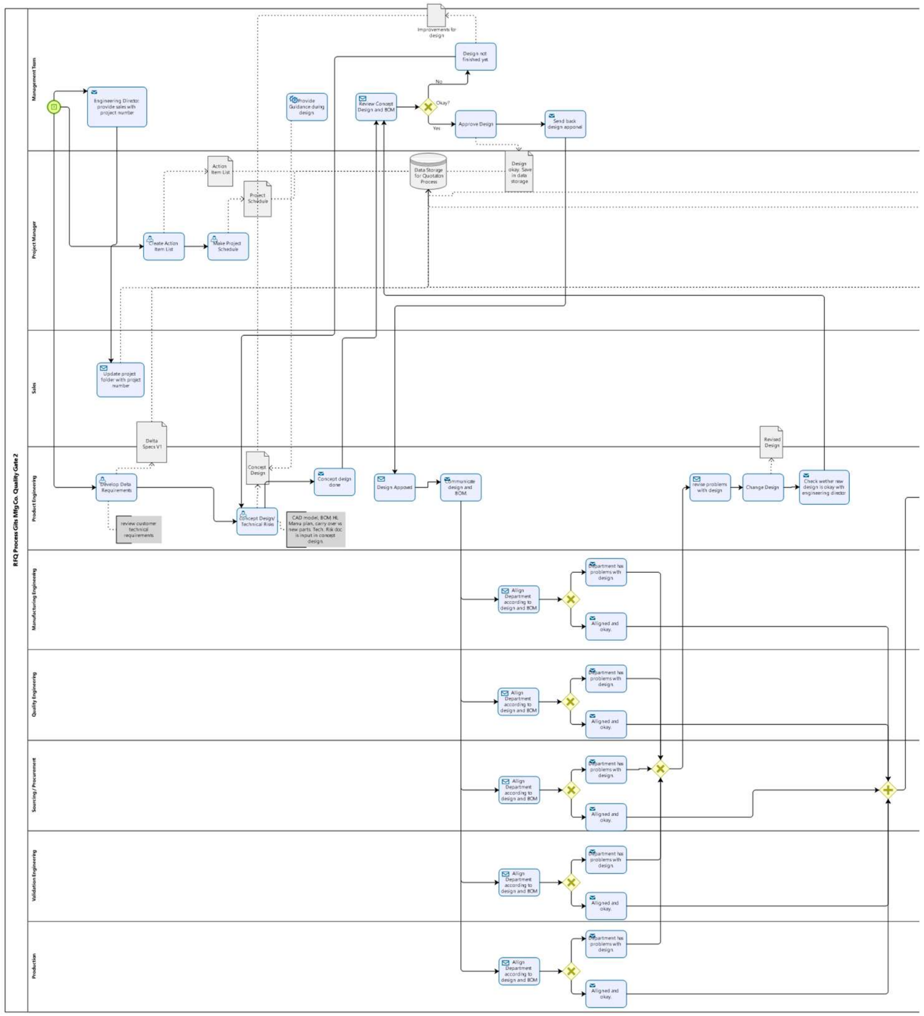


9.3.2 Critical Path "Alien", "Minor" and "Major"

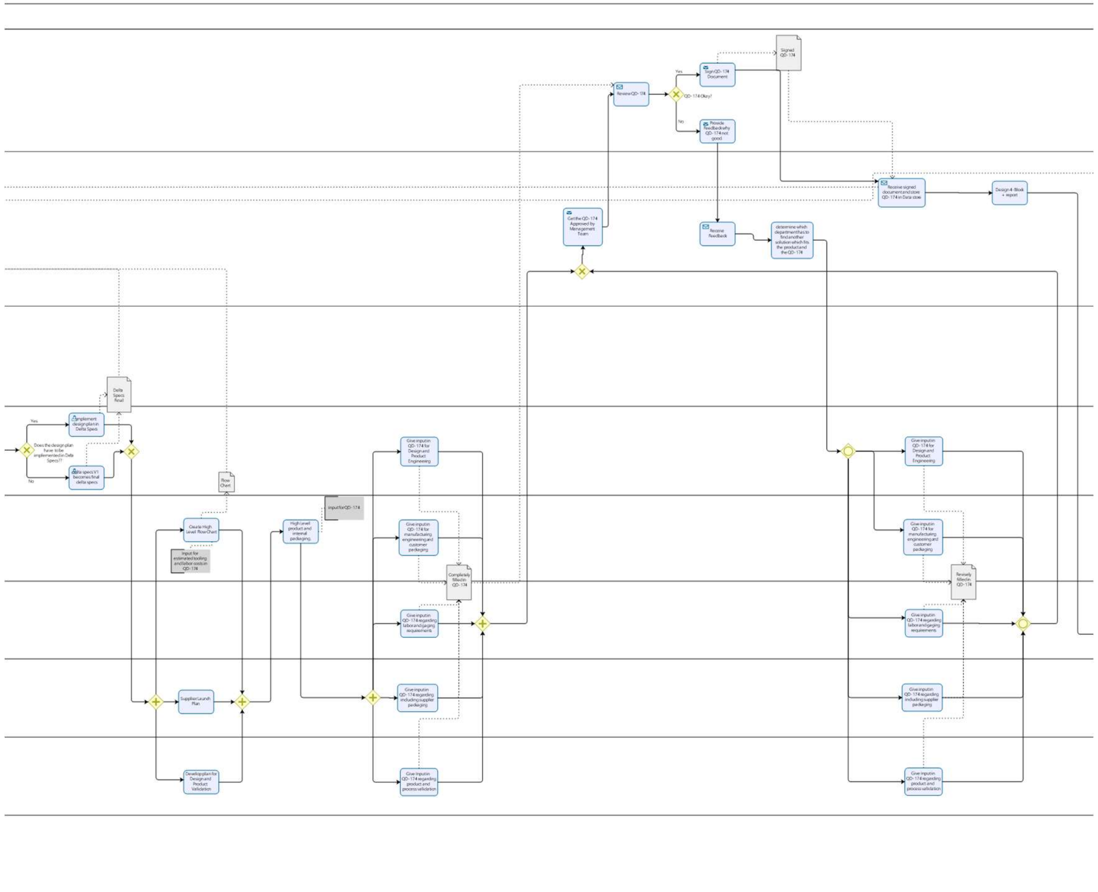
Quality Gate 1.



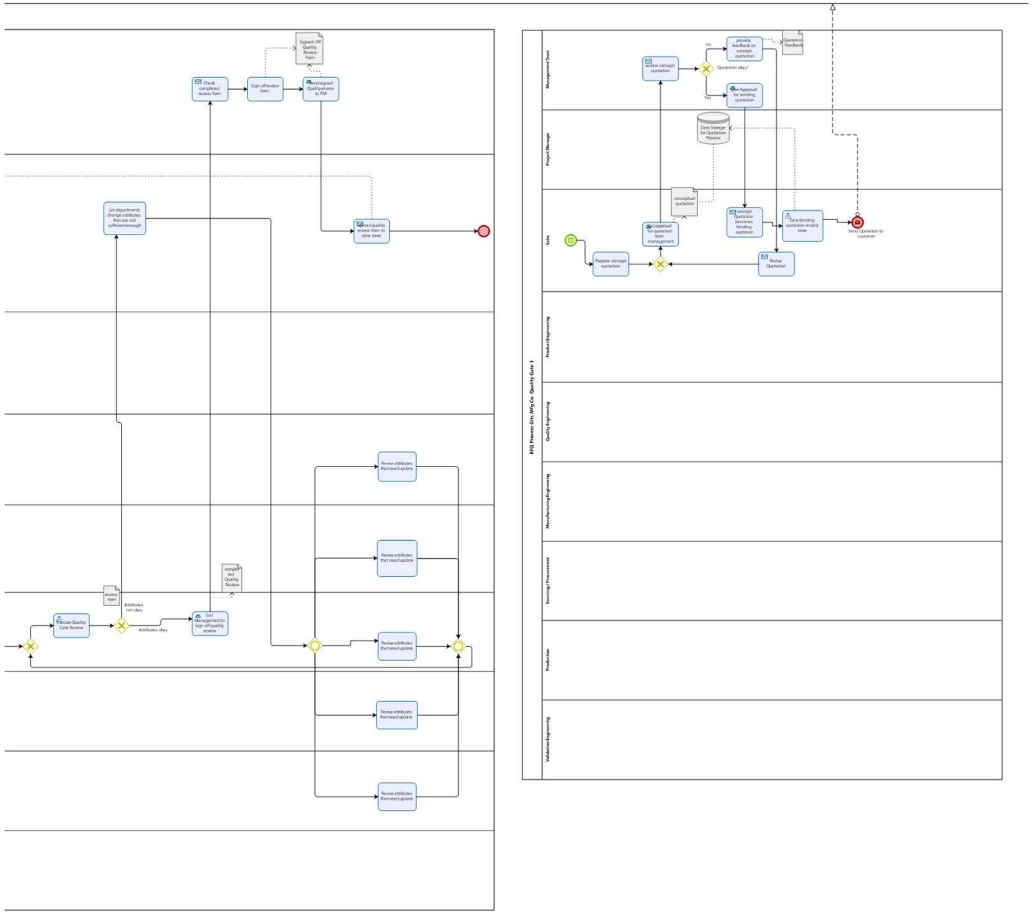
Beginning of Quality Gate 2



Middle of Quality Gate 2



End of Quality Gate 2 and sending of the quotation.



9.4 Appendix D: Realistic Process Schedule

Date	Monday, January 1, 2024	Tuesday, January 2, 2024	Wednesday, January 3, 2024	Thursday, January 4, 2024	Friday, January 5, 2024	Saturday, January 6, 2024	Sunday, January 7, 2024	Monday, January 8, 2024	Tuesday, January 9, 2024	Wednesday, January 10, 2024	Thursday, January 11, 2024	Friday, January 12, 2024	Saturday, January 13, 2024	Sunday, January 14, 2024	Monday, January 15, 2024	Tuesday, January 16, 2024	Wednesday, January 17, 2024	Thursday, January 18, 2024	Friday, January 19, 2024	Saturday, January 20, 2024	Sunday, January 21, 2024	Monday, January 22, 2024	Tuesday, January 23, 2024	Wednesday, January 24, 2024	Thursday, January 25, 2024	Friday, January 26, 2024	Saturday, January 27, 2024	Sunday, January 28, 2024	Monday, January 29, 2024	Tuesday, January 30, 2024	Wednesday, January 31, 2024	Thursday, February 1, 2024	Friday, February 2, 2024	Saturday, February 3, 2024	Sunday, February 4, 2024	Monday, February 5, 2024	Tuesday, February 6, 2024	Wednesday, February 7, 2024	Thursday, February 8, 2024	Friday, February 9, 2024	Saturday, February 10, 2024	Sunday, February 11, 2024	Monday, February 12, 2024	Tuesday, February 13, 2024	Wednesday, February 14, 2024
Day nr.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Deliverables:																																													
Project Set Up																																													
Customer Requirements																																													
Bid/No-Bid																																													
Project Charter																																													
QG Sign Off																																													
Action Item List																																													
Project Schedule (optional)																																													
Delta Specifications																																													
Concept Design / BOM																																													
Design Plan																																													
Process Flow Chart																																													
Packaging																																													
DV Plan																																													
Supplier Launch Plan																																													
QD-174																																													
4-Block																																													
QG Sign Off																																													
Quotation																																													

Thursday, February 15, 2024	Friday, February 16, 2024	Saturday, February 17, 2024	Sunday, February 18, 2024	Monday, February 19, 2024	Tuesday, February 20, 2024	Wednesday, February 21, 2024	Thursday, February 22, 2024	Friday, February 23, 2024	Saturday, February 24, 2024	Sunday, February 25, 2024	Monday, February 26, 2024	Tuesday, February 27, 2024	Wednesday, February 28, 2024	Thursday, February 29, 2024	Friday, March 1, 2024	Saturday, March 2, 2024	Sunday, March 3, 2024	Monday, March 4, 2024	Tuesday, March 5, 2024	Wednesday, March 6, 2024	Thursday, March 7, 2024	Friday, March 8, 2024	Saturday, March 9, 2024	Sunday, March 10, 2024	Monday, March 11, 2024	Tuesday, March 12, 2024	Wednesday, March 13, 2024	Thursday, March 14, 2024	Friday, March 15, 2024	Saturday, March 16, 2024	Sunday, March 17, 2024	Monday, March 18, 2024	Tuesday, March 19, 2024	Wednesday, March 20, 2024	Thursday, March 21, 2024	Friday, March 22, 2024	Saturday, March 23, 2024	Sunday, March 24, 2024	Monday, March 25, 2024	Tuesday, March 26, 2024	Wednesday, March 27, 2024	Thursday, March 28, 2024	Friday, March 29, 2024	Saturday, March 30, 2024	Sunday, March 31, 2024	Monday, April 1, 2024	Tuesday, April 2, 2024	Wednesday, April 3, 2024	Thursday, April 4, 2024	Friday, April 5, 2024	Saturday, April 6, 2024
46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97

Sunday, April 7, 2024	Monday, April 8, 2024	Tuesday, April 9, 2024	Wednesday, April 10, 2024	Thursday, April 11, 2024	Friday, April 12, 2024	Saturday, April 13, 2024	Sunday, April 14, 2024	Monday, April 15, 2024	Tuesday, April 16, 2024	Wednesday, April 17, 2024	Thursday, April 18, 2024	Friday, April 19, 2024	Saturday, April 20, 2024	Sunday, April 21, 2024	Monday, April 22, 2024	Tuesday, April 23, 2024	Wednesday, April 24, 2024	Thursday, April 25, 2024	Friday, April 26, 2024	Saturday, April 27, 2024	Sunday, April 28, 2024	Monday, April 29, 2024	Tuesday, April 30, 2024	Wednesday, May 1, 2024	Thursday, May 2, 2024	Friday, May 3, 2024	Saturday, May 4, 2024	Sunday, May 5, 2024	Monday, May 6, 2024	Tuesday, May 7, 2024	Wednesday, May 8, 2024	Thursday, May 9, 2024	Friday, May 10, 2024	Saturday, May 11, 2024	Sunday, May 12, 2024
98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133