Bachelor Thesis

# Improving the new product introduction time of a production company in the automotive industry

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Faculty of Behavioural, Management and Social Sciences (BMS),

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# I. Research Information

### Bachelor Thesis

Improving the new product introduction time of a production company in the automotive industry

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### Company

Company X

### Supervisors

| | |
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| Company Supervisor | Project Leader 2 |
| University Supervisor (First) | dr. ir. J.M.J. Schutten |
| University Supervisor (Second) | dr. ir. P. Hoffmann |

# II. Preface

Dear reader,

This document contains my bachelor's thesis that I performed at Company X to complete my bachelor's degree in industrial engineering and management at the University of Twente. The company where this research is conducted prefers to remain anonymous. Thus, I will refer to this company as Company X.

I want to thank Company X for the opportunity to acquire a lot of knowledge about product development and internal company processes. In addition, I also want to thank my supervisors Project Leader 1 and Project Leader 2 for helping me perform my research and answering all my questions about the company. I also want to thank Mr. M. Schutten for being my first university supervisor. His elaborate feedback and input helped me a lot to understand how to structure and perform this research. Next to this, I also want to thank my second supervisor, Mrs. P. Hoffmann.

Lastly, I want to thank my friends and family for putting up with me during this assignment.

I hope you enjoy reading this report.

Adeline Stiny

# III. Management summary

The research takes place at Company X in the Netherlands. Company X is a market leader in a specific field of the automotive industry and will remain anonymous in the continuation of this report.

Business is thriving and the company has had to quickly develop itself to facilitate the additional workload of the past few years. The New Product Introduction (NPI) time is the time it takes to take a product from concept to its final form. (*Understanding the New Product Introduction (NPI) Process - Pacific Research*, n.d.) The action problem for this research is the large increase in the NPI time at Company X. This increase is caused by multiple factors. The development project leaders believe that processes are placed and designed inefficiently in the NPI process chain. For example, some processes might take place sequentially when they could take place in parallel. This causes a lot of wasted time and encapsulates the entire NPI process chain. This research focusses on the suboptimal process flow design as the core problem. The core problem is expressed in the main research question:

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*"How can the New Product Introduction Time be improved and by how much?"*

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The New Product Introduction flow currently goes through 36 different processes and 8 different departments. Some departments have different teams. A team at Company X consists of a few employees from the department that perform a specific task within the department as a team. Teams can exist in different locations and work separately from the other locations. Table 1 shows the total overview.

| **Department** | **Team** | **Location(s)** | |
|---|---|---|---|
| Business Development | Product Management | Netherlands | |
| Finance | | Netherlands | |
| Research and Development | | Netherlands | |
| Product Development | Project Leaders | Netherlands | |
| | Quality | Netherlands | China |
| | Logistics | Netherlands | China |
| | Technology | Netherlands | |
| | Costs/Purchasing | Netherlands | |
| Total Quality Management (TQM) | | Netherlands | |
| Production | | Netherlands | China |
| Archive | | Netherlands | |
| Customer Service | | Netherlands | |

*Table 1 Department and Team Overview*

Almost every team or department experiences operational issues. The issues in the same order as their occurrence in the NPI flow are:

1. Not enough research is performed to analyse which projects need to be prioritized
2. Many projects are prioritized impromptu which causes delays in other projects
3. Communications between the Netherlands and China often take a long time
4. Meetings often lack preparation and follow-ups from the attendees
5. The logistics teams are often included too late in the design process
6. The existing processes and functions lack detailed descriptions, including step-to-step explanations, checklists, responsibilities per person and clear policies
7. Purchasing and Logistics teams lack a good overview of suppliers, their products, delivery times and internal current stocks of parts
8. There is no system to track the progress of each department and team with regard to a project
9. The ERP system lacks an overview of the current stocks

In order to solve these issues, we perform literature research. This research shows multiple things:

Design For Six Sigma (DFSS) is the most suited method to construct design projects in Company X. DFSS contains multiple concepts:

- Project Charters: A description of the project that needs to be constructed before the project can take place.
- Management by Project: Dividing projects into individual assignments.
- Organizational steps: Setting up a management team and implementing the triple C (Communication, Cooperation, Coordination)
- Scheduling methods: using the Critical path method, the Program evaluation and review technique and Gantt Charts
- Design Phases
- Technical Design Reviews
- Control guidelines.

In addition to this, literature indicates that Bottom-Up Resource allocation method is the most suited to solve the issues that are experienced by Company X. This is a theory that relies on employees building their own schedule instead of having this task executed by project leaders. Last but not least, the literature indicates 10 steps that need to be taken to ensure productive meetings:

1. Answer preliminary questions
    a) Is the meeting really needed?
    b) Who needs to attend the meeting?
    c) How much time will the meeting take?
2. Clearly indicate the purpose of the meeting
3. Invite all the needed attendees
4. Develop an agenda with all discussion points for the meeting
5. Request attendees to prepare in advance
6. Assign roles to participants (Facilitator, Scribe, Timekeeper, Contributor, Expert)
7. Start the meeting on time
8. Make participants write down their questions to ask them at the end of the meeting
9. Make notes and list future steps and action points
10. Send a meeting recap or follow up to all participants

Last but not least, to make sure that the changes in the company are implemented successfully, it is important to carefully construct a change project. This is a step by step plan on how to apply changes within a company while paying attention to several possible failure factors.

Based on this literature review, the recommendations are:

- Create a business case before every project in order to create a clear view of the value of the project and substantiate which projects obtain priority. Section 3.3.1.1 describes the way to construct the business case.
- Use the PERT or Gantt Scheduling method and Bottum-Up Resource allocation method as described in Sections 3.3.4.2, 3.3.4.3 and 3.4 respectively in order to create reliable schedules that avoid delays.
- Follow the DFSS organizing steps as described in Section 3.3.3 to create an efficient design project.
- Use the guidelines described in Section 3.5 to organize and structure meetings in the future.
- Waste less time and effort in the design processes by including the logistics teams earlier in the design processes as they can procure information that is useful in early design steps.
- Invest into creating clearer process and function descriptions all around Company X in order to avoid mistakes and create a clear overview of who is responsible for what. Since doing this is a very elaborate project, it is recommended to focus on the processes that are experiencing the most issues. Namely:
  - Processes for entering data into the ERP system
    i) Order entry processes
    ii) Project, part, material and document naming processes
    iii) Data deletion processes
  - Requirement Document (A0) Standards
    i) Design specifications
    ii) Delivery Time
    iii) Expected Purchasing amounts
  - Logistic Policy documentation
  - Release Processes
    i) Document uploading checklists
    ii) Responsibilities between releases
- The final recommendation is to analyse current systems for further possibilities in the following directions:
  - Creating an overview of suppliers, their products, delivery times and internal current stocks of parts that are needed for prototypes for the purchasing and logistics teams
  - Creating a way to track the progress of each department and team with regard to a project

We recommend implementing recommendations 1, 4, 5 and 7 in parallel and respectively executing recommendations 6, 3 and 2 sequentially.

**The time it would take to implement all the solutions would equal around 2 years and 47 weeks. The NPI time is expected to decrease by an estimated 8.875 months if all the proposed solutions are applied. Reducing the average 20 months (19.89 months rounded up as stated in section 1.2.1) by 8.875 months means that a project would take about 11 months to complete. Thus, the company goal for projects to take around 1 year would be achieved.**

We also recommend improving processes in the future by using a balanced scorecard method with a cross-efficiency model in a data envelopment analysis. This will make it easier for the company to keep track of their processes and improve them when necessary.

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| Abbreviation | Meaning |
|---|---|
| NPI | New Product Introduction |
| ERP | Enterprise Resource Planning |
| QLTC | Quality, Logistics, Technology & Costs |
| ROI | Return On Investment |
| R&D | Research and Development |
| TQM | Total Quality Management |
| TPD | Technical Product Documentation |
| DTV | Document Technisch Voorschrift |
| PDM | Product Data Management |
| BPMN | Business Process Modelling Notation |
| CPK | Process Capability Index |
| DMAIC | Design, Measure, Analyse, Improve, Control |
| DFSS | Design For Six Sigma |
| SMART | Specific, Measurable, Achievable, Realistic & Time bounded |
| CPM | Critical Path Method |
| ES | Earliest Start |
| EF | Earliest Finish |
| LS | Latest Start |
| LF | Latest Finish |
| PERT | Program Evaluation and Review Technique |
| TDR | Technical Design Review |
| DEA | Data Envelopment Analysis |

# 1. Introduction

This chapter introduces the problem that is analysed in this report. It explains the background of Company X and the problems that they experience. In addition to this it elaborates on the research questions and phases that are needed to solve the problems.

## 1.1 Company Description

This section describes Company X and the products it fabricates.

### *Company X*

The research takes place at Company X in the Netherlands. Company X is a market leader in the field of a specific car part in the automotive industry. The company's headquarters are in the Netherlands whereas its factories are mainly in China. To keep the company anonymous, this report does not include further details that could give away its identity.

### *Product Streams*

2 different product streams can be identified within Company X: the A line and the B line. The way of developing and producing the A line is completely different compared to the B line. The big difference between the 2 lines is the way in which the designs are constructed. Product line A receives its designs from customers whereas the teams and departments of line B have to design them themselves. This research focusses on the B line since the A line processes are going smoothly.

## 1.2 Problem Description

This section elaborates on the issues that Company X experiences.

### 1.2.1 Action Problem

Business is thriving and the company quickly developed itself to facilitate the additional workload. The New Product Introduction (NPI) time is the time it takes to take a product from concept to its final form. (*Understanding the New Product Introduction (NPI) Process - Pacific Research*, n.d.) According to the project leaders, the NPI time has seen a huge increase due to the growing amount of work.

| Project no. | Name | Start date | Expected end date | Days | Months |
|---|---|---|---|---|---|
| **ABC-000063-04** | Product ab Phase B | 17/12/2018 | 12/07/2019 | 207 | 6.90 |
| **ABC-000258-03** | Product ac Sales Ready | 02/09/2020 | 28/02/2022 | 544 | 18.13 |
| **ABC-000275-05** | Product ba QLTCs Improvements | 02/09/2020 | 25/06/2021 | 296 | 9.87 |
| **ABC-000301-07** | Product c Series B Release | 21/05/2021 | 31/01/2022 | 255 | 8.50 |
| **ABC-000368-03** | PDM Live - Product a Series Conversion | 03/12/2021 | 31/03/2022 | 118 | 3.93 |
| **ABC-000368-04** | PDM Live - Product b Series Conversion | 05/07/2022 | 25/11/2022 | 143 | 4.77 |
| **ABC-000393-01** | Product bb – Phase A Concept Choice | 18/06/2021 | 30/07/2021 | 42 | 1.40 |
| **ABC-000413** | Product d Revision 8 | 09/02/2022 | 07/06/2022 | 118 | 3.93 |
| **ABC-000423-01** | Product e Implementation -Technical Ready | 22/04/2022 | 03/06/2022 | 42 | 1.40 |
| **ABC-000424** | Product d Revision 9 | 22/04/2022 | 02/12/2022 | 224 | 7.47 |
| | | | **Average** | **198.9** | **6.63** |

*Table 2 Expected Project Planning*

Table 2 is obtained from the ERP system of Company X and shows anonymized data of new product introduction projects. The introduction process is split into different phases. Different NPI projects can be recognized by their structure “ABC-xxxxxx-xx” in the Project no. column. The last 2 numbers in this string indicate the phase of the project. Since some projects need more iterations than others, the number of phases needed differs per project. The project leaders indicate that the average project uses at least 3 iterations. Using the average phase duration as obtained from Table 2, an average project takes 19.89 months (6.63 months per phase x 3 phases) or 1.6575 years. Looking at project no. ABC-000258-03 however, this phase takes 18 months. The time used for each phase in the New Product Introduction varies a lot and can go up to 3 years for certain projects according to the project leaders. The management of the involved departments expects this to be caused by multiple bottlenecks in their process flows but has no clear overview of the total flow.

There is not much data available to compare these current projects to however, interviews with project leaders and employees indicate that the NPI is taking a lot longer than before the start of the growth. While growing, the company lost track of its process flows and increased its product design rates without optimizing its processes. This created inefficient ways of working. This report focuses on mapping every process that a new product goes through from being a product concept to being a finished product that can be sold to customers. The goal of this research is to reduce the New Product Introduction time as much as possible. The company would like all the projects to take around 1 year.

### 1.2.2 Problem Cluster

The project leaders at Company X have indicated that the long NPI is presumably caused by several factors. Figure 1 shows the problem cluster. The A and B in this figure identify 2 different problem directions and both relate to the B Line.

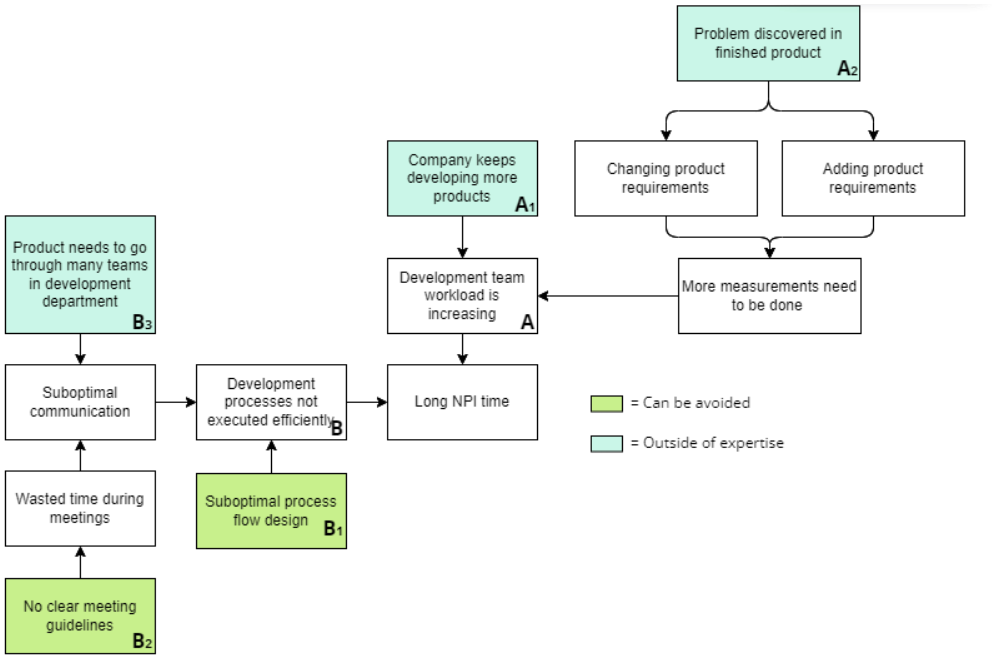


*Figure 1 Problem Cluster Company X*

The problem cluster is obtained from interviews with project leaders and is separated into problem directions A and B. A focusses on the workload that enters the system from an external source (problems identified by customers), whereas B focusses on the internal problems at Company X.

A summary of flow A: The workload of the product development department is increasing (A). This is caused by the development of new products that are requested by customers and by the number of requirements per product that keeps on growing. The number of requirements grows when problems are discovered in a finished product or when laws and new insights create the need for additional requirements (A2). If an issue is discovered, this means that the requirements that were initially used for the production of this product need to be altered and/or requirements need to be added. These altered and new requirements entail new tests and measurements to make sure that they are fulfilled and thus take up more time.

Flow B can be summarized: Development processes are not executed efficiently (B). Project Leaders indicate that this is caused by a suboptimal process flow design (B1) and suboptimal communication between the departments and teams. They state that these communication issues are caused by the large number of groups that are involved in the development of new products (B3) and the wasted time during meetings because the meetings do not have any clear guidelines (B2).

### 1.2.3 Core problem

The development project leaders believe that processes are placed and designed inefficiently in the process chain. For example, some processes might take place sequentially when they could take place simultaneously. This causes a lot of wasted time and encapsulates the entire development process chain. The main problem to handle in this situation is the *suboptimal process flow design*(B1). The only cause for the suboptimal flow design was the quick growth of the company which did not leave enough space for process optimization. At this moment there is no other cause directly influencing this that we would need to tackle first. The problem can be influenced by analysing the entire chain and reordering/shaping it where necessary.

## 1.3 Research Questions

This research is divided into 4 phases, each with its sub-question to answer the main question:

### 1.3.1 Main question

To solve the core problem, the main research question is:

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*"How can the New Product Introduction Time be improved and by how much?"*

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### 1.3.2 Phase 1 Current Situation

The first phase of this research focusses on mapping the current processes and their performance at Company X. The question that is answered in this phase is:

*Which processes are currently used in the New Product Introduction chain and are there any issues or challenges with the processes*?

The ERP system from Company X does not contain much information to answer this question as not much data is categorized per project and/or project phase and little data is collected in general. Thus, to solve this question we perform interviews in all the departments and teams that are involved with the New Product Introduction chain at Company X. To make sure that the information is accurate and obtained from multiple perspectives, multiple people from each department are interviewed where possible. To properly map the information obtained from these interviews, the data is displayed in a business model. Company X already has some process flows mapped out. We use Business Process Modelling Notations to build our NPI process overview since the already documented flows resemble this notation the most. This makes it easier for the employees to understand the model. This phase is documented in Chapter 2.

### 1.3.3 Phase 2 Theoretical framework

The second phase researches the existing literature to find theories that can improve the current NPI processes at Company X. The question that is answered in this phase is:

What methods exist in literature to optimize product development processes?

This phase is documented in Chapter 3 and gives an overview of techniques that can be used to construct an ideal development process chain and builds the basis of comparison for phase 3.

### 1.3.4 Phase 3 Measures

To apply the theory to the current situation, a comparison is made with the current situation to show where changes need to be made. This phase answers the question:

Which measures can be taken to improve the New Product Introduction Chain?

This phase includes a detailed plan of the measures and how to adequately apply them to the involved departments and teams at Company X. This phase is documented in Chapter 4.

### 1.3.5 Phase 4 Conclusion

The final phase of this research relates the previous phases to the main question. We answer this question using the information gathered from all the phases. This phase includes recommendations for Company X and further research areas and is documented in Chapter 5.

# 2. Current Situation

This chapter documents phase 1 of the research, the current situation of Company X. It describes the different teams and departments that are involved with the NPI flow. It maps all the NPI processes in a BPMN model and indicates what problems are experienced. The descriptions are not a guideline of how Company X should be working but a description of the actual workflow is performed. The issues mentioned in this chapter will then be used in Chapter 3 to find the appropriate theoretical solutions.

## 2.1 Product Release phases

A product goes through 4 phases before it can be mass-produced at Company X. These phases are called release phases since with each phase different new documents are released. Table 4 contains an overview of all the phases.

| **Release** | **Description** | **Responsible teams/departments** |
|---|---|---|
| A0 document | The requirements for the product need to be fixed. | Business Development |
| A release | The A0 documents need to be accepted. This gives the green light for a project to start. | Managing Board, Finance, Product Management, Product Development, Production |
| B release | All the requirements need to be met with the final design. Customers can order the product after this release. The product has reached its final form. | Product Management, Product Development, Production |
| C release | The product has to be produced a certain number of times to track down possible mistakes and optimize mass production processes. | Product Management, Product Development, Production |

*Table 3 Release Phases*

## 2.2 Department description

The New Product Introduction flow goes through 8 different departments. Some departments have different teams. A team at Company X consists of a few employees from the department that perform a specific task within the department as a team. Teams can exist in different locations and work separately from the other locations. Table 3 shows an overview of the involved groups.

| **Department** | **Team(s)** | **Location(s)** | |
|---|---|---|---|
| Business Development | Product Management | Netherlands | |
| Finance | | Netherlands | |
| Research and Development | | Netherlands | |
| Product Development | Project Leaders | Netherlands | |
| | Quality | Netherlands | China |
| | Logistics | Netherlands | China |
| | Technology | Netherlands | |
| | Costs/Purchasing | Netherlands | |
| Total Quality Management (TQM) | | Netherlands | |
| Production | | Netherlands | China |
| Archive | | Netherlands | |
| Customer Service | | Netherlands | |

*Table 4 Department and Team Overview*

### 2.2.1 Business Development

The process chain starts in the Business Development department. This department functions as the customer or internal client of the company. It receives product requests and remarks from customers and translates that into new products that need to be designed, alterations that need to be made to existing products, or research that needs to be conducted before new designs can be made. If a department has a question about the product, it will come back to this department with questions just as if it was the client that was requesting the product. This department also does its own market research to come up with new products that could be profitable to produce.

#### *Product Management*

Product Management is a small team within the Business Development department. Once a new product needs to be designed or an alteration needs to be made, this team will build the roadmap for the product by either performing additional market research or consulting with the customer. This roadmap contains all the requirements that need to be met in order for the product to be complete.

### 2.2.2 Finance

The finance department is responsible for signing off the project budget and checking the budget along the way of the designing process. Projects can only start once the finance department has released the project in the ERP system. In addition to this, the department is responsible for sending invoices to customers once they order products. If a project expects to entail high costs, this department is sometimes asked to analyze the Return On Investment (ROI) of the project.

### 2.2.3 Research and Development (R&D)

The R&D department is responsible for proving unproven theories within the company. This means they research whether certain requested requirements from the client are feasible to achieve with the current technology that is used by the company. This research is not always needed as new products can possibly be requested with clearly feasible requirements. However, if it is not clear whether requirements can be met, research needs to be conducted before the product development department can start designing it.

### 2.2.4 Product Development

The product development department is responsible for designing and building the actual product by using the roadmap from the Product Management. Multiple teams exist within this department.

#### *Project Leaders*

Once the requirements for a new product or alteration have been fixed, a project within the design department is started. These projects are led by a project leader. There are specific project leaders depending on whether the project's goal is to create a new product or to change an already existing design. The project leaders make a year plan at the beginning of each year to predict the expected projects and their capacity and time flow. Looking at this flow and the current projects that are running in the design teams, the project leader makes a specific plan for the new project.

#### *Quality*

Before a product reaches its B release, it needs to be tested to check whether it meets all the requirements from the A0 document. This is done by the quality team. This staff is located in the Netherlands as well as on the production site in China. The staff in China mostly performs the functional tests whereas the staff in the Netherlands assesses the theory (does it perform well within theoretically set boundaries) and reliability (does it perform the same every time). Once test data is received, it is analyzed together with the Total Quality Management (TQM) department and decisions are made to either change the design or move on to the B release of the product.

#### *Logistics*

The logistics team can be split into 2 parts: the logistics staff that is located in the Netherlands and the logistics staff in the factory in China.

The staff in the Netherlands is responsible for setting the delivery performance and -time targets and communicating this information to the logistics team in China. The employees in the Netherlands create order forecasts. Next to this, they also manage the product stocks and inform the Product Development department in the Netherlands about the delivery times and policies for the parts and materials that are needed in their designs.

The logistics staff in China works together with the purchasing team in China and is responsible for setting the targets for ordering the raw materials that are needed for production. It also makes the production plan to meet the targets that have been set by the staff in the Netherlands.

#### *Technology*

The technology team uses the product requirements to build the requested products. It designs new products and changes existing products to match change requests. Once a design has been made and accepted, the design is made into a prototype in China. The technology team writes out the tests that need to be performed on the prototypes to assess whether all the requirements have been met.

#### *Purchasing*

This team is responsible for purchasing the parts for the prototype and signing contracts with the producers to be able to produce the product in series after it has reached its C-Release phase (explained in section 2.2). It is responsible for purchasing the right materials so that they arrive on time to match the production plan and finally reach the targets that are set by the logistics employees in the Netherlands.

### 2.2.5 Total Quality Management (TQM)

TQM focusses on optimizing the existing processes within the company. In addition to this, it performs audits for the current departments and their flaws to maximize their efficiency and checks whether all the processes are in agreement with the current legislation. Finally, this department is responsible for receiving complaints from customers and starting new projects with project leaders to solve these.

### 2.2.6 Production

The production division can be split into 2 teams: The production team in China and the one in the Netherlands.

The team in China is responsible for checking whether product designs are compatible with the current setup in the factory and carrying out the production plan. This department is also currently responsible for performing the performance tests to ensure that all the product requirements have been met and sending the results to the Product Development department in the Netherlands. Before the corona pandemic, the teams in the Netherlands used to travel to China to perform these tests themselves.

The team in the Netherlands produces a smaller amount of products and mostly performs liability tests.

### 2.2.7 Archive

This department is responsible for correctly archiving Technical Product Documentation (TPDs) and Document Technisch Voorschrift (DTVs). TPDs document the use, functionality, creation, or architecture of a product (MacKay, 2018) whereas DTVs document all the technical aspects of the product and the work instructions. TPDs and DTVs are received from the Technology team once the product has reached its B release and its C release.

In addition to this, the department also accepts and performs changes to the documents.

### 2.2.8 Customer Service

Customer Service receives all the customer orders and passes them on to the logistics team. They are the end station for the NPI flow as they will be the entry station for orders for the newly designed products. Once the product can be ordered, it has reached the end of the NPI flow.

## 2.3 BPMN

The current processes and collaborations within Company X are not elaborately documented. Thus, we obtain a complete view of the process chain by performing interviews. To visualize the current processes within the New Product Introduction chain, we use a process map. The model used is the Business Process Modelling Notation (BPMN). This model focuses on displaying Processes, Choreographies and Collaborations (Object Management Group, 2010). Since a big part of this research is about mapping the processes and collaboration between departments and teams that have not been well documented yet, this modelling notation is an ideal tool to use. The few processes that have been documented at Company X use a notation that is similar to BPMN. Since employees have already worked with these models, it should not be complicated to understand the BPMN model. The total model can be found in Appendix A. The flow is discussed in words on the next page.

#### Product Request

The NPI Flow starts when a client or product management has a request for a new product. The client starts a conversation with the Sales department to discuss the product they need. Once Sales has gathered the product description, it will check whether the product can be built using existing company knowledge. If new knowledge or technology is needed, a project will start in the R&D department to solve all the knowledge problems. Once the knowledge is gathered and all the requirements have been set, the A0 document is constructed and presented to the Product Development department. If requirements are unclear or incomplete, the development department will request the sales department to specify the A0 document.

#### Project Plan Acceptance

The Project Leaders construct a plan with the Product Development department to carry out the project and present this plan to the Sales, Finance and Managing boards. If any of the departments do not agree with the plan, the plan is redesigned and follows the same flow again until it is accepted.

#### Product Design

Once all the departments have accepted the project plan, the product has reached the A release. Before the work can start, the administrative tasks need to be performed by the Project Leaders. This means opening the project in the ERP system, creating the appropriate folders, mailing all the stakeholders and planning the regular meetings. Once this is done, the teams and departments can start brainstorming, (re)designing and checking whether all the requirements are met until the design is complete.

### Final Design Test

When the design is finalized, the development department orders the prototype parts via the Purchasing team and produces the product in the factory in China. The quality team in China then performs several tests on the prototype and sends the results back to the Product Development department in the Netherlands. The department in the Netherlands can then perform additional tests to make sure every feature has been tested. If they do not like the test results, the product will be redesigned until it meets all the requirements.

### Continuous Planning Control

The Project Leaders continuously check whether the project does not exceed the planning or budget constraints. If the targets are exceeded, the project leader has to decide whether the project plan needs to be adjusted or whether they will put in additional work to get the project back on the targets.

### Handover Project

If everything works well and all the requirements are met, the handover project can be started. Product Development, Production, Product Management and Sales all need to sign off the product documents. Product Development schedules a meeting with the production department to discuss the finished product and design. Once the project is accepted, the product has reached its B release and the design is frozen. The Technical Product Documentation (TPD) needs to be uploaded to the archive to make sure that the production and development department can access all the required files and the product is archived correctly.

### Orders Start

The final step to finalize the design flow before the C release is the logistics team that needs to add the new product to its sales and production forecasts as the product can now be ordered by clients. Once a client orders a product that has been B released, the order enters the flow again in the Customer Service Lane. Once the order is added to the system, the logistics team can start making the production targets and planning for the factory. The production and logistics teams are responsible for meeting the targets and thus producing and delivering the products on time.

### C-Release & Mass Production

Before a product can be C released, the production department needs to be able to prove that the product can efficiently be built in bulk with the current designs. The more often an item is produced, the more knowledge is gained. Currently, there is no fixed number of products that need to be made before a design can be C released. The company currently just performs the C release once they feel like they have enough knowledge to produce the product in bulk. Once this release has been reached, the design is ready for mass production. Only then, the product will be fully finished and the NPI flow will be done.

## 2.4 Problems

To get an overview of the issues that occur in the NPI flow, multiple employees from each department are interviewed where possible. The employees are kept anonymous, thus the summary of the issues experienced per team/department are a summary of multiple interviews in that team/department. The problems that are currently experienced per department or team can be described as follows and are shown in the BPMN Model in Appendix B:

### 2.4.1 Sales/Business Development

This department indicates that it could be beneficial to spend more time on market research and the value that is added per project in order to be able to prioritize projects and/or products.

### 2.4.2 Finance

This department experiences an extra workload because purchase entries that are needed for the development of a new product are entered into the ERP system incorrectly. This is caused by 2 factors: The first one is that the ERP system does not indicate the current stock of tooling parts, which means employees are prone to ordering new parts while they were already available directly from the stock. The second cause is the absence of clear instructions on how to enter orders into the system. Orders have to be placed in specific projects in the ERP system, which is not always being done properly.

### 2.4.3 Product Development

#### *Project Leaders*

These employees sometimes lack a total overview of the tasks and all their specific subtasks to guide the teams in the Development department. The mail goal of a task is usually well explained, but employees could use a more in-depth description of the steps that need to be taken before the main task is completed. In addition to this, project leaders state that it would be beneficial to have a system in which the progress of the tasks is shown.

Last but not least, the project leaders indicate that team meetings could be more efficient. It often occurs that attendees are not well prepared for the subjects on the agenda. This leads to a lot of time being spent searching for information during meetings or even having to postpone discussion subjects to later meetings as additional work or information is needed that cannot be provided during the meeting. In addition to this, it often occurs that attendees do not take notes on action points and discussions that have been held. This leads to action points being delayed and identical discussions having to be held several times as no clear conclusion has been noted down.

#### *Logistics*

Since the problems that are faced in this team differ per location, they are split below.

##### Logistics - Netherlands

This location is experiencing issues while overseeing the production times of new products. This issue can be split into 2 parts.

The first part is the often-vague description of the delivery time and order number requirements that are received from the customers. For example, it is currently possible for projects to be completed and only receive feedback from the customer that the delivery time is too long at the end of the project. Thus, this staff would see the benefits of establishing the desired delivery time before starting the designing process. The same goes for the expected number of orders.

The second part of this issue is that the employees are often included too late in the design process. The development discipline does not have a complete overview of the delivery times of all the parts and materials. If the logistics staff would be included earlier, they could give clear indications on which materials to use or not to use to achieve the wanted delivery time which would result in less potentially wasted time.

In addition to the production time issues, the employees also miss a connection with the purchasing team. Logistics could benefit from information about which materials or parts are hard to acquire, whereas now they often obtain this information late in the designing chain.

Another issue that is experienced by this discipline is that they do not have a clear view of all the policies that should be taken into account while producing a product. It often occurs that policies are overseen since they are not clearly documented or are too hard to find. E.g., the use of a specific material is prohibited, but this information is hard to track down.

Finally, Company X has a certain way of naming projects, parts and materials in the ERP system. However, this way of naming has often changed. This results in some documents being named in an old fashion, which makes them hard to find. Additional confusions arise when older documents are not deleted from the system and are confused with newer documents.

#### Logistics - China

This location mostly experiences communicational issues during the design processes. Firstly, the staff in the Netherlands sometimes needs to contact the team in China for some questions. However, it often occurs that the wrong person is contacted for these questions. This results in a lot of wasted time to find the correct contact person.

The second issue that the employees encounter is the communication of changes in the prototypes. The production could be smoother if this information was communicated earlier and clearer.

#### *Development*

**Quality**

The employees in the Netherlands lack some overview of the progress and planning of the testing staff and other disciplines withing this department. This makes it somewhat harder to plan their own tasks.

**Technology and Engineering**

This group often does not take enough initiative when it comes to solving problems. When questions or issues arise, it is unclear who can be contacted to resolve the matter. In addition to this, the workload per employee is relatively high, with many impromptu tasks that arise due to projects that are unexpectedly prioritized. Projects can be prioritized because of their urgency, most often due to customer complaints, or due to deadlines that are approaching. Practice shows that questions are therefore often dropped until the last moment or until the employees are emphatically requested about the progress of the task.

An additional issue that is experienced is that this staff lacks some overview of the progress and planning of the other disciplines within this department. This makes it somewhat harder to plan their own tasks.

Next to this, the employees indicate that communication from the purchasing team could be more optimal. Information about delivery delays could be communicated sooner to be able to construct a correct plan.

Last but not least, a lot of time is spent to finalize the A0 document as requirements could often use more detail or clarifications when initially receiving them from the Sales department.

#### *Costs/Purchasing*

This discipline indicates that it lacks a clear overview of suppliers and their exact products and delivery times. This staff also suffers from being short-staffed. The workload often grows to such an extent that the purchasing processes for prototypes are backlogged for several projects.

### 2.4.4 Total Quality Management (TQM)

This department experiences a lack of function descriptions in the overall company. It describes that the procedures are globally documented but the exact responsibilities could use more explanations.

### 2.4.5 Production

Products are sometimes produced before they have been B Released, this entails that the responsibilities for the product have not completely been handed over to the production department yet. This causes a lot of confusion as it is not clear who is responsible for the maintenance of the product design in this state. E.g., since the maintenance plan is not yet made, who is responsible for repairing and maintaining tools if they are worn?

The C Release often takes a very long time and no clear guidelines have been set as to how many products need to be produced before they can reach the C Release. E.g., the Process Capability Index (Cpk) of products are not set. This index measures the ability of a process to produce output within the customer's specification limits(*Process Capability Index (Cpk)*, n.d.). The Cpk measures how close a process is performing compared to its specification limits and accounts for the natural variability of the process. In general, the larger the Cpk the better, because this means that the product is more likely to be within the specification limits. (*Process Capability (Cp & Cpk)*, n.d.)

In addition to this, when the production team in China notices something that should be altered in the design of a product or process, it often takes multiple weeks to come to a consensus with the teams in the Netherlands. This is mostly because the communications occur via mail, which causes a lot of miscommunications due to the language barrier. It is also caused by an unclear division of who is responsible for this communication.

Last but not least, this department has some issues with the way that production documents are shared. During the B Release, it often occurs that documents are missing or not fully clear. It then takes a long time to contact the team in the Netherlands to receive additional explanations or documentation. In addition to the missing files, it also occurs that old files are not deleted from the system. Once a change is made, the new document is not automatically added to the project folder and the old document is also not automatically deleted. Therefore, the team in China may continue to work with obsolete documents.

### 2.4.6 Archive

This department experiences some issues with the current change request forms. The existing forms are very brief. Due to this, it often happens that additional explanations have to be requested and that the stakeholders are unclear. This costs a lot of time that could be used more efficiently. However, this issue is currently already underway to be solved by the department.

## 2.5 Conclusion

The description of the current situation and problems answers our first research question: "*Which processes are currently used in the New Product Introduction chain and are there any issues or challenges with the processes?"*.

The New Product Introduction chain goes through 36 different processes, involving 8 different departments containing specific 14 teams. Out of these departments, 10 teams experience operational issues. The issues are also shown in the NPI flow in Appendix B.

**Issue Summary**

1. Not enough research is performed to analyse which projects need to be prioritized
2. Many projects are prioritized impromptu which causes delays in other projects
3. Communications between the Netherlands and China are often taking a long time
4. Meetings often lack preparation and follow-ups from the attendees
5. The logistics teams are often included too late in the design process
6. The existing processes and functions lack detailed descriptions, including step-to-step explanations, checklists, responsibilities per person and clear policies
7. Purchasing and logistics teams lack a good overview of suppliers, their products, delivery times and internal current stocks of parts
8. There is no system to track the progress of each department and team with regard to a project
9. The ERP system lacks an overview of the current stocks

# 3. Theoretical Framework

This chapter focuses on answering the sub-question from phase 2 of the research: "What methods exist in literature to optimize product development processes. This chapter will discuss theoires that can be used to solve the issues mentioned in Chapter 2. Section 3.1 elaborates on the different process improvement methodologies that exist. Section 3.2 explains the general principles and benefits of Six Sigma (SS). Section 3.3 goes into depth on the implementation methods of Design For Six Sigma (DFSS). Section 3.4 describes different methods for Resource Allocation. Section 3.5 elaborates on ways to organize productive meetings. Last but not least, section 3.6 elaborates on critical success factors that need to be used to maximize the impact of the changes.

## 3.1 Process Improvement Methodologies

A lot of different improvement methodologies exist. In order to use the correct one for Company X, we need to research which methodology fits the best. This section will elaborate on the use and differences of the existing methods that are documented in the book 'Operations Management Eight Edition' by Slack et al (Slack et al., 2016) (the first 5 paragraphs) and a few methodologies that were found by searching for process improvement methodologies (the last 3 paragraphs).

### Six Sigma

Six Sigma aims at reducing the variability in products to reduce the level of failures and defects. It is very popular in the manufacturing industry because of its focus on output quality and consumer satisfaction (Shibani et al., 2021). This methodology helps business leaders understand how well their processes work (*7 Types of Process Improvement Methodologies [2023] • Asana*, n.d.). One of the processes within Six Sigma is DFSS. DFSS is a method more than a universal methodology and is used for designing and redesigning processes (Shibani et al., 2021). This is exactly what the research is focusing on. We want to analyse and redesign the NPI flow within Company X.

### Total Quality Management

Total Quality Management (TQM) is a management approach that seeks to provide long-term success by providing unparalleled customer satisfaction (*7 Types of Process Improvement Methodologies [2023] • Asana*, n.d.). A core definition of total quality management (TQM) describes a management approach to long-term success through customer satisfaction (*Total Quality Management (TQM): What Is TQM? | ASQ*, n.d.). This methodology focuses on customer satisfaction which is not the direction of this research.

### Lean Manufacturing

Lean manufacturing focuses on minimizing waste within manufacturing systems and maximizing productivity. Benefits of this methodology can include reduced lead times, reduced operating costs and improved product quality (Daniel, 2023). This method focuses on literal production processes. Thus, this methodology would be most applicable in research about optimizing production processes. There are methods that are more appropriate and specific to our area of research since our research is about analysing the design process of products and not the actual producing of products.

### Business process management

Business Process Management (BPM) is a systematic approach to analyzing, editing, improving, and streamlining business processes to achieve organizational goals (*Key Goals of Business Process Management*, n.d.). This method fits within the goals of this research but is very broad. Since other methods exist that are more specified in our direction of research, we will not go into depth on this subject.

### Business process re-engineering (BPR)

BPR has been defined as: 'the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed' (Slack et al., 2016). It focuses on eliminating processes that do not add direct value to customers. Since the processes in the NPI flow can not directly be assessed on how much value they add, we will not elaborate a lot on this subject.

### Continuous Improvement

Continuous improvement is the ongoing improvement of products, services or processes through incremental and breakthrough improvements (*Continuous Improvement Model - Continual Improvement Tools | ASQ*, n.d.). It is a method for identifying opportunities for streamlining work and reducing waste (*What Is Continuous Improvement? | Planview LeanKit*, n.d.). This methodology would fit within the research at Company X. However, since other methods focus more specifically on design processes and seem more accurate for our research, we will not go into depth about this principle.

### Plan Do Check Act

PDCA is an improvement cycle based on the scientific method of proposing a change in a process, implementing the change, measuring the results, and taking appropriate action (*Plan, Do, Check, Act (PDCA) — A Resource Guide*, n.d.). This method focuses on carrying out process improvement but is not applicable for researching how to improve design processes.

### Whys analysis

The 5 Whys method allows uncovering the root cause of a problem by simply asking "Why" 5 times (*5 Whys: The Ultimate Root Cause Analysis Tool*, n.d.). This method is useful for uncovering the cause of an issue but is not applicable for creating solutions for design process issues.

### Best Methodology for Company X

The method that fits the best for improving design processes in a production environment is Six Sigma. All the subjects mentioned above have an improvement goal. Only a few of them focus on Process Improvement. Out of these Six Sigma is the only one that specifies in Design Processes. This comparison is described in the matrix in Appendix C. This method is very applicable to improving design processes specifically and can help the company to understand how their processes are functioning. Thus, this is the methodology that we will be focusing on.

## 3.2 General focus

In this section, we explore the Six Sigma perspective within the theoretical framework of the report. We'll highlight the advantages of Six Sigma and discuss the main concepts used in the research.

### 3.2.1 Benefits of Six Sigma

Six Sigma is one of the most powerful methodologies for business process improvement (Zhang et al., 2016). According to I. Alhuraish, C. Robledo, & A. Kobi (2015), a greater number of years in which Six Sigma has been implemented in a company corresponds with higher financial and operational performance (Alhuraish et al., 2015). The benefits of applying Six Sigma principles are manifested in increased profits, efficiency and quality. These outcomes are reached by reducing cost and variance and improving employee involvement, customer satisfaction and lead times. In addition to this I. Alhuraish, C. Robledo, & A. Kobi (2015) show that Six Sigma improves overall quality within departments and lean management creates safe environments and increases employee involvement.

Six Sigma helps companies set different standards. It broadens the definition of quality to include (for both company and customer) expected standards of economic value — for example, the costs to produce a product — and practical utility (Harry & Schroeder, 2000). The principle allows for a lot of process improvement. Six Sigma creates specific improvement goals for every process within an organization, allowing companies to understand and incorporate new technologies for improved process performance (Harry & Schroeder, 2000).

### 3.2.2 Six Sigma, DMAIC and DFSS

2 principles exist within Six Sigma: Design, Measure, Analyse, Improve, Control (DMAIC) and Design For Six Sigma (DFSS).

DMAIC is the most commonly used and is made up of 5 sequential phases which aim to improve the performance of a current process or a set of processes that are not meeting required specifications (Pande et al., 2000). DMAIC is not used for redesigning a process, it is only to be used to incrementally rectify process performance to meet requirements and/or standards (Shibani et al., 2021).

The difference between DMAIC and Design for Six Sigma is that DMAIC focusses on reducing variability in already existing processes. This is a costly and reactive strategy, whereas Design for Six Sigma focusses on the design of new processes. Thus, this is a proactive and relatively less expensive strategy. (Cudney & Agustiady, 2016).

Design for Six Sigma (DFSS) is an extension of Six Sigma that integrates its design theories into the product design processes (Montgomery, 2010). DFSS focusses on new products, services and processes by shaping all the development processes. It encapsulated all the processes from analyzing customer needs to the final launch of the product. DFSS determines the requirements of a product and the business possibilities by elaborately establishing the customer needs. One of the biggest gains from the design is a reduction in the development lead time, the time needed to bring new technology and products to the market (Montgomery, 2010).

## 3.3 Design for Six Sigma

Designing new products while using Design for Six Sigma contains a lot of different elements according to E. A. Cudney and T. K. Agustiady (2016), which are discussed below.

### 3.3.1 Project Charters

Before a project can be started in a company, it is important to clearly write out a description of the project in a project charter. According to E. A. Cudney and T. K. Agustiady (2016), the charter should include the following elements:

- Problem statement
- Overview of scope, participants, goals, and requirements
- Provides authorization for a new project
- Identifies roles and responsibilities

At the start of a project charter, a few elements should get defined: the project name, the department of focus, the focus area, and the product or process. During the project, people can refer to the project charter to ensure that everyone is accountable and the project is going in the right direction. All in all, this document is meant to give governance during a project. According to E. A. Cudney and T. K. Agustiady (2016), a few steps need to be taken to develop a proper charter:

1. Develop the problem statement
2. Identify the key customers and stakeholders
3. Develop the critical satisfaction characteristics
4. Identify the project goals*
5. Determine the project scope and products/processes/services to be improved
6. Identify the potential financial benefits
7. Determine potential project risks
8. Identify the project resources
9. Determine the project milestones

*Goals need to follow SMART principles. According to E. A. Cudney and T. K. Agustiady (2016), these principles are stated:

- Specific: pursue specific and explicit outputs.
- Measurable: design of outputs that can be tracked, measured, and assessed.
- Achievable: make outputs achievable and align them with organizational goals.
- Realistic: pursue only goals that are realistic and result oriented.
- Time bounded: give deadlines to outputs to facilitate accountability.

#### *3.3.1.1 Business Case*

Before investing in a new project, it is important to analyze its benefits. Subjects to analyze are (Cudney & Agustiady, 2016):

**Market target:** This research should inventorize the customers for the new product/process, the costs of similar products that are already on the market, the current competition and the market share of such a product/process.
**Growth potential:** Short and long-term expectations, future possibilities and competitive position.
**Contributions to sustainability goals:** Direct and indirect benefits of the project should be analyzed.
**Profitability:** This should analyze how much the project would contribute to profitability. It should answer the question 'How much value will the project add to the company?'
**Capital investment:** This research should display all the costs involved in the project.
**Skill and resource requirements:** Which resources will be used? This can include materials, technology, equipment and personnel.
**Risk exposure:** To prepare for risky events, different possible scenarios need to be assessed for the initial investment, return on investment and payback period.

#### *3.3.1.2 Risk Assessment*

Since no project exists without having any risk, it is essential to identify risks early on and plan appropriate countermeasures. The risks and measures should be reviewed during team meetings.

Potential risks are the events that could occur and affect whether a project is successful or not. According to E. A. Cudney and T. K. Agustiady (2016), a table should be used to indicate the probability of risks and their impact with High (H), Medium (M) or Low (L) as shown in Table 5. Subsequently, the strategy to avoid each risk should be noted. This table will allow the project team to ensure the project's success by proactively researching the risks.

| Potential risks | Probability of risk (H/M/L) | Impact of risk (H/M/L) | Risk mitigation strategy |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

*Table 3 DFSS Risk Analysis Example* (Cudney & Agustiady, 2016)

### 3.3.2 Management

Project management is crucial to create an efficient environment in a company. Enterprise-wide project management is the application of project management techniques and practices across the full scope of an enterprise (Cudney & Agustiady, 2016). Another name for this is 'Management by project' (MBP). This concept is based on defining every individual assignment as a project. According to E. A. Cudney and T. K. Agustiady (2016), projects like these should include:

- Identified scope and goal
- Desired completion time
- Availability of resources
- Defined performance measure
- Measurement scale for review of work

An MBP approach helps to identify specific projects within functional product requirements. This makes it easier to create plannings and schedules and control the projects. Enterprise-wide project management facilitates a unified view of organizational goals and provides a way for project teams to use the information generated by other departments to carry out their functions (Cudney & Agustiady, 2016).

### 3.3.3 Organization

DFSS identifies several steps for the organization of design projects according to E. A. Cudney and T. K. Agustiady (2016):

1. The first step is to construct the project management team
    a. List who is going to be involved in the project organization structure
        i. Matrix structure
        ii. Formal and informal structures
        iii. Justify the structure
    b. List the involved employees and departments
        i. Purchasing
        ii. Materials management
        iii. Engineering, design, manufacturing, etc.
    c. List the responsibilities of project management
        i. Select the project manager
        ii. Write the project charter
        iii. Establish project policies and procedures
2. Implement the triple C (Communication, Cooperation, Coordination) model
    a. Communication
        i. Determine the communication interfaces
        ii. Develop the communication matrix
    b. Cooperation
        i. Outline cooperation requirements, policies, and procedures
    c. Coordination
        i. Develop the work breakdown structure
        ii. Assign the task responsibilities
        iii. Develop a responsibility chart

### 3.3.4 Scheduling

DFSS identifies several tasks that need to be performed to efficiently allocated resources for design projects and build the schedule (Cudney & Agustiady, 2016):

1. Estimate the duration of all the tasks
2. List the priorities of the tasks
    a. Technical priorities
    b. Resource-imposed priorities
    c. Procedural priorities
3. Use analytical models
    a. Critical path method (CPM)
    b. Program evaluation and review technique (PERT)
    c. Gantt chart

The analytical models are discussed below.

#### *3.3.4.1 Critical Path Method*

The CPM makes it possible to describe all the tasks that need to be done to complete the project. The critical path in project management is the longest sequence of activities that must be finished on time to complete the entire project (Team Asana, 2021). This means finding the longest flow of processes that have to be carried out successively within the total design process. Figure 2 shows how to use the Critical Path Method.


*Figure 2 CPM Steps to find Critical Path* (Team Asana, 2021)

**1. List activities**

Divide the project into different phases and all their separate tasks. Clearly define all the tasks and map them in a concept map. A concept map is a diagram or graphical tool that visually represents relationships between concepts and ideas (*Concept Mapping Guide and Tutorial | Lucidchart*, n.d.).

**2. Identify dependencies**

Once the map is made, it is important to define which tasks are dependent on each other. Doing this will also create an overview of which tasks could be performed in parallel. The list of dependent tasks is referred to as an activity sequence, which will be used to determine the critical path (Team Asana, 2021).

**3. Create a network diagram**

The next step us to create a chronological flowchart of all the elements and activities that need to be performed in the project.

**4. Estimate task duration**

Estimations on the task duration can be made by using experiences from previous projects. An alternative for this is using the forward pass and backward pass technique.

- Forward pass: This principle determines the earliest start (ES) and earliest finish (EF) dates by using the previously specified start date of tasks. ES is the highest EF value from immediate predecessors, whereas EF is ES + duration (Team Asana, 2021). The task flow starts with 0 at the ES of the first task and continues its way through the tasks using the EF of the previous task as the ES of every new task. Determining ES and EF dates allows for the earliest allocation of resources to the project(Team Asana, 2021).

- Backward pass: This principle determines the latest start (LS) and latest finish (LF) dates. Just like the ES and EF principle, LS is equal to LF - duration, where LF is the lowest LS value from the next task. The calculation works backwords through the schedule and begins with the last planned task.
  Last but not least, the estimate can be calculated based on the PERT principle as discussed in the next Section.

**5. Calculate the critical path**

This calculation can be made by listing the starting and end times of each activity. The start time of a task is equal to the end time of a previous task, using the times calculated in step 4. The critical path refers to the sequence of tasks that have the shortest duration. It is the longest path through the network diagram and represents the minimum time needed to complete the project.

**6. Calculate the float**

Float, or slack, refers to the amount of flexibility of a given task. It indicates how much the task can be delayed without impacting subsequent tasks or the project end date (Team Asana, 2021). Using the float principle can help to check whether a project is on track. The bigger the float, the more likely to task will be able to finish early or on time (Team Asana, 2021). In addition to this, it makes it easier for project leaders to prioritize tasks that have 0 float and postpone high float tasks. For projects that experience a lot of unexpected delays, it can also give extra time to cover these risks.

Some tasks cannot be flexible and have a set date. These are the critical tasks and have 0 float. If a task has a float > 0, it is placed on a non-critical path. This task may be delayed while still allowing the project to finish in time.

2 types of float can be defined:
- Total float: This represents how much time a task can be delayed from the early start date without delaying the project deadline or interfering with the planning. Total float = LS - ES or LF - EF
- Free float: This represents how much time a task can be delayed without interfering with the next task. This only occurs when 2 or more tasks share a common successor. Free float = ES (next task) - EF (current task)

#### *3.3.4.2 Program evaluation and review technique*

PERT analyzes the time required to complete each task and its associated dependencies to determine the minimum time to complete a project. It estimates the shortest possible time each activity will take, the most likely length of time, and the longest time that might be taken if the activity takes longer than expected (AcqNotes LLC, 2022).

This principle can be executed in 3 steps:

1. **Define all the tasks involved in the project**
2. **Determine optimistic $(O)$, pessimistic $(P)$, and most likely $(M)$ duration estimates for each task**
3. **Calculate the estimated task duration**
   This is done by applying the formula $(P + 4M + O)/6$ (AcqNotes LLC, 2022)
   In order to calculate the estimated project duration, a sum must be made of the optimistic, pessimistic and most likely durations individually and these sums must be applied to the same formula.

#### *3.3.4.3 Gantt chart*

A Gantt chart shows what needs to be done and when. This is shown in a bar chart. The left side includes a list of tasks while the top indicates a time scale. The position and length of the bar reflect the start date, duration and end date of the activity (Gantt.com, n.d.). Figure 3 shows an example.

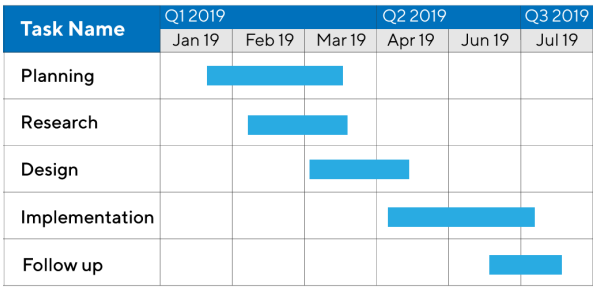


*Figure 3 Gantt Chart Example* (Lean Six Sigma Groep, n.d.)

#### *3.3.4.4 Most Suited Analytical Methods*

CPM is better suited for well-defined projects and activities with little uncertainty, where accurate time and resource estimates can be made, and the percentage of completion of an activity can be determined. PERT is better to use when there is much uncertainty and when control over time outweighs control over costs (PRESS & FORT BELVOIR, 2001). Since the processes at Company X vary a lot and do not have clearly defined process times, PERT is better suited than CPM. “PERT charts are best used during the planning phase of a project, and allow users to map out the full scope” (Hennigan & Bottorff, 2022). “Gantt charts are more helpful once a project is underway, as they can be adjusted if the scope changes” (Hennigan & Bottorff, 2022). Since we want to focus on adequately scheduling processes before projects start and being able to adjust schedules if needed during a project, PERT and Gantt charts seem the most adequate for our research.

### 3.3.5 DFSS Phases

Designing a product using DFSS is split into 5 phases:

- Define: Define the problems and opportunities of a new product or process
- Measure: Gather data related to the problem and the design of a new product or process
- Analyze: Analyse the data and generate product concepts
- Design: Design the product or process to fulfill all the requirements
- Validate: Validate the new product or process to check whether all the requirements have been accomplished

The questions that need to be answered in each phase and the steps that need to be taken are stated in Tables 6 and 7 on the next 2 pages. In both tables, the first column indicates the phase and the last column indicates the tools that can be used. The big difference between the tables is that Table 6 lists the questions that need to be answered in a phase whereas Table 7 shows the tasks that need to be performed in a phase.

| Phase | Questions addressed | Tools used |
|---|---|---|
| Define | Who are the customers?<br>What are the customer requirements?<br>What processes are involved?<br>What is the business case/need/problem statement?<br>Who is the process owner?<br>Who are the team members?<br>What resources are required?<br>Which processes(es) has the highest priority to improve?<br>What data supports the decision (metric)?<br>What are the project goals?<br>What is the scope of the project? | Project charter<br>Voice of customer<br>Stakeholder analysis<br>Process flow diagram<br>Suppliers, input, process output, customers (SIPOC) diagram<br>Project plan<br>Responsibilities matric<br>Communication plan<br>Team ground rules |
| Measure | How is a defect determined?<br>How is the process performed?<br>How is the process performance measured?<br>How will data be collected?<br>Is the measurement system accurate and precise?<br>What are the customer driven specifications for the performance measures?<br>Is the process capable?<br>What are the sources of variation in the process?<br>What sources of variability are controlled and how? | Process flow diagram<br>Measurement system analysis<br>Data collection plan<br>Benchmarking<br>Cause and effect diagram<br>Process capability<br>Sigma level<br>Voice of the customer<br>Operational definitions |
| Analyze | What are the performance objectives?<br>Which process steps are value/non-value adding?<br>What are the key variables affecting the average and variation of the performance measures?<br>What are the relationsips between the key variables and the process output?<br>Is there interaction between any of the key variables? | Histogram<br>Pareto chart<br>Run chart<br>Cause and effect diagram<br>5 whys<br>Value stream map<br>Regression analysis<br>Hypothesis testing |
| Improve | What are the key variable settings that optimize the performance measures?<br>At the optimal setting for the key variable, what variablity is in the performance measure?<br>What are potential solutions to improve on target performance and reduce variation?<br>What are the potential failure modes?<br>What improvements should be made? | Brainstorming<br>Process failure mode and effects analysis (FMEA)<br>Poke-yoke<br>Design of experiments |
| Control | How will the process be controlled?<br>What standards and procedures should be implemented?<br>How much improvement has the process shown?<br>How should the improvements be handed off to the process team and process owner?<br>How much time and/or money was saved?<br>How will the process be monitored long term? | Statistical process control<br>Control plan<br>Cost analysis<br>Process capability<br>Sigma level |

*Table 4 Design for Six Sigma phase questions* (Cudney & Agustiady, 2016)

| Phase | Phase description | Tools used |
|---|---|---|
| Define | Define customer (internal and external)<br>Define customer requirements<br>Gather needs<br>Identify the business case for the project<br>Create project charter<br>Develop project plan<br>Form the team<br>Translate needs to critical to satisfaction (CTS)<br>Translate CTS's functional requirements<br>Assess technology<br>Develop plan<br>Assess risk | Project charter<br>Responsibilities matrix<br>Communication plan<br>Team ground rules<br>Voice of the customer<br>Stakeholder analysis<br>Data collection plan<br>Survey design<br>Quality function deployment<br>Project plan<br>Kano model<br>Product technology road map<br>Balanced scorecard<br>Measurement systems analysis |
| Measure | Translate customer requirements into engineering requirements<br>Translate functional requirements to design parameters<br>Develop/evaluate design alternatives<br>Resolve design conflicts<br>Flow down system design to subsystems<br>Design for reliability and maintainability<br>Mistake proofing<br>Assess risk | Benchmarking<br>Voice of the customer<br>Operational definitions<br>Quality function deployment<br>Pugh concept selection matrix<br>TRIZ<br>Design scorecard<br>Design failure modes and effects analysis<br>Axiomatic design<br>Standardization |
| Analyze | Develop transfer functions<br>Develop system capabilities<br>Generate concepts<br>Evaluate concepts<br>Assess design gaps<br>Select concept<br>Assess risk | Brainstorming<br>Quality function deployment<br>Design of experiments<br>TRIZ<br>Pugh concept selection matrix<br>Design scorecard<br>Process verification<br>Design failure modes and effects analysis<br>Process failure mode and effects analysis<br>Reliability testing<br>Measurement systems analysis |
| Design | Optimize the product or process design for robustness<br>Optimize tolerances<br>Demonstrate process/product capability<br>Mistake proof design<br>Assess risk | Brainstorming<br>Design failure modes and effects analysis (FMEA)<br>Poke-yoke<br>Design of experiments<br>Parameter design<br>Tolerance design<br>Design for X<br>Capability analysis |
| Verify | Verify product performance<br>Verify process performance<br>Monitor system capability<br>Implement design and process control plans<br>Develop transition plans | Statistical process control<br>Control plan<br>Cost analysis<br>Process capability<br>Sigma level |

*Table 5 Design for Six Sigma phase descriptions* (Cudney & Agustiady, 2016)

### 3.3.6 Technical Design Reviews

One of the elements used in the design of new products is Technical Design Reviews. DFSS focusses on correctly designing a product in 1 try as design usually takes up 70% of the cost of the product. Thus, saving money during the design phase is very profitable. Technical design reviews (TDRs) are critical elements of the design phase to make sure that any problems are detected and escalated timely and properly. It is important to have subject-specific experts available during these meetings to properly address field-specific matters. For TDRs to be successful, all the participants must be properly prepared and informed about the discussion topics. Every TDR should be documented to capture the observed issues and resolutions. Reviewing these documents at each review ensures that there is progress is being made (Cudney & Agustiady, 2016).

TDR reviews should take place at the following phases of the design process:

• Concept phase: The goal of the concept phase is to make sure that the product concept is appropriate and that all the technical specifications are fixed. This phase is conducted before the actual development of a product to avoid big costly changes at a later phase.

• Development phase: Once the design has been finished, the development phase can start. During this phase, the product is produced and made ready for implementation.

• Evaluation phase: During the evaluation phase, all the technical specifications get tested to make sure that they are properly executed and all the requirements have been reached.

### 3.3.7 Control (Tracking, Reporting, and Correcting)

Overseeing design projects can be done in 2 steps according to the DFSS principles. First of all, guidelines need to be set to track, report and control progress. In order to do this, it is necessary to define the data requirements. Project leaders need to define which data categories they want to keep track of and on which scale this data is going to be measured. In addition, it is necessary to define the update requirements, the quality control of the data and the security measures of the data.

The second step is categorizing the control points. The check-up moments need to focus on specific categories. The audit subjects and subpoints are described below:

Schedule

a. Activity network and Gantt charts
b. Milestones
c. Delivery schedule

Performance

a. Employee performance
b. Product quality

Cost

a. Cost containment measures
b. Percentage completion versus budget depletion
c. Identify implementation process

Comparison with targeted schedules

Corrective course of action

a. Rescheduling
b. Reallocation of resources

## 3.4 Methods of Resource Allocation

Resource allocation is the process of assessing resource availability and project needs in terms of specific development needs, expertise, experience working with particular customers and partners and assigning suitable resources to different tasks (Huemann et al., 2007). The literature documents several methods of resource allocation. 2 methods that closely apply to the situation of Company X are Hybrid Resource Planning and Bottoms-up Resource Planning. These methods focus on project-based companies that experience a lot of unexpected and ad hoc tasks. The definitions and differences can be seen in Table 8.

The hybrid resource allocation process focusses on allocating resources based on availability and skill by the staff and project leaders together. The bottom-up resource process enables the staff to plan their resources themselves and be supported by the project leaders when needed.

| | Company A: hybrid resource allocation process | Company B: bottom-up resource allocation process |
|---|---|---|
| Resource allocation practice | The resource planner plans resource allocation based on the availability and technical skills of the staff. The service managers and service staff plan the workload and negotiate to solve issues | The service staff plan their resource allocation. The service managers support them in critical situations |
| Authority to prioritise activities | The planner sets the priorities in cooperation with the service manager | The service staff set the priorities of their own tasks. The service managers support them in critical situations |

*Table 6 Hybrid and Bottom-up resource allocation differences* (Momeni & Martinsuo, 2018)

The findings of the research performed by K. Momeni & M.M. Martinsuo (2018) are shown in Table 9. The goal of this research is to "to identify resource allocation challenges and practices in service units that perform both project and non-project activities in dynamic environments" (Momeni & Martinsuo, 2018). As can be read, hybrid resource allocation ensures the right prioritization of activities in a dynamic environment whereas the bottom-up approach ensures fast reactions to changes and quick adaptations to uncertainties in the environment. The latter one fits better into the process flow of Company X since schedules often need to be changed during a project.

| | Hybrid approach | Bottom-up approach |
|---|---|---|
| Where? | Medium complexity in terms of structural and emergent complexities (Maylor and Turner, 2017) | High complexity in terms of structural and emergent complexities (Maylor and Turner, 2017) |
| What? | Organising resources while increasing responsiveness | Increasing responsiveness |
| Why? | Ensuring the right prioritisation of activities in a dynamic environment | Reacting fast to the changes in time, scope and type of activities<br>Adapting to uncertainties in the environment |
| How? | Using a planner as the intermediary role between managers and staff | Empowering individuals; managing the information flow between units; supporting by managers in critical situations |

*Table 7 Findings on Hybrid and Bottom-up resource allocation* (Momeni & Martinsuo, 2018)

## 3.5 Organizing Productive Meetings

Meetings are the secret weapon of many work teams but can also be a struggle for those who do not quite get it right (Rodríguez, 2021). Understanding how to organize a meeting can help plan efficient meetings that communicate information effectively and stay on schedule (Indeed Editorial Team, 2021).

### 3.5.1 Types of meetings

Before organizing a meeting, it is important to determine what type of meeting it is going to be and to communicate it accordingly. According to S. Irina (2020), several types of meetings are:

**Staff meeting (status meeting):** The structure of this type of meeting consists of an introduction and the main part, including the rules, format and goals, general questions, results of work, reports of participants and analysis of results.
**Report:** This meeting contains presentations by several participants. A presentation lasts no more than 7 minutes, considering this is the length of time that can hold the audience's attention (IRINA, 2020).
**Exchange of views:** The participants give their views in turns.

**Briefing:** These meetings consist of an introduction, including plans, the importance of the subject and a problem definition. The main part consists of plans, rules and instructions. Finally, the meeting ends with a discussion, task allocation and summation.
**Discussion:** These meetings are organized to reach a consensus about a subject that was previously not reached.

### 3.5.2 10-Steps for a productive meeting

To organize productive meetings, several steps need to be taken to be properly prepared and structured. According to K. Dagher (2020), these steps are:

11. Answer preliminary questions
    a) Is the meeting really needed?
    b) Who needs to attend the meeting?
    c) How much time will the meeting take?
12. Clearly indicate the purpose of the meeting
13. Invite all the needed attendees
14. Develop an agenda with all discussion points for the meeting
15. Request attendees to prepare in advance
16. Assign roles to participants
    a) Facilitator: guides the discussion, making sure all sides of the issue are raised (Dagher, 2020).
    b) Scribe: captures key ideas and decisions and distributes notes (Dagher, 2020).
    c) Timekeeper: helps move the discussion along (Dagher, 2020) and keeps track of the time.
    d) Contributor: contributor keeps the discussion lively and on track (Dagher, 2020).
    e) Expert: shares knowledge on particular issues (Dagher, 2020).
17. Start the meeting on time
18. Make participants write down their questions to ask them at the end of the meeting
19. Make notes and list future steps and action points
20. Send a meeting recap or follow up to all participants

## 3.6 Succes factors for change projects

As shown in Figure 4, different disciplinary contributions lead to different benefits in management efforts. Since the processes that are currently used in Company X have been used for many years, it is important to research which factors and steps are essential to obtain the wanted results from a change project and apply this knowledge when performing the changes.

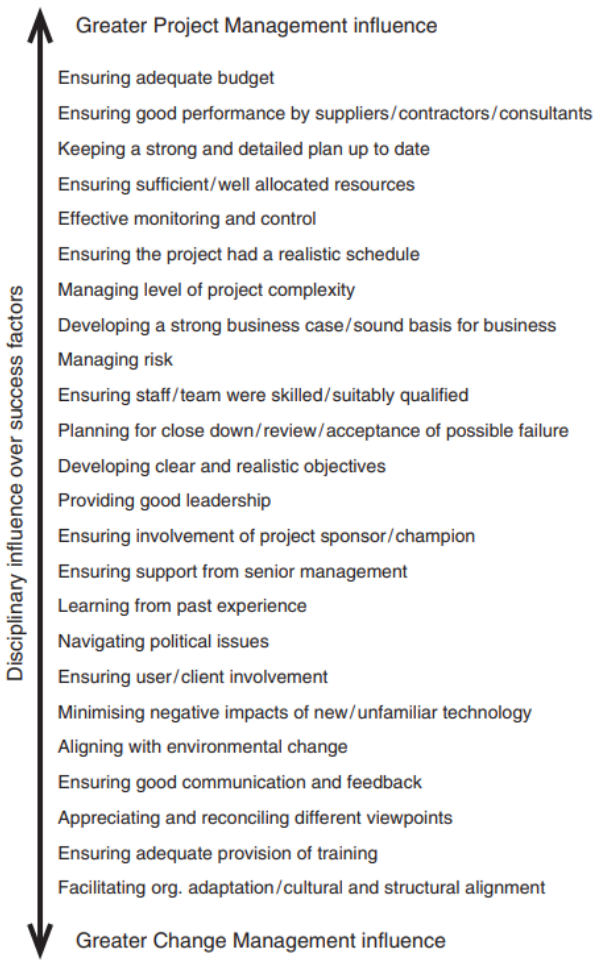


*Figure 4 A comparative ranking of disciplinary contribution to project success factors* (Pollack & Algeo, 2016)

### 3.6.1 4-Step plan for success

The success of a change project is critical for its future strategy and major project implementation. It is crucial that a systematic process be followed to implement this change (Appelbaum et al., 2017). According to Steven H. Appelbaum et al. (2017), 4 steps are established to achieve the best results:

**Step 1: establish a sense of urgency through a guiding coalition**

The first step to a change project needs to focus on describing the urgency of the change. This description needs to clearly state why the change needs to happen and which stakeholders are involved. Employees need to feel proud to be a part of the project. In addition to this, change agents need to be chosen. Change agents are people who act as catalysts and assume responsibility for managing change activities and can be managers or non-managers. These agents will form the link between the teams and the management (more about this in Section 3.6.2.1).

**Step 2: develop and communicate the change vision**

Goals need to be divided into clear and reachable objectives (more about this in 3.6.2.4). Specific strategies for transitioning the teams into their new roles in the new subsidiary need to be defined (Appelbaum et al., 2017). This plan needs to be shared and understood by involved employees (more about this in 3.6.2.2).

**Step 3: remove obstacles to achieve the new vision and generate short-term wins**

Decisions that are made during the project need to be communicated transparently so that all employees understand what is happening during all times of the project and why decisions have been made. In addition to this, it is important to enable small wins. Celebrating the small wins will create a sense of victory, motivate people to achieve more and also reassure them that they are on the right track (Appelbaum et al., 2017) (more about this in 3.6.2.3).

**Step 4: consolidate gain, produce more change and anchor new approaches in the corporate culture**

The final step consists of making sure that the change project keeps the stakeholder processes coherent with the rest of the company. Leaders have to maintain the organizational structure and systems to be coherent with the parent organization so that the integrated teams not only feel secure but also see the enormous growth potential that the new opportunity offers (Appelbaum et al., 2017).

### 3.6.2 Attention Factors

During the execution of a change project there are several factors to pay attention to according to E. A. Cudney and T. K. Agustiady (2016).

#### *3.6.2.1 Role models/Change agents*

The first factor to pay attention to is acting as a role model. People want to be facilitated through changes and need guidance and coaching (Cudney & Agustiady, 2016). It is important to reassure the employees and gain their respect. Role models need to be able to project themselves in other situations since it is important to understand how employees are experiencing the change. To understand how fellow employees can feel, it is useful to analyze what reasons could exist to dislike the change but also clearly state its possible benefits. Leaders need to show that the change is beneficial for the entire company and not 1 specific employee.

#### *3.6.2.2 Employee involvement*

Another important point is including all employees. Involving more members in the implementation of a change project delivers more ideas on how to execute the project. Everyone should have equal rights of speaking and adaptability to other people's viewpoints, schedules, concerns, and styles should be taken into consideration (Cudney & Agustiady, 2016). Showing that the change project is open for remarks helps employees appreciate the project leader's principles and anticipate the change. Workdays might not go along the most perfect way during change projects. This expectation should be communicated to all members to give them the needed consideration during the project.

#### *3.6.2.3 Motivation*

Critical factors for a project to succeed are all about people and their commitment to a project. Thus, it is of utmost importance that no issues subsist within the employee groups. Many organizations recognize this, but only a few have been able to actualize the ideals of managing people productively (Cudney & Agustiady, 2016). To obtain the best commitment it is important to create incentives, encourage employees and allow them to determine how to carry out their work in an optimal way.

Motivating people is crucial to change projects. Employees need to understand why the change needs to happen and be involved in how it is going to happen. As employees are involved with developing DFSS, this will also drive buy-in (Cudney & Agustiady, 2016). In addition to this, it is important to truthfully manage all information and expectations during the project. The vision needs to be not just stated, but shared and agreed on by all (Cudney & Agustiady, 2016).

#### *3.6.2.4 Targets*

Before a change project can start, every member of the project needs to understand what their role is going to be. The targets and planning need to be clear and include near-term goals to allow for early motivating successes.

#### *3.6.2.5 Timing*

Finally, the timing of the project is also of the essence. Informing employees about changes can take time and should allow for question- and thinking time to make sure that no one is rushed into the change.

### 3.6.3 Reasons for failures

Failures in change projects can always occur. A few factors that could entail failures are described in Table 10. The first column indicates what could go wrong, the second column indicates which specific component of Six Sigma made it fail and the final column describes the exact reason that it did not work. It is smart to check whether these components have properly been thought through before the beginning of a change project. Projects can fail if no analysis is conducted on whether Six Sigma is properly suited for the problems within the company and that it is applied to the right project. In addition to this, change projects can fail if the chosen change leader is not credible or capable enough to lead the change. Resistance from the team and process owners can also cause projects to fail. Next to this, it is also possible that the culture does not fit with the wanted change. Last but not least, failures can also occur due to a shift in priorities or the change processes being designed sub-optimally.

| **Change Components** | **Six Sigma components** | **Reasons for failures in Six Sigma** |
|---|---|---|
| *What:* What was changed, failed to address the problem | Six Sigma management system | Six Sigma was not suitable for the problem |
| *What:* The change addressed the wrong problem | SS projects | Too ease a project, or wrong project |
| *Who:* The person leading the change was ineffective | SS executive, Champion | Not credible, not capable for leading |
| *Who:* Poor adaptation of employees expected to change their behavior | Practitioners, teams | Practitioners (Black Belt, Green Belt) were not capable. Resistance from team and process owners |
| *Context:* Inside events or factors derail the change | Organization culture | Culture did not fit with Six Sigma |
| *Context:* Outside events or factors derail the change | Outside factors | Shift to other priorities, change in economic conditions |
| *How:* Weak change management | Change management | Poor change process |

*Table 8 Change management components (Lertwattanapongchai & Swierczek, 2014)*

### 3.6.4 Keeping track of change

According to E. A. Cudney and T. K. Agustiady (2016), system success relies on total system management (hardware, software, and people). Thus, these are subjects that should be evaluated regularly. Management should regularly analyze the following elements during the change projects in order to track whether the project has the wanted effects:

- Operational effectiveness
- Operational efficiency
- System suitability
- System resilience
- System affordability
- System supportability
- System life cycle cost
- System performance
- System schedule
- System cost

## 3.7 Conclusion

This chapter answers our second research question: "*What methods exist in literature to optimize product development processes?".*

This literature research has shown that DFSS is the most suited method to construct design projects in Company X. To make sure that the changes in the company will go as expected, it is important to carefully plan this change project while paying attention to several attention factors and reasons for failure. DFSS contains multiple concepts that can be used in Company X: Project Charters, Management by Project, Organizational steps (based on setting up a management team and implementing the triple C), Scheduling methods (using PERT or Gantt Charts), Design Phases, Technical Design Reviews and Control guidelines. In addition to this, literature indicated multiple methods of allocating resources. The most suited for Company X is the Bottom-Up Resource allocation method which focusses on having employees construct the planning. Last but not least, the literature indicates 10 steps that need to be taken to ensure productive meetings.

# 4. Improvement measures

This chapter describes phase 3 of the research. Based on the theoretical research performed in Chapter 3, it will relate theory to the issues mentioned in Chapter 2. It compares the current way of working to the theoretically proven way of working as described in the theoretical framework to establish the areas where improvements could be made. This phase includes proposed solutions and their benefits and a proposed change strategy.

## 4.1 Proposed solutions

This section will document the solutions to the issues in Chapter 2 by using basic reasoning and the knowledge gained in Chapter 3. The continuation of this Section will be divided into specific issues and their proposed solutions.

### 4.1.1 Solution 1: Creating Business Cases to get insight into project prioritization

Company X is currently not performing enough research to be able to properly prioritize projects. Since the goal of a project is to add value to the company, this added value should be analysed before the start of a project by the Business Development department.

#### *Creating Business Cases*

As described in Section 3.3.1.1, before the start of any project, a business case should be made. This case should be used to compare projects and correctly prioritize them based on the goals of the company. The case should include:

- Market target
- Growth potential
- Contributions to sustainability goals
- Profitability
- Capital investment
- Skill and resource requirements
- Risk exposure

#### *Benefits*

Doing this would solve issue 1) from Section 2.5 of this report.

1. Not enough research is performed to analyse which projects need to be prioritized

Subsequently, it would resolve the issues experienced by Sales in Section 2.4.1 where is stated that more market research would be beneficial to properly prioritize projects.

### 4.1.2 Solution 2: Using PERT/Gantt Scheduling and Bottom-Up Resource allocation to avoid delays

Design tasks of a project are often delayed due to other projects being suddenly prioritized by Company X. Most delays are experienced in the Product Development department. Thus, this is where this solution should be implemented. Chapter 3 proposes 2 solutions.

#### *Using PERT/Gantt scheduling*

Section 3.3.4 documents the use of PERT or Gantt to efficiently calculate estimated task durations. These methods includes optimistic, pessimistic and most likely points of view, which allows for more accurate scheduling.

#### *Using Bottom-Up Resource allocation*

In addition to this, Section 3.4 discusses the Bottom-Up Resource allocation method. By enabling staff to make the schedules and plan their resources themselves, changes in a project are quickly solved and teams and departments can quickly adapt to new scenarios.

*Benefits*

Using 1 or both of these solutions will solve issue 2) from Section 2.5.

2. Many projects are prioritized impromptu which causes delays in other projects

Subsequently, this would solve some issues experienced by the Technology team as discussed in Section 2.4.3. It would take account of uncertainty in the scheduling and would allow for quick reactions if changes do happen to the project. In addition to this, making staff create their own schedule, would increase the employee initiative and feeling of responsibility.

### 4.1.3 Solution 3: Using DFSS Organizing steps

Current responsibilities lack elaborate descriptions, which causes unclarities on personal responsibilities and mistakes in process handling. This solution is applicable in the entire company but should be performed by the Project Leaders for each new project.

*Using DFSS Organizing steps*

As described in Section 3.3.3, several steps need to be taken by the Project Leaders to organize a project and document every needed detail for the staff to be able to work efficiently.

1. Construct the project management team
    a. List stakeholders in the project organization structure
        i. Matrix structure
        ii. Formal and informal structures
        iii. Justify the structure
    b. List involved employees and departments
        i. Purchasing
        ii. Materials management
        iii. Engineering, design, manufacturing, etc.
    c. List responsibilities of project management
        i. Select project manager
        ii. Write project charter
        iii. Establish project policies and procedures
2. Implement triple C (Communication, Cooperation, Coordination) model
    a. Communication
        i. Determine communication interfaces
        ii. Develop communication matrix
    b. Cooperation
        i. Outline cooperation requirements, policies, and procedures
    c. Coordination
        i. Develop a work breakdown structure
        ii. Assign the task responsibilities
        iii. Develop a responsibility chart

*Benefits*

Using this solution would solve issue 3) from Section 2.5.

3. Communications between the Netherlands and China are often taking a long time

This solution offers benefits for every team in the Product Development department as contact flows and responsibilities would clearly be defined before the start of a project. These were issues identified by the Technology team and Production department (Section 2.4.3 and 2.4.5 respectively). It would improve communication in the Netherlands as well as between the Netherlands and China.

### 4.1.4 Solution 4: Following guidelines to organize meetings

Meetings in Company X are currently often not productive. People often do not prepare or make notes which makes it hard to have good discussions and follow up on action points. This is an issue that is experiences company wide. Thus, the solution should also be implemented company wide.

#### *Determine the type of meeting*

To prepare yourself it is important to determine what type of meeting you will be organizing as described in Section 3.5.1 Types are:

- Staff meeting
- Report:
- Exchange of views
- Briefing
- Discussion

#### *Follow 10-Steps to productive meetings*

As described in Section 3.5.2, 10 steps can be followed to organize a productive meeting:

1) Answer preliminary questions
    a) Is the meeting really needed?
    b) Determine attendees
    c) Determine meeting duration
2) Indicate the purpose of the meeting
3) Invite all attendees
4) Develop an agenda
5) Request attendees to prepare in advance
6) Assign roles to participants
    a) Facilitator
    b) Scribe
    c) Timekeeper
    d) Contributor
    e) Expert
7) Start the meeting on time
8) Make participants write down their questions to ask them at the end of the meeting
9) Make notes and list future steps and action points
10) Send a meeting recap or follow up to all participants

#### *Benefits*

Using these solutions would solve issue 4) as stated in Section 2.5.

4. Meetings often lack preparation and follow-ups from the attendees

This would solve the issue experienced by the project leaders as stated in Section 2.4.3 as attendees will come to a meeting prepared and leave with notes and action points.

### 4.1.5 Solution 5: Including logistics teams earlier in the design process

*Benefits*

This issue mostly speaks for itself. The logistics team in the Netherlands indicated that time could be saved by involving this team in the design activities in earlier phases than is currently done (Section 2.4.3). Logistics could provide useful information about the delivery time of parts and materials which could be beneficial for the quick development of a product. The logistics team in China indicates that it would be beneficial to communicate prototype changes earlier than the current way of working by the Product Development department (Section 2.4.3).

This solution would solve issue 5) as stated in Section 2.5.

5. The logistics teams are often included too late in the design process

### 4.1.6 Solution 6: Creating process descriptions

Many processes within Company X seem to lack guidelines, standards and/or descriptions.

*Creating full-scale process descriptions*

In order to get everyone on the same page about performing their work, tasks must be clearly defined and standards must be set. Looking at the issues experienced in Company X, processes that need to be developed the most and their focus points are:

- Processes for entering data into the ERP system
  - Order entry processes
  - Project, part, material and document naming processes
  - Data deletion processes
- Requirement Document (A0) Standards
  - Design specifications
  - Delivery Time
  - Expected Purchasing amounts
- Logistic Policy documentation
- Release Processes
  - Document uploading checklists
  - Responsibilities between releases

*Benefits*

Using this solution would solve issue 3) from Section 2.5.

6. The existing processes and functions lack detailed descriptions, including step-to-step explanations, checklists, responsibilities per person and clear policies

This solution would resolve the issues that Finance experiences due to incorrect order entries in the ERP system as described in Section 2.4.2. It would also solve the issues experienced by the Logistics team in the Netherlands due to incorrect file naming and old files existing in the ERP system. Logistics would likewise benefit from the first solution as policies are currently not properly defined and thus make it harder to work effectively. The Technical and logistics team would also benefit from this solution since standards would be set for the A0 document, allowing them to work quicker and more efficiently (Section 2.4.3). In addition to this, the issues experienced by the Production department where old documents are still available or documents are incomplete or missing as described in Section 2.4.5 would be resolved. Finally, production would benefit from these measures as responsibilities between releases would be defined that are currently very vague.

### 4.1.7 Solution 7: Analysing current systems for further possibilities

Solutions for issues 7), 8) and 9) should be found in the currently already existing software that is used within Company X.

7) Purchasing and logistics teams lack a good overview of suppliers, their products, delivery times and internal current stocks of parts
8) There is no system to track the progress of each department and team with regard to a project
9) The ERP system lacks an overview of the current stocks

## 4.2 Solution Priorities

Implementing all the proposed solutions can take a long time. Thus, it would be beneficial to prioritize the solutions and see which ones can be applicated in parallel and which ones need to be applicated sequentially.

Solutions that can be used in parallel are:

- Solution 1: Creating Business Cases to get insight into project prioritization
  This solution needs to be applied at the beginning of the NPI process and should not influence the other solutions directly since it will mainly affect the sales department and that department is not directly responsible for applying any other solution.
- Solution 4: Following guidelines to organize meetings
  This solution can be implemented company wide and would only optimize the efficiency of meetings. Thus, it would not hinder the progress of other solutions.
- Solution 5: Including logistics teams earlier in the design process
  This solution is relatively simple and would therefore not stand in the way of other solutions.
- Solution 7: Analysing current systems for further possibilities
  This solution focusses on doing research. Since no immediate action is affiliated with it, it should be possible to perform this at the same time as the other solutions.

Solutions that should be executed sequentially are:

- Solution 2: Using PERT/Gantt Scheduling and Bottom-Up Resource allocation to avoid delays
- Solution 3: Using DFSS Organizing steps

These solutions would mainly impact the Product Development department. Since they can both have large impacts on the department. Implementing them at the same time could be chaotic.

- Solution 6: Creating process descriptions

This solution could cause for a lot of discussion when creating process descriptions that are currently not properly drawn up (e.g. discussions about which employee would have which responsibilities and which rules and policies exist). Thus, it is best not to implement it at the same time as solution 2 or 3 as they already would have a big impact on the Product Development department.

In order to start with a steady basis to apply solutions 2 and 3 it would be advised to start by implementing solution 6 to get clear descriptions of the processes. The most important solution to implement after this is solution 3 and then solution 2. Solution 3 would help to define structures in the NPI flow. Applying new methods of scheduling and/or resource allocation would be easier once these are defined.

## 4.3 Expected Investments and Returns

### 4.3.1 Investments

Based on the current way of working of Company X, implementing new processes will require a few steps:

1. Appointing and activating change agent: Choosing an appropriate agent from the involved teams or departments. Choosing the correct employee can be done by asking for volunteers in the appropriate teams/departments. The employees need to be informed about the responsibilities as a role model.
2. Informing involved staff about change project: Once the agent is chosen, they need to start executing the steps as mentioned in chapter 3.6.2.1. Establishing a sense of urgency, communicating the change vision, removing obstacles and consolidating gain.
3. Training personnel to understand new process
4. Trying out process
5. Evaluating process implementation
6. Improving process implementation
7. Process is fully implemented

Depending on the difficulty of the process, step 5 and 6 can be repeated a number of times. Assuming that the most important issues will be solved within a few iterations, an assumption is made that these steps will be repeated 3 times before passing to step 7. The total expected time can be calculated:

$$Step\ 1 + Step\ 2 + Step\ 3 + Step\ 4 + 3 * Step\ 5 + 3 * Step\ 6 \approx Total\ Implementation\ Time$$

For these calculations we will count a period of 4 weeks as 1 month. The paragraphs below go into detail on the duration of these steps and the involved employees per solution. The durations per steps are estimations. Thus, the Total Implementation Time should not be seen as a strict timeline but merely as an estimation. Many steps require meetings to be planned for discussions, evaluations etc. The initial calculations act as if these meetings could quickly and easily be planned. Taking into consideration that Company X is very busy, we expect that planning meeting could take a bit longer and could delay the Total Implementation Time of a solution by 20 %. Thus, the calculation becomes:

$$1{,}2 * (Step\ 1 + Step\ 2 + Step\ 3 + Step\ 4 + 3 * Step\ 5 + 3 * Step\ 6) \approx Total\ Implementation\ Time$$

*Solution 1: Creating Business Cases to get insight into project prioritization*

1. This research would logically be performed by the sales department and project leaders together; thus, this is also where a change agent should be chosen. The sales department and project leader teams are relatively small. To choose the agent an estimated 2 weeks will be needed. The first week can be used to spread information and the second one to choose the final employee. Choosing and informing them about Business Cases and their exact tasks as a role model will take an additional week. In total, this step is expected to take approximately 3 weeks.
2. Informing and preparing staff for the change project can take approximately 2 weeks. 1 week to spread information about the project and 1 week to answer questions from employees.
3. In order to create a good Business Case, employees need to be trained. An example of a training that could be followed in the Netherlands is a training by CapGemini, costing 750 euros per employee and taking up 2 working days (CapGemini Academy, n.d.). Selecting the employees that need this training and planning a good moment for it can each take a week. Thus, this step will expectedly take approximately 2 weeks to complete.

4. Implementing the training into actual business processes can only be done at the beginning of a NPI flow. Thus, implementing this will take as long as it takes for a new project to start. We do not have much information about the interval between new projects. In the best scenario, this will be immediately. In the worst scenario, we will assume that this takes 6 months. To even out the possibilities, we will take the average of these (3 months) as the duration of this step.
5. Evaluating can be done as soon as the Product Development department starts working on the product. If the department misses information, this needs to be included in the next business case. For the department to get started and notice that information needs to be added to the business case, we will assume that this takes approximately 2 weeks.
6. The changes that were needed in previous projects can be implemented in this phase. This will need to wait until a new project is started. In the best scenario, this will be immediately. In the worst scenario, we will assume that this takes 6 months. To even out the possibilities, we will take the average of these (3 months) as the duration of this step.
7. Assuming that the process is efficiently implemented after repeating step 5 and 6 at least 3 times, the total time it would take to implement this solution is constructed:

$$1{,}2 * (3\,Weeks + 2\,Weeks + 2\,Weeks + 3\,Months + 3 * 2\,Weeks + 3 * 3\,Months) \approx 1\,Year\ and\ 21\,Weeks \approx Total\ Implementation\ Time$$

*Solution 2: Using PERT/Gantt Scheduling and Bottom-Up Resource allocation to avoid delays*

1. This solution will mainly be executed in the Product Development department; thus, this is also where a change agent should be chosen. Since the Project Leaders are currently the best link between all the teams, it would make sense to appoint 1 or both as the Agent. Deciding this could probably take up to a week.
2. Informing and preparing staff for the change project can take approximately 4 weeks since many employees are involved. 2 weeks to spread information about the project and 2 weeks to answer possible questions from the teams.
3. We will assume that Company X will use PERT Scheduling. To use PERT scheduling in an optimal way, a training can be followed. An example of such a training is the online course by Udemy, costing 85 euros and taking up 1 working day (Pathak, 2022). Training staff for resource allocation costs around 100 euros, taking up about 1 hour (Dehora, n.d.). Selecting the employees that need this training and planning a good moment for it can take relatively long since multiple teams are involved. This could take 5 times as long as solution 1, assuming that multiple employees from each team (5 teams in total) need to be trained. Thus, this step will expectedly take approximately 10 weeks to complete.
4. Implementing PERT Scheduling to make employees build their own schedules can be done relatively quickly as it does not necessarily need to wait until a new project starts. We will assume that employees can start using PERT Scheduling with a Bottom-Up Resource allocation for the month directly after the training.
5. Evaluating can be done halfway through each month to see what needs to be changed for the following month. Thus, this will take approximately 2 weeks.
6. Implementing the changes as proposed in step 5 can be done for the following month and will thus take approximately 2 weeks.
7. Assuming that the process is efficiently implemented after repeating step 5 and 6 at least 3 times, the total time it would take to implement this solution is constructed:

$$1{,}2 * (1\,Week + 4\,Weeks + 10\,Weeks + 1\,Months + 3 * 2\,Weeks + 3 * 2\,Weeks) \approx 37\,Weeks \approx Total\ Implementation\ Time$$

*Solution 3: Using DFSS Organizing steps*

The investment of this solution is difficult to calculate as the steps will be taken during the NPI flow and no specific trainings are required.

1. This solution will be executed by the project leaders. Deciding this could probably take up to a week. It would make sense to appoint 1 or both as the Agent here as well. Deciding this could probably take up to a week.
2. Even though the project leaders will mainly be responsible for the work, the employees in the Product Development department will all need to work according to the structures constructed in this solution. Informing and preparing staff for the change project can take approximately 4 weeks since many employees are involved. 2 weeks to spread information about the project and 2 weeks to answer possible questions from the employees.
3. There is no exact training for these processes. In order for the project leader(s) to understand the exact tasks that they need to do, we will assume 1 week per subpoint (a,b,c…) is required. Thus, this step will take 6 weeks.
4. Implementing this solution will mean to construct all the elements that are mentioned in the DFSS steps and implement them within the teams and departments once they are done. For each subpoint (a,b,c…), we will estimate 1 week is needed to properly construct it. Properly implementing it within all the teams and departments will take a bit longer since more employees are involved. We assume that 2 weeks can be needed to get everyone on the same page per subpoint (a,b,c…). This sums up to 3 weeks per subpoint and a total of 18 weeks.
5. Evaluations can be done at any moment since these structures and documents are not related to very specific processes in the NPI flow.
6. Implementing changes can take up to 2 weeks to get everyone on the same page again.
7. Assuming that the process is efficiently implemented after repeating step 5 and 6 at least 3 times, the total time it would take to implement this solution is constructed:

$$1{,}2 * (1\,Week + 4\,Weeks + 6\,Weeks + 18\,Weeks + 3 * 0\,Weeks + 3 * 2\,Weeks) = 42\,Weeks \approx Total\ Implementation\ Time$$

*Solution 4: Following guidelines to organize meetings*

1. This solution will be executed by all the employees that organize a meeting. The change agent should thus be chosen somewhere in the higher structures of Company X. Choosing the appropriate agent could take up to 1 month since it is more vague who would be the best fit.
2. Informing and preparing staff will be the longest part of this solution since this could be implemented company wide. We will assume that this can take up to 2 months.
3. Since the guidelines can simply be sent to the employees while informing and preparing them, this does not require additional time.
4. Implementing the guidelines also does not require additional time as the employees should be instructed to use the guidelines once they receive them.
5. Evaluating whether every employee is correctly applying the guidelines could be done every 2 months to leave a clear reminder for all the employees.
6. Implementing changes and/or reminders could take an additional week. This time could be used to create an information mailing or reminder to all the employees.
7. Assuming that the process is efficiently implemented after repeating step 5 and 6 at least 3 times, the total time it would take to implement this solution is constructed:

$$1{,}2 * (1\,Month + 2\,Months + 0\,Weeks + 0\,Weeks + 3 * 2\,Months + 3 * 1\,Week) \approx 32\,Weeks \approx Total\ Implementation\ Time$$

*Solution 5: Including logistics teams earlier in the design process*

1. This solution will be executed by all the employees in the Product Development department. Since the Project Leaders have the best overview of these teams, 1 or both should be the change agent for this project. Choosing the appropriate agent could take up to 1 week.
2. Informing and preparing staff will not take very long as it will simply be a request to the involved teams to involve the logistics teams earlier on in the processes. We will assume that this communication can take up to 2 weeks to reach all the employees.
3. The employees do not require additional training.
4. Implementing the request could possibly take until the next NPI. We do not have much information about the interval between new projects. In the best scenario, this will be immediately. In the worst scenario, we will assume that this takes 6 months. To even out the possibilities, we will take the average of these (3 months) as the duration of this step.
5. Evaluating whether the logistics team is involved at the right moment can be done at the end of a project. We will assume that a project takes 6 months.
6. Implementing changes could be done during the next project. In the best scenario, this will be immediately. In the worst scenario, we will assume that this takes 6 months. To even out the possibilities, we will take the average of these (3 months) as the duration of this step.
7. Assuming that the process is efficiently implemented after repeating step 5 and 6 at least 3 times, the total time it would take to implement this solution is constructed:

$$1{,}2 * (1\,Week + 2\,Weeks + 0\,Weeks + 3\,Months + 3 * 6\,Months + 3 * 3\,Months) \approx 2\,Years\ and\ 47\,Weeks \approx Total\ Implementation\ Time$$

*Solution 6: Creating process descriptions*

The investment for this solution is hard to calculate. Since it encapsulates creating process descriptions for a lot of processes, it is expected that this can take several months. Since this solution is mainly about mapping the ways of working and not necessarily implementing anything new, no employees need to be trained and no evaluations need to be done. The process descriptions simply need to be made and employees need to be made aware that they exist and can be used as a base of working. The steps become:

1. Choosing an appropriate employee to document the process could take up to 2 weeks depending on the size of the team or department in which the process is located.
2. We estimate that each process can take up to 2 months to properly be explained.
3. Informing all employees about the newly created process document could take up to a week.
4. Creating the process descriptions can be done for multiple processes at the same time. Assuming that the steps above take place at the same time for all 9 processes, the total time it would take to implement this solution is constructed:

$$1{,}2 * (2\,Weeks + 2\,Months + 1\,Week) \approx 13\,Weeks \approx Total\ Implementation\ Time$$

*Solution 7: Analysing current systems for further possibilities*

The investment for this solution can not be estimated yet as it is not clear yet what the possibilities are using the current systems.

*Total*

Assuming that 1, 4, 5 and 7 can be tackled simultaneously. The estimated Total Implementation Time would be the longest duration of either solution 1, 4, 5 or 7 individually or the summation of solution 2, 3 and 6. Since solution 7 does not have a clear duration, we will leave it out of the equation.

- Solution 1 ≈ 1 Year and 21 Weeks
- Solution 4 ≈ 32 Weeks
- Solution 5 ≈ 2 Years and 47 Weeks
- Solution 2 + Solution 3 + Solution 6 ≈ 37 Weeks + 42 Weeks + 13 Weeks ≈ 1 Year and 40 Weeks

Thus, the time it would take to implement all the solutions would equal around 2 years and 47 weeks as this is the duration of the longest solution (2).

### 4.3.2 Returns

In order to find the expected result of applying the proposed solutions, employees estimated the effects of all the solutions together. The company decided to make its employees elaborate on the solution set as a whole since estimating the result of each specific solution can be difficult without having read their full descriptions. The question that is asked is:

*How much will the proposed methods below improve the time you spend in the New Product Development chain?*

The questionnaire received responses from the departments:

| **Department** | **Response 1** | **Response 2** | **Response 3** | **Response 4** | **Average** |
|---|---|---|---|---|---|
| Business Development | 0 % | | | | 0 % |
| Research and Development | 50 % | | | | 50% |
| Product Development | 60 % | 90 % | 30 % | 80 % | 65% |
| Total Quality Management | 80 % | | | | 80% |
| Archive | 60 % | 30% | | | 45% |

To calculate the expected improvement in working hours, we first need to estimate the time that a product spends in each of these departments in the NPI flow. Using the average NPI project duration of 20 months (19.89 months rounded up as stated in section 1.2.1) and based on the work descriptions received from the employee interviews, a product follows the timeline:

| **Department** | **Time spent** |
|---|---|
| - Business Development | 3 months |
| - Finance | 0.5 months |
| - Research and Development | 3 months |
| - Product Development | 11 months |
| - Total Quality Management | 0 months |
| - Production | 2 months |
| - Archive | 0.5 months |
| - Customer Service | 0 months |

The departments that show 0 months will not be considered since they don't directly influence the NPI time. This means that Total Quality management will be left out of the equation even though it did send in a response.

Thus, we calculate the expected improvement in the NPI flow time by multiplying the average response of a department with the estimated time that a product spends in that department.

$$Business\ Development\ Response * 3\ months + Research\ and\ Development\ Response * 3\ months + Product\ Development\ Response * 11\ months + Archive\ Response * 0.5\ months =$$

$$0\% * 3\ months + 50\% * 3\ months + 65\% * 11\ months + 45\% * 0.5\ months = 8.875\ months$$

Thus, the NPI time is expected to decrease by an estimated 8.875 months if all the proposed solutions are applied.

## 4.4 Change strategy

This section documents the strategy to alter the current processes to the theoretical ideal situation.

### 4.4.1 Applying 4-Step

This report describes 7 solutions to tackle the issues identified within Company X. It is important to apply the literature of Section 3.6.1, following the 4-Step plan to success. The change agents that are chosen for the solutions will be responsible for managing change activities and thus execute the steps that are described in this section. These agents will form the link between the employees and the management. They will carry out the 4-Step plan:

- Step 1: Establish a sense of urgency through a guiding coalition
- Step 2: Develop and communicate the change vision
- Step 3: Remove obstacles to achieve the new vision and generate short-term wins
- Step 4: Consolidate gain, produce more change and anchor new approaches in the corporate culture

### 4.4.2 Attention Factors

While performing the changes, it is important to pay attention to the factors mentioned in Section 3.6.2 by the change agents. For the project to be successful, the following elements are crucial:

- Having Change Leader/Agents
- Keeping Employees actively involved
- Keeping Employees motivated
- Setting clear and reachable targets
- Timing the announcement and execution of change within a reasonable interval.

To check whether the change has the wanted effects, the following elements need to be checked periodically (Section 3.6.4):

- Operational effectiveness
- Operational efficiency
- System suitability
- System resilience
- System affordability
- System supportability
- System life cycle cost
- System performance
- System schedule
- System cost

## 4.5 Conclusion

This chapter answers our third research question: “Which measures can be taken to improve the New Product Introduction Chain?”.

7 solutions can be implemented to improve the New Product Introduction Chain:

- Solution 1: Creating Business Cases to get insight into project prioritization
- Solution 2: Using PERT/Gantt Scheduling and Bottom-Up Resource allocation to avoid delays
- Solution 3: Using DFSS Organizing steps
- Solution 4: Following guidelines to organize meetings
- Solution 5: Including logistics teams earlier in the design process
- Solution 6: Creating process descriptions
- Solution 7: Analysing current systems for further possibilities

The expected results from these solutions are:

- Projects will be prioritized more efficiently.
- Schedules will be more realistic and delays will be minimized
- Communication flows in and between the Netherlands and China will go faster
- Meetings will be more productive
- Processes in every department and team will go smoother, quicker and easier
- Purchasing and designing processes will be easier
- Employees will have an overview of the progress of other teams and departments and will thus be able to schedule their activities more efficiently
- Ordering parts and products through the ERP system will be easier

Solutions that can be used in parallel are Solution 1, 4, 5 and 7. Solutions that should be executed sequentially are Solution 6, 3 and 2 respectively.

The time it would take to implement all the solutions would equal around 2 years and 47 weeks as this is the duration of the longest solution (2).

# 5. Conclusion

The 4th and final phase of this research relates the previous phases to the main question.

*"How can the New Product Introduction Time be improved and by how much?"*

We answer this question in Section 5.1 using the information gathered from all the phases. Section 5.2 documents the limitations for this research. Last but not least, Sections 5.3 and 5.4 describe the recommendations and further research respectively.

## 5.1 Conclusions

**Phase 1 describes the current situation and answers research question:**

*Which processes are currently used in the New Product Introduction chain and are there any issues or challenges with the processes*?

The New Product Introduction chain goes through 36 different processes, involving 8 different departments containing specific 14 teams. Out of these departments, 10 teams experience operational issues. The issues can be summarised:

1. Not enough research is performed to analyse which projects need to be prioritized
2. Many projects are prioritized impromptu which causes delays in other projects
3. Communications between the Netherlands and China are often taking a long time
4. Meetings often lack preparation and follow-ups from the attendees
5. The logistics teams are often included too late in the design process
6. The existing processes and functions lack detailed descriptions, including step-to-step explanations, checklists, responsibilities per person and clear policies
7. Purchasing and logistics teams lack a good overview of suppliers, their products, delivery times and internal current stocks of parts
8. There is no system to track the progress of each department and team with regard to a project
9. The ERP system lacks an overview of the current stocks

**Phase 2 describes the theoretical framework and answers research question:**

What methods exist in literature to optimize product development processes?

This literature research has shown that DFSS is the most suited method to construct design projects in Company X. DFSS contains multiple concepts that need to be used while setting up a new project in Company X. In addition to this, literature indicated multiple methods of allocating resources. The most suited for Company X is the Bottom-Up Resource allocation method which focusses on having employees construct the planning. Literature also indicates 10 steps that need to be taken to ensure productive meetings. Last but not least, to make sure that the changes in the company will go as expected, it is important to carefully plan this change project while paying attention to several attention factors and reasons for failure.

**Phase 3 answers research question:**

Which measures can be taken to improve the New Product Introduction Chain?

- Creating Business Cases to get insight into project prioritization
- Using PERT/Gantt Scheduling and Bottom-Up Resource allocation to avoid delays
- Using DFSS Organizing steps
- Following guidelines to organize meetings
- Including logistics teams earlier in the design process
- Creating process descriptions
- Analysing current systems for further possibilities

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*"How can the New Product Introduction Time be improved and by how much?"*

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**Phase 4 describes the measures that need to be taken in order to improve the New Product Introduction time in Company X and the expected investments and results**:

7 solutions can be implemented to improve the New Product Introduction Time:

- Solution 1: Creating Business Cases to get insight into project prioritization
- Solution 2: Using PERT/Gantt Scheduling and Bottom-Up Resource allocation to avoid delays
- Solution 3: Using DFSS Organizing steps
- Solution 4: Following guidelines to organize meetings
- Solution 5: Including logistics teams earlier in the design process
- Solution 6: Creating process descriptions
- Solution 7: Analysing current systems for further possibilities

The expected results from these solutions are:

- Projects will be prioritized more efficiently.
- Schedules will be more realistic and delays will be minimized
- Communication flows in and between the Netherlands and China will go faster
- Meetings will be more productive
- Processes in every department and team will go smoother, quicker and easier
- Purchasing and designing processes will be easier
- Employees will have an overview of the progress of other teams and departments and will thus be able to schedule their activities more efficiently
- Ordering parts and products through the ERP system will be easier

Solutions 1, 4, 5 and 7 can be used in parallel. Solution 6, 3 and 2 can respectively be executed sequentially.

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*The time it would take to implement all the solutions would equal around 2 years and 47 weeks. The average expected improvement in NPI flow time is 8.875 months. Reducing the average 20 months by 8.875 months means that a project would take about 11 months to complete. Thus, the company goal for projects to take around 1 year would be achieved.*

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## 5.2 Limitations

Company X currently does not keep records of the time spent on individual processes in a project. Due to this, it is hard to establish average process durations. This means that it is also hard to predict the expected improvements per specific process from the solutions proposed in Chapter 4.

## 5.3 Recommendations

The first recommendation for Company X is to create a business case before every project in order to create a clear view of the value of the project and substantiate which projects obtain priority. Using the DFSS business case description as described in Section 3.3.1.1 is recommended.

The second recommendation is using the PERT or Gantt Scheduling method and Bottom-Up Resource allocation method as described in Sections 3.3.4 and 3.4 respectively in order to create reliable schedules that avoid delays.

Our third recommendation is following the DFSS organizing steps as described in Section 3.3.3 to create an efficient design project. In addition to this, we recommend following all the DFSS steps that are described in Section 3 to create the design project.

Since meetings are currently not as efficient as wanted, our 4$^{th}$ recommendation is using the guidelines described in Section 3.5 to organize and structure meetings in the future.

Our fifth recommendation revolves around wasting less time and efforts in the design processes. We recommend including the logistics teams earlier in the design processes as they can procure information that is useful in early design steps.

The 6$^{th}$ recommendation is investing into creating clearer process and function descriptions all around Company X in order to avoid mistakes and create a clear overview of who is responsible for what. Since doing this is a very elaborate project, we recommend currently focussing on the processes that are experiencing the most issues. Namely:

- **Processes for entering data into the ERP system**
  - Order entry processes
  - Project, part, material and document naming processes
  - Data deletion processes
- **Requirement Document (A0) Standards**
  - Design specifications
  - Delivery Time
  - Expected Purchasing amounts
- **Logistic Policy documentation**
- **Release Processes**
  - Document uploading checklists
  - Responsibilities between releases

Last but not least, we recommend analysing current systems for further possibilities in the following directions:

- Creating an overview of suppliers, their products, delivery times and internal current stocks of parts that are needed for prototypes for the purchasing and logistics team
- Creating a way to track the progress of each department and team with regard to a project

## 5.4 Further Research

To keep improving in the future while focussing on the right processes, it is important to strategically choose these processes. One way of supporting these decisions could be by using the 'Balanced scorecard method'. This method is based on picking measuring areas and indicators that display the efficiency of processes, e.g.: "Environment and community perspective with as indicator 'Compliance with environmental laws', or Employee satisfaction with as indicators 'Number of complaints of staff' and 'Staff movement rate'." Using several of these areas and indicators, the involved processes should all be scored using a cross-efficiency model in a data envelopment analysis (DEA). The highest scoring process is the least efficient and should thus be given priority. (Bazrkar & Iranzadeh, 2017)

In order to perform this research, more data needs to become available about the details per process, e.g. the average costs and duration of a specific process. Thus, if Company X were to pursue the Lean Six Sigma Cycles, it is important to invest in recording more specific data per process.

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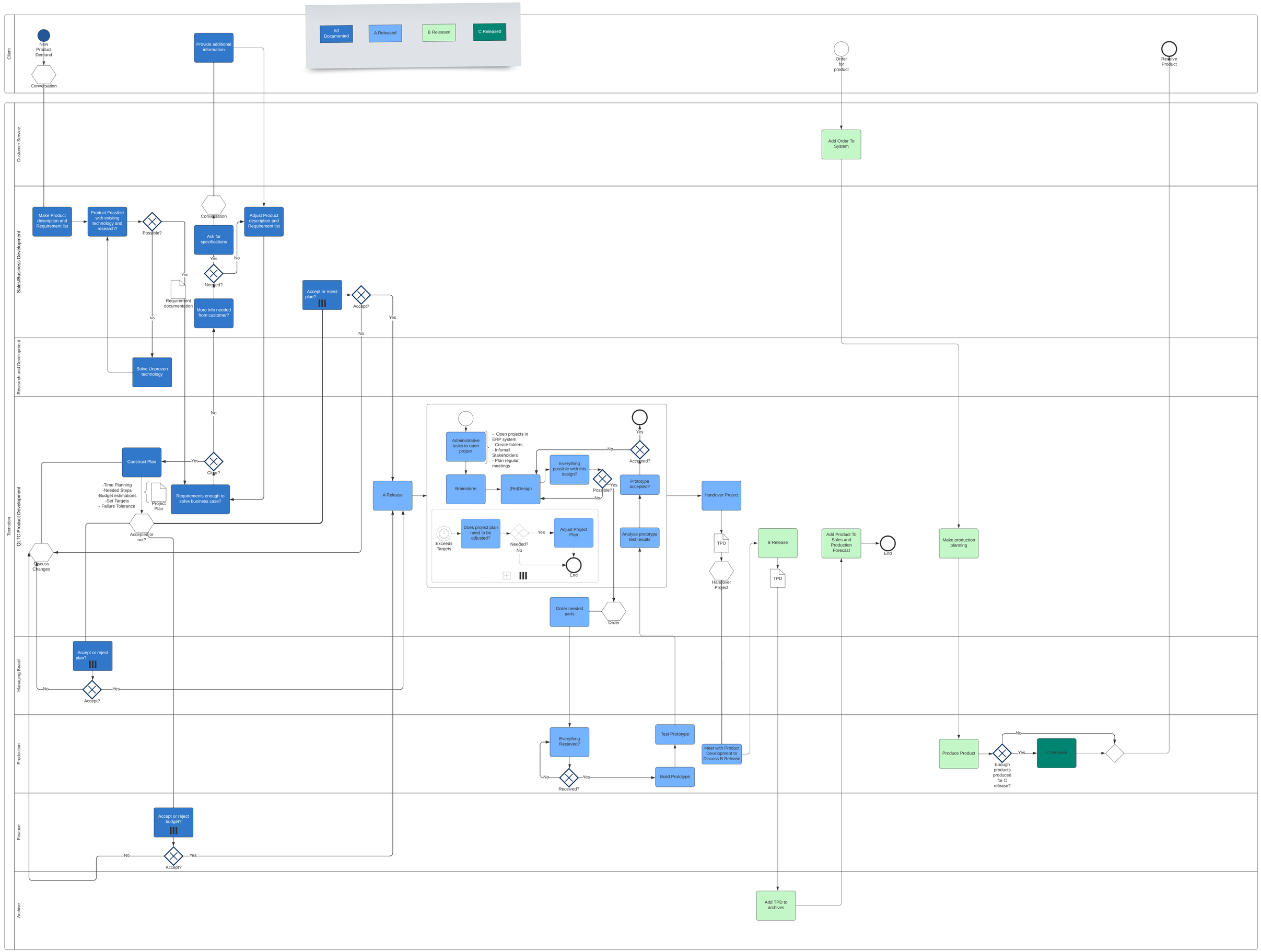
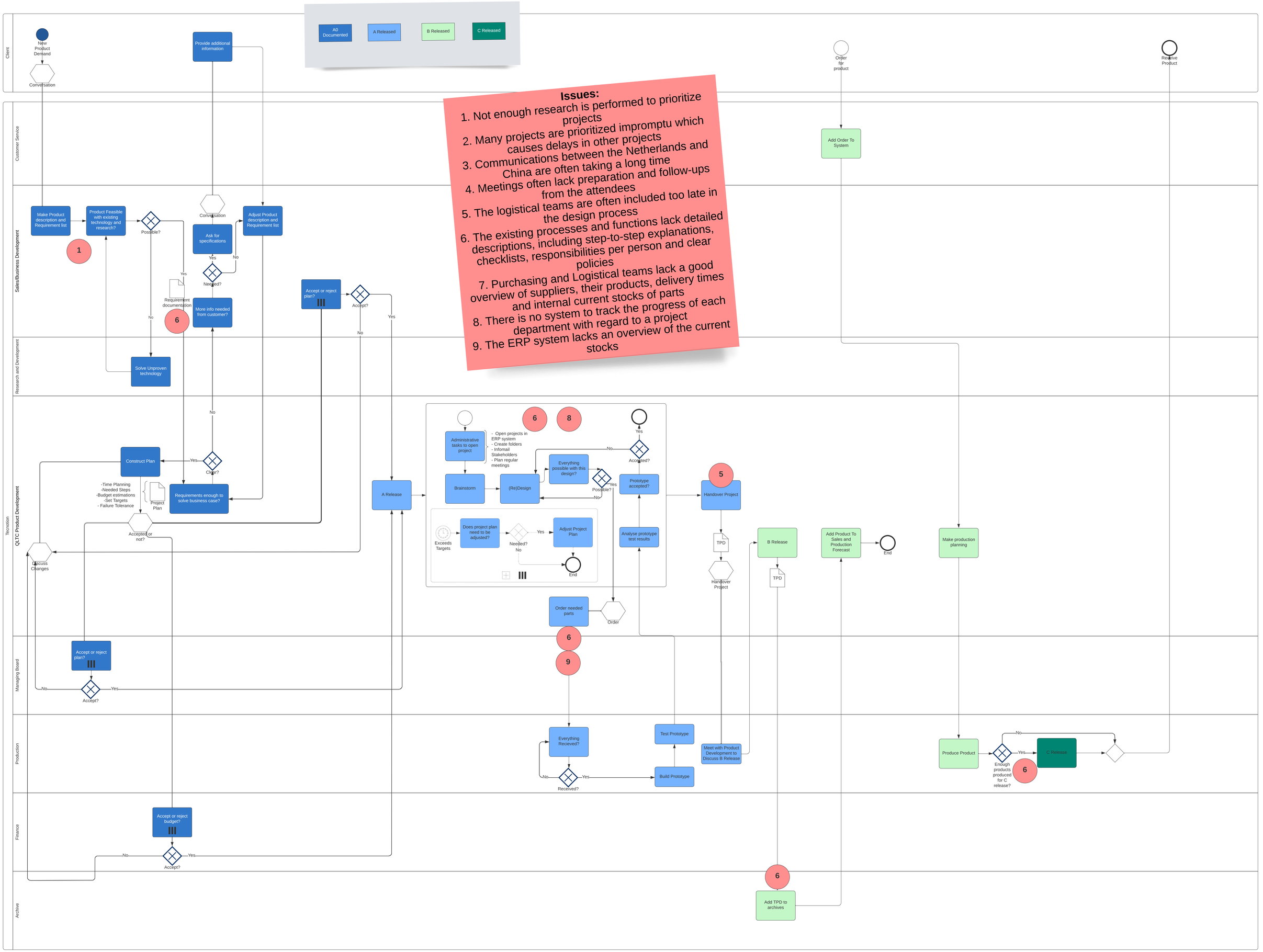
# Appendix A BPMN Model



# Appendix B BPMN Model with issues indicated in Flow



# Appendix C Methodology Comparison Matrix

| Methodology | Optimization through what? | Improvement Methodology | Process Optimization | Focus on Design Processes |
|---|---|---|---|---|
| Six Sigma - DFSS | (Re)Designing Processes | X | X | X |
| Total Quality Management | Customer Satisfaction | X | X | |
| Lean Manufacturing | Reducing Waste, Maximizing Productivity | X | X | |
| Business Process Management | Achieving Organizational goals | X | X | |
| Business process re-engineering | Optimizing Customer Value Adding Processes | X | X | |
| Continuous Improvement | Incremental and Breakthrough Improvements | X | X | |
| Plan Do Check Act | Well structured Implementation Cycle | X | | |
| Whys analysis | In depth questioning | X | | |