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Analysis and improvement of the New Product Introduction centre for Company X using Key Performance Indicators

Bachelor Thesis

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Bachelor thesis Industrial Engineering and Management

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Introduction

This thesis report is conducted on behalf of the University of Twente with the goal of completing the undergraduate program Industrial Engineering and Management and to assist Company X with their goals of analysing and improving their New Product Introduction department.

I would like to thank Mr. B as my direct supervisor at Company X, for helping me shape my research and providing me with critical feedback and useful internal information of the company as well as fully supporting the research on the improvement of the NPI centre.

For the opportunity of conducting my research at Company X, the hospitality and the open mindedness towards my research I would like to thank my problem owner and final supervisor Mr. P and the other employees of the NPI centre who provided the critical information from which this research was created.

I would like to thank Dr. Devrim Yazan as my UT supervisor for providing critical reviews of my work and allowing me to shape my research to be both more useful for the company as well as provide a more critical overview and analysis for the research collective.

Finally, I would like to thank fellow students; David van den Berg as my buddy, providing dissertation and research review on my report, as well as Lars Tijhuis who was conducting his Master Thesis at Company X for providing guidance and help in understanding the company and shaping my research.

Thom Sparrius – August, 29th, 2019

Management summary

Introduction
This research is conducted for the NPI centre of Company X. Company X is one of the leading providers of customer solutions on a global basis. These solutions are design and manufacturing oriented, resulting in the engineering and production of products based on customer requirements. Company X, being a business-to-business corporation solely provides their solutions to customers and therefore does not have products themselves they are therefore classified as a contract design house/manufacturer.

The problem originates from the fact that the NPI process is currently not measuring their performance and should therefore be analysed and optimised. For this purpose, a list of KPI's was requested. It was however decided that a more fundamental analysis was required beforehand, and the following research question was formulated;

"How does Company X NPI currently function, what are the perceived main problems and what should be done to improve." With the purpose of finally allowing the analysis and improvement of the NPI centre using KPI's.

Approach
In order to understand the process and problems the following steps were undertaken;

- Primary data was gathered using interviews, in order to understand both the employee perception of the department and problems, as well as understanding the requirements and observations by the internal customers.
- A model was formulated using the primary interview data and internal company information, models and overviews. The new model combined current information and attempted to create a clear structure within the NPI centre.
- The fundamental problems perceived by the employees were discovered and explained and some solutions to them were provided.
- A list of conceptual KPI's was created which, after quantitative and literary reference, serve as a tool for measurement and optimisation of the department.
- Relationships between the problems and solutions were given to visualise their intended solution.

Results, conclusions & recommendations
The main fundamental problems appeared to be miss-/lack of communication and lack of standardisation/structure. Which cause misunderstanding of the current process and dissatisfaction. The other fundamental problems all appeared to be related, and to some degree influence or cause each other within the NPI.
It was discovered that the main reason for the current situation is that the current operations and projects are completed with personal skills and experience rather than an implemented system. Therefore, collective action and guidelines do not exist and new employees or struggling employees within the NPI have a hard time successfully completing task without assistance, instruction or supervision.

The main conclusion of the research is that the problem exists due to inconsistency of actions. This research therefore conclusively advises Company X to invest in increasing the consistancy of operations

at the NPI centre, since this both accommodates the systematic increase of knowledge as well as establishing a structure which can be used as reference and allow for better communication. This will increase efficiency and effectivity of within NPI centre, inter-departmental and other multi-disciplinary work. This can be done through the mandatory learning of the main process principles as well as application of the full-project scale for the first few projects, after which short-cuts and adjustments to projects can be made from an informed position. Research believes that eliminating these fundamental problems will therefore in the long term greatly increase revenue generation and overall satisfaction towards customers and employees.

This research indicated the issues which need to be resolved first and what steps can be taken towards solving these problems using a series of solutions and KPI's. For future research the recommendation is that Company X accommodates the further implementation of the KPI's and creates an implementation plan.

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1. The company

Chapter 1 will provide context and explain the purpose of this research with an introduction to Company X as a general corporation. Section 1.1 will provide a general introduction to Company X after which section 1.2 will describe the departments in general and provide a more in-depth description of the New Product Introduction centre.

1.1 Company X

Removed for anonymity of the company

1.2 Situation description

Company X consists of three main departments which all provide services to eventually deliver a product which fits the customer requirements. These departments are the following;

- Design engineering and development
- Manufacturing engineering and production
- New Product Introduction

In Figure 1.2.1 the relation between these departments is displayed. In which the New Product Introduction centre should be seen as the actor with the purpose of balancing both the other departments' wishes and the customer requirements.

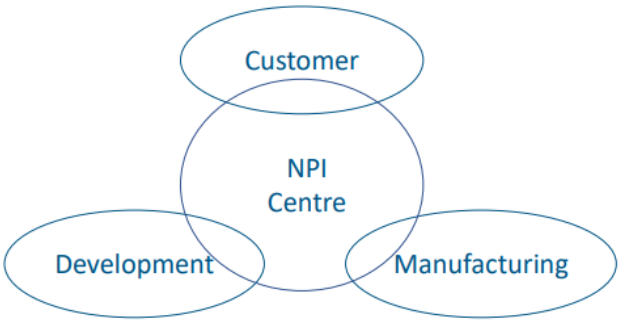
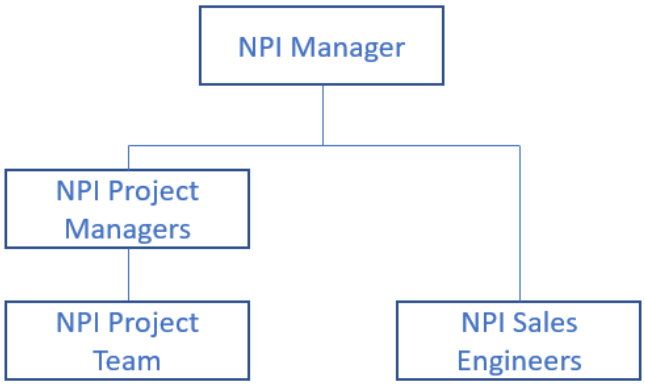


Figure 1.1.1: Departmental relationship visualisation

The NPI centre is the department for which this research is conducted. It is important to note that the other departments, the relationships and their expectations must be regarded to provide a foundation for the changes within the NPI centre since the actual operation of providing a customer with a quality product, catered to their needs, is achieved with work from all departments and strongly dependant on inter-departmental relationships. The NPI processes will be explained more in-depth in Chapter 3.



The hierarchy within the NPI centre is fairly simple and is visualised in figure 1.2.2, the members an NPI team usually consist of planners, manufacturing engineers, quality engineers, test development engineers, design engineers and purchasers.

Figure 1.2.2: Organigram of the Company X, NPI centre

2. Research design

Chapter 2 aims to clarify how the research was designed and what questions and situations need answering in order to solve the main problem. In section 2.1 the problem is described, in section 2.2 an explanation is given how the information needed to answer the problem is acquired, section 2.3 explains the desired outcomes, section 2.4 provides the research questions which are used to achieve the desired outcomes, section 2.5 elaborates on the scope of the research and section 2.6 explains the deliverables.

2.1 Problem description

The request from Company X was to deliver a list of measurable and optimisable key performance indicators for the new product introduction centre. By itself this would not suffice as a research topic so further investigation was done regarding the reasoning behind the need for these KPI's and the underlying problems. Some of these fundamental problems will be discussed in Chapter 4.

The main problem however is that, even though the NPI centre of Company X is operating relatively well and their revenue as an absolute number is decent enough for management, the stagnation of the department poses threat for the future in which innovation and growth is an important pillar.

For this purpose, the research is changed to provide a consultancy report regarding the NPI with the help of self-introduced KPI's rather than just an analysis regarding the formulation of proper KPI's. The reasoning behind this is that the NPI centre currently does not measure their performance in any way. The actions are mostly based on top-down desired result without a full grasp of the situation.

The research should be prefaced with the fact that the term key performance indicators will also be used to address key result indicators in some cases. This is specified in the cases where the difference is relevant.

The main problem and purpose warrant the following overarching questions: "How does Company X, NPI currently function, what are the perceived main problems and what should be done to improve?" The problem cluster is visualised in Figure 2.1.

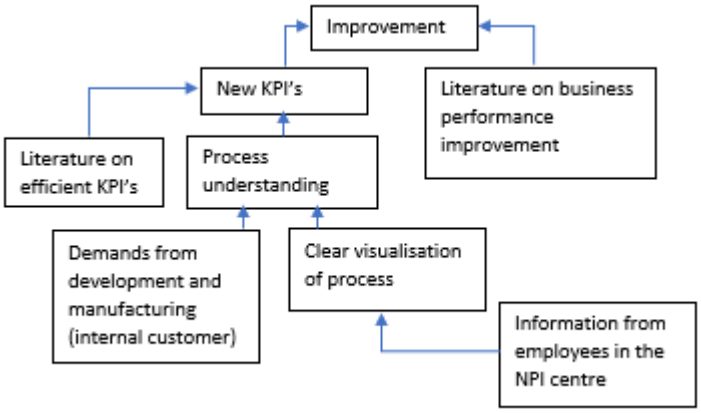


Figure 2.1: Problem cluster

The problem cluster addresses the following knowledge problem; “How can the NPI process at Company X best be improved using KPI’s”. This cluster is also an accurate representation of what this research aims to establish. Which is how the NPI centre can improve and where.

2.2 Information gathering method

For this purpose, primary data must be gathered. The nature of this research is by design more qualitative since investigation needs to be done regarding a department which creates value through knowledge of employees rather than manufacturing or machining.

The first source of information for this research will be interviews conducted with employees of the NPI centre, in which interviewing employees with similar functions as well as interviewing employees on different levels of hierarchy and experience allowed the research to be more valid. These interviews will be confidential and analysed afterwards with the purpose of accumulating points of interest and inconvenience within the workforce and trying to understand what circumstances and parameters accommodate these findings.

The secondary source of information is interviews with internal customers. These interviews will serve as both a reference to the information provided by the employees of the NPI centre regarding their self-perceived work, as well as an indication regarding the discrepancies between delivered work and expectations. Some internal customers are employees of Company X which serve the purpose of being a project manager and are therefore literal internal customer whilst others represent aspects of the company like a representative for procurement with whom the NPI also operates to ensure proper delivery of product.

The third source of information are internal documents which contain information regarding the processes within the company or templates for work-approaches. This information is both helpful in understanding the current structure as well as discovering where in these documents or within the company itself the information is communicated/delivered to or not.

The last piece of information will be literature. This literature is acquired with the purpose of referencing formulated findings within the research and to allow for critical review possibilities, which eliminate personal interpretation from the research.

2.3 Desired outcomes

The intention of this research is to create clarity within the NPI department of Company X. The research hopes to, with the creation and discussion of the current and improved model of the process, create an understanding regarding the fundamental process on which the NPI centre can improve. The research also hopes that by addressing fundamental problems and providing general solutions a better fundament for improvement and growth is created. To the end of creating a platform for measurement and optimisation a list of KPI’s is presented by which Company X could help solve some of the fundamental issues. A secondary goal of this research is to very clearly indicate how the problems and KPI’s are correlated.

2.4 Research questions

A number of research questions is made in order to realise these desired outcomes and to support in guiding the research to answer the questions which need to be answered to allow Company X NPI to improve. Here in section 2.4 are the three main questions with a series of sub-questions which are needed to answer the main questions.

1. What is the current NPI process and how is it perceived?
How does the NPI process work?
What are the bottlenecks in the current process?
What are the requirements by the other departments?
What are considered the main points of improvement by the management of the NPI?

2. What does literature about KPI's indicate?
What should be considered when formulating KPI's?
What are optimal KPI's?

3. *How does the formulation of KPI solve the fundamental problems?*
What is the relationship between the fundamental problems?
What is the relationship between the key performance indicators?
How do the KPI's solve the existing issues?

2.5 Scope

The research scope defines the depth of the research and on what levels of the organisation the research is applicable. The scope of the research is mainly the NPI centre, as an individual department. But in order to establish context, the departments with which direct relations are occurring, were also included in the research, this was with the main purpose of determining if the operations in the NPI were perceived by 'internal customers' as sufficient. The main level on which the NPI centre was reviewed in this report was the operational level. This operational information will then be used to provide managerial advice, so the research is mostly aimed at what Company X considers level 4; the departmental and therefore managerial level. There has currently been no measurement meaning this research is mostly advisory and implying that in the future measurement must occur in order realise the proposed improvement.

2.6 Deliverables

This bachelor thesis will contain a series of deliverables with which the NPI centre at Company X will be able to improve their process. The following deliverables will be included:

- A model containing the process flow of the NPI centre. This model will summarize the flow within an NPI project, responsibilities within an NPI project and the interactions between actors within the project process. Helping to clarify which departmental interactions occur and which tasks should be completed when.
- An overview of measurable and optimizable conceptual KPI's, which will both be compared to literature to understand whether or not they have theoretical grounding as well as a quantitative data analysis of interview information to understand which problems are supported by whom.
- A fundamental advisory and implementation advise.
- Recommendations and suggestions for future research.

3. Process description and model

Chapter 3 is intended to explain which information the research required in order to create an accurate report on the NPI centre of Company X. In section 3.1 the current models used in describing the NPI process are explained. In section 3.2 the models are critically reviewed, and information is provided regarding the current efficiency of use and availability of information. In section 3.3 an improved version of the model is given and explained. Section 3.4 will then conclude chapter 3 by giving elaborating how this model could be implemented in the NPI centre.

3.1 Current situation and model

Before the New Product Introduction process at Company X can be understood a description of the order process is given. This provides context to the interaction with the other departments and how Company X generally supplies to their customer requirements. The ordering process overview is made by Tijhuis (2019) and can be found in Appendix A.1.

After understanding what general steps are taken to realise a product for a customer, the rest of the process can be explained. Project work at Company X and particularly the NPI centre is elaborated using two models which are interchangeably used, whether or not that is efficient will be discussed in section 3.2.

These models are called the '7-step model' and the 'V-model'. Both models describe what steps are undertaken towards the realisation of a product and in what order this should be done. First the 7-step model, which can be seen in Figure 3.1.1 will be explained.

FIGURE REDACTED FOR ANONIMITY REASONS

Figure 3.1.1: 7-step model

The 7-step model is a process overview which is displayed in most meeting rooms in Company X and was used by some employees to explain the NPI process. Initially Company X existed with only two main departments; engineering and manufacturing until NPI was introduced to help. This model therefore only displays Engineering, Manufacturing and Supply Chain as components. The 7-steps model contains eight main phases, in which step 0 is the initiation phase, where a new customer presents their idea/concept.

The 7-step model generally describes what is supposed the be delivered in which phase and how an idea proposed by a customer is eventually turned into a volume product. A table with these deliverables is given in Figure 3.1.2.

Phase	Phase name	Typical Activities
1	Concept	Requirements and Specifications (Design Inputs) Technology Verification Design Concepts Cost Estimate Design and Development Plan Phase Completion Review
2	Design	Detailed Product Design Design Verification and Validation Plans Component Selection and Procurement Design Review Phase Completion Review
3	Prototype	Form-Fit, Functional Prototype Build, System integration activities, with the electrical, mechanical, and software modules. Phase Completion Review
4	Design Verification	Design Verification Testing Review and Improve Design Phase Completion Review
5	Pre-production	Pilot Build Design Validation Testing Phase Completion Review
6	Qualification	Qualification Build Production Tooling Process Validation and Process Qualification Phase Completion Review
7	Production	Product Launch Volume Production

Figure 3.1.2: 7-step model deliverables

The second model is called the V-model, it is shown in Figure 3.1.3, and is designed to more clearly explain the four main phases of product realisation and which deliverables fit the process steps.

The V-model is a more complete overview of qualification process steps and is more catered to the NPI process specifically rather than the general steps taken by Company X to realise a product. It displays the 7 phases from the 7-step model as well as indicating the design-, installation-, operational- and production qualification phases. This model is mostly used for the creation of products in the medical field since it very carefully explains all NPI steps and what can be expected in what phase (DQ, IQ, OQ & PQ). It is often used in project realisations to explain when certain aspects of the product are going to be delivered and what can be expected of Company X.

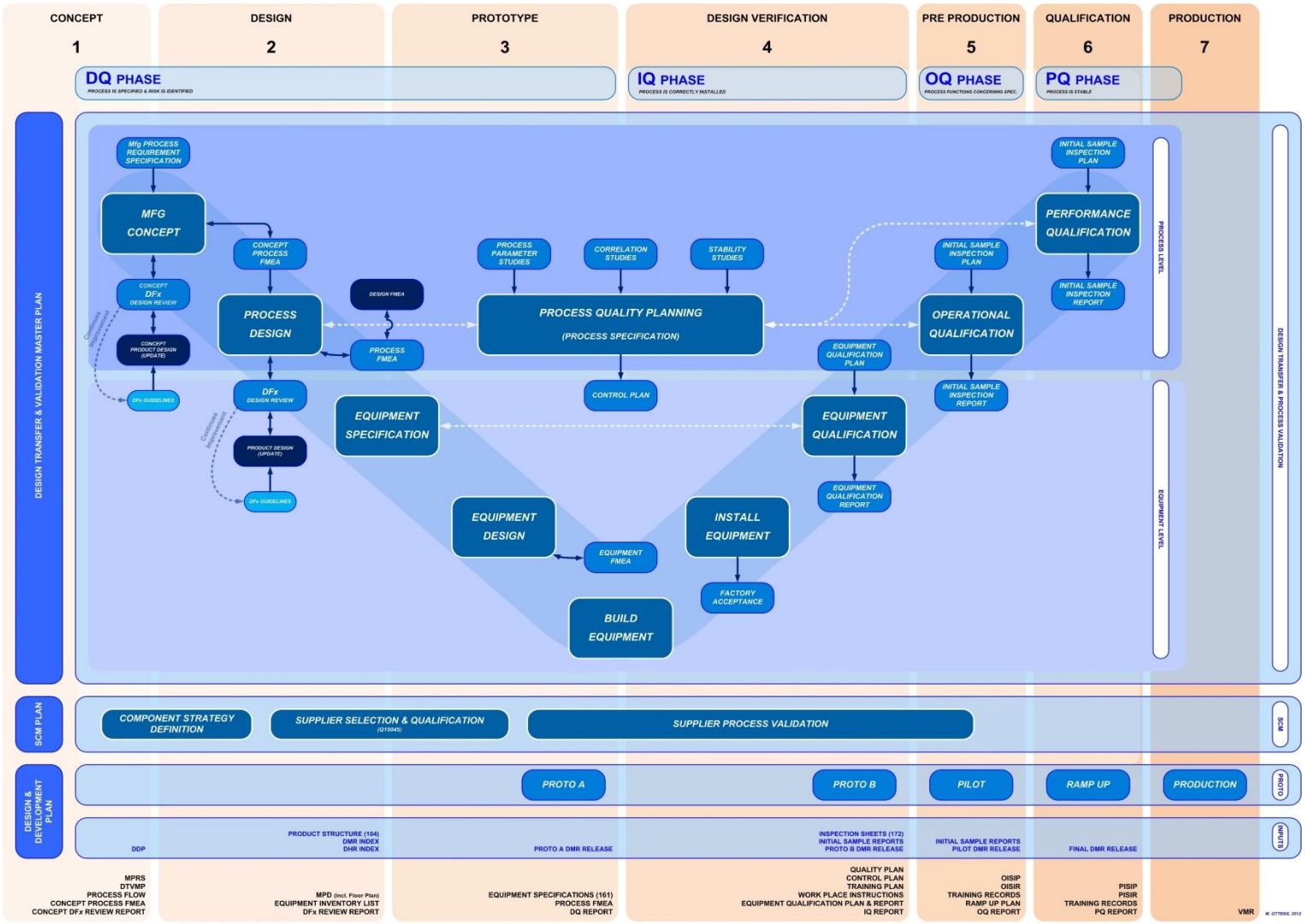


Figure 3.1.3: The V-model

In addition to the 7-step model and the V-model an overview explaining the general New Product Introduction process was found on the digital information system of Company X. Figure 3.1.4 visually describes concisely which inputs the process requires, who should perform them and what they deliver.

In combination these overviews supply a fairly concise description of the NPI process. The abbreviations for the term are provided in Appendix D.1: Glossary.

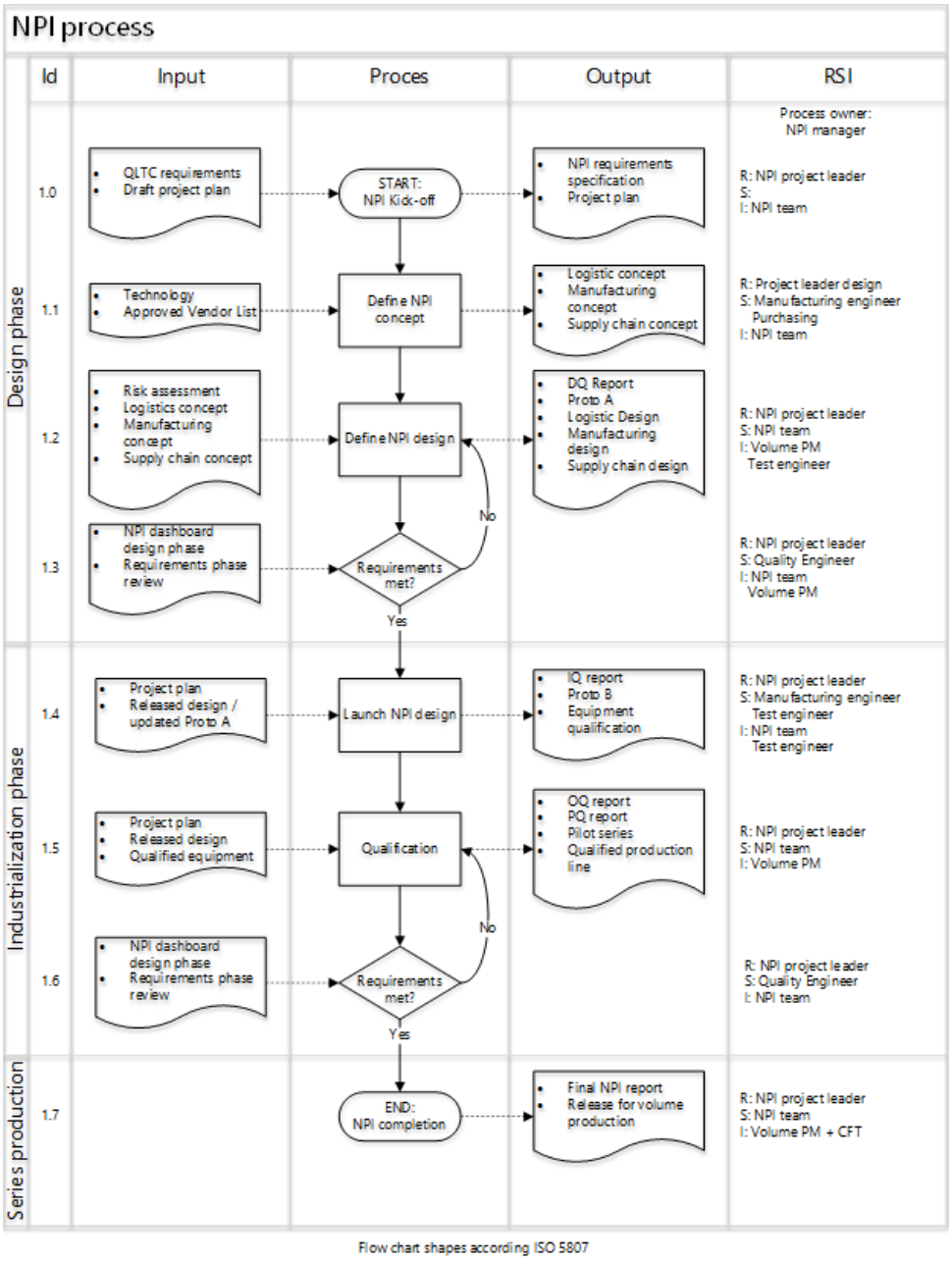


Figure 3.1.4: NPI process flow through diagram

3.2 Shortcomings with current situation and model

The models in section 3.1 are all process overviews and serve to explain to the employees and customers what steps will be undertaken for project realisation, what order of operation is usually performed and what is expected beforehand.

There are however limitations to all three models. These models give a flow through and absolute indication of what can be expected at which phase whilst in reality they serve more as a 'diner menu' on which the customers can indicate that certain aspects of the NPI carry less importance or should be executed more carefully. This all has to do with budgeting and the way Company X realises customer requests. Company X provides products to many different customers, from varying field, with different product specifications and budgets. This therefore leads to a complete lack of standardisation and uniformity, making certain aspects of the models in section 3.1 completely obsolete for some customers whilst the complete NPI process might be applied to others.

Other shortcomings are that the phase indications and practical application of the model differs per project and even per person. Some prefer the 7-step model as a general guideline because it grants more freedom of realisation, whilst others prefer the completeness of the V-model.

The last model indicating the process overview was not widely known across the NPI centre and only a few employees knew that this file existed. This shortcoming could be interpreted in two ways, since it could either be a problem with the availability and ease of access of documents or with the dedication and work mentality of the employees since they might not feel like putting in the effort of understanding the process. This problem will be discussed further in chapter 4 since it proved to be a fundamental issue for the NPI centre.

The last problem with the models is that although they do regard interaction between departments to some degree they mostly regard the NPI centre as a separate entity whilst in reality the realisation of a product for a customer happens because of parallel action between the departments, disregarding the deliverables from development or manufacturing might create a model which does not completely encompass the entire scope of NPI work.

3.3 Improved version of the model

The new version of the NPI process model is given in Appendix A.2, A.3, A.4 and A.5. The size of the model is created for A3 and therefore given in the Appendix with a close-up. This section attempts to elaborate on the new model.

The new model approaches the NPI process with the process flow-through of Figure 3.2.4 as the main line of primary tasks. What most models currently lacked was the inter-departmental responsibilities and deliverables in the realisation of the product for the customer. The new model represents this using SWIMM lanes containing the different departments. It then visually represents the respective tasks per NPI phase per department and shows which deliverables are required per phase. This information is taken primarily from the 7-step model with additional information from the V-model.

In the bottom left corner of the model the quotation and proposal phase of the project is visualised since this is the starting point of all projects. It is also important to consider that some phases require input or approval by the customer, this is included in the 'input' SWIMM-lane within the Company X

Process. Green dots represent starting points per department, the red dots indicate the completion or end of the project and diamonds indicate a decision split.

3.4 Implementation of new version

This section will describe what parameters would allow for successful implementation of the new model and therefore serves as advice, ideally an implantation plan could be written to ensure that the benefit of this new model is maximised. This topic will later be discussed in chapter 4 and 7.

The implementation of the new version is a step which can be realised when a series of fundamental issues (chapter 4) are resolved. It is essential that management of the NPI centre allows the employees to familiarise themselves with the new model and that there is room for the employees to understand.

A secondary parameter is that management needs to encourage learning behaviour which will result in employees feeling that commitment to understanding the process is beneficial which will allow for the information to actually be understood by all of the employees.

The new model does to a certain degree require understanding of the other departments within Company X since the amount of inter-departmental work done is high, it should therefore also be encouraged that employees take the time and understand what happens in other links of the chain.

The new model should be used as tool for understanding the new process and be used in combination with assistance and guidance by supervisors and senior employees to familiarise employees.

4. Fundamental issues and solutions

Chapter 4 aims to inform about the fundamental issues discovered by the research. After conducting interviews with employees of Company X a number of issues became apparent. The employees perceive the company to be operating decently but fear that without the proper actions, stagnation might occur in the future, the initial purpose was for a series of KPI's to allow these problems to be solved but after analysis it appeared that some fundamental issues would complicate the actual implementation of KPI's and restrain their effectivity. Section 4.1 gives a further explanation regarding the information acquired about the problems in Company X, section 4.2 introduces and discusses these issues and section 4.3 attempts to provide solutions to these problems other than the KPI's in chapter 5.

4.1 Current situation

The interviews served a secondary purpose, next to understanding the business process of the NPI centre, which was to understand which issues and problems were perceived by the employees and internal customers of Company X, these issues could then be used to help understand which variables should be measured in order to eventually optimise the NPI centre.

After careful analysis of the interviews with employees, interviews with internal customers, the process structure, supply of information and informal conversations with employees and supervisors; a series of fundamental challenges became apparent.

The KPI's which, will be presented in chapter 5, require some managerial decision making, behavioural commitment and possibly top-down involvement to realise. The observation is made that inefficient communication and lack of structure and consistency create uncertainty, gaps and delay in the achievement of departmental goals; such as customer satisfaction, work efficiency increase, department improvement and growth. First the issues which are experienced in the NPI centre are explained and then the solutions are given for the fundamental issues which (partially) cannot be measured yet or require managerial action/change first.

4.2 Issues within the NPI centre

The following issues were perceived by the employees and internal customers. They are numbered and named. These issues will be mentioned later in both the formulation of KPI's as well as the description of their relationships, since some of these issues might have causal relationships and could therefore be solved by solving others.

1. Communication.
The interview population expressed issues with the communication within the department and inter-departmental communication. The communications issues primarily mentioned related to misunderstanding of responsibilities and requirements which exist due to a lack of prior formulation of tasks and responsibilities and a perceived lack of knowledge between the positions in the NPI centre and other disciplines.

2. Standardisation and structure
There also appeared to be a reason with perceived lack of standardisation and structure within the NPI centre. 77% of the NPI employees scored the clarity of the processes insufficient. Two reasons were given and a third was deduced; the information not being available to a person, the information not being clear enough to a person and the person not committing to understanding the process.

3. Flexibility and rigidity
Another issue, which became clear through the interviews with the internal customers, was that the balance between the rigid operations and requirements of the manufacturing department and the flexible input and output of the development department was a hard thing to balance for the NPI centre. The perception was that rather than translating the wishes of the customer to suit the rigid parameters of production, the NPI centre tended to prefer working from the constrained perspective of production which often resulted in quality products but a mismatch with customer preference which could be considered wasted resource and negative for customer satisfaction.

4. Knowledge
Knowledge was an important discussion point in the interviews and conversations since the lack thereof appeared to be both a cause for some of the other issues as well as being caused by a lack of structure and standardisation. Lack of knowledge appeared to be a strong reason for the problems with communication within the department since an understanding of the work descriptions of colleagues and the impact of their action seemed to be missing in some cases. In other cases, the lack of knowledge was perceived to be created due to a lack of proper structure and availability of instructions which created fundamental difficulties to some from the start. Others viewed it to be due to competencies, capabilities and personalities of employees and their willingness to learn.

5. Ownership and commitment
The issues of ownership and commitment were expressed. Projects and execution of tasks were perceived to not always go according to plan due to a lack of ownership to deliverables, which might be due to time constraints as well as issues with commitment to improving work results and the department itself.

6. Capacity (employees)
Currently the workload per employee is high and most employees of the NPI centre operating at full capacity (maximum hours) with regards to projects and additional upgrade/revision work. This does not allow for the sufficient amount of time to be put into personal development or development of the department.

It is also perceived by the workforce that there is too much switching of tasks and responsibilities, in which the number of hours spent transferring these projects is perceived to be omitted. This creates extra hours which are not considered in the capacity planning. This makes the workload higher.

7. Knowledge- and employee retention
Retention of assets and skills is an important issue to consider as well since the other issues currently lead to a high number of employees in loan employment and relatively short employee longevity. Resolving the other issues will decrease this problem significantly since it broadens the future perspectives for employees and provides attractive prospects.

4.3 Solutions for fundamental issues

In order to solve some of the fundamental issues a series of non-measurable solutions is presented in this section. They serve to supply Company X with potential solutions and assist with realising improvement projects.

1. Consistency of projects
The first solution could serve to create consistency in work and therefore create structure and a form of standardisation, it would improve knowledge in the employees and therefore also improve communication.

Implementation of project standardisation for new employees is the first solution. If new employees or inexperienced employees are granted the time to study the process model and learn what is expected of them a system could be enforced in which the first X number of projects needs to be done exactly following the process model and protocols. This amount X is variable threshold which can be determined after application.

Following these protocols and understanding the process allows for the employee to create insight and a better understanding in the reasoning behind certain deliverables and the goals which they try to achieve, this in turn will lead to them to be able to cater to customer specifications and expectations better and be more useful long term.

Currently employees are given the freedom to learn their own process which will often lead them to learn the process specific to their first customer which is by definition a specific approach to the standard process and protocols, this therefore in the long term creates problems with task transitions and work for new customers since they operate based on their knowledge of specific customer and not from insight and general understanding.

2. Creation of learning courses for NPI
Currently Company X has an online education platform in which courses can be done to improve knowledge on certain topics. Information is currently stored on a web platform but is stored in a convoluted and unclear way which leads to the employees being unable to find the information easily which makes process understanding more difficult.

The NPI centre should provide a concise course in which this information is presented to the employees of the NPI centre in which a theoretical understanding of the full NPI lifecycle can be learned. This can then later be promoted or monitored.

These learning courses, can with the perspective of future optimisation, be improved and expended on to elevate and increase knowledge even more and eventually strive for maximum department knowledge.

3. Behaviour as an aspect of the employee assessment system
Currently there are steps being taken towards adding behaviour with regard to company improvement as an assessment aspect of the employee assessment forms and therefore an influence factor for their growth opportunity and salary within the company.

This criterion is a good criterion to help with overcoming the third reason for insufficient knowledge and improve involvement in company growth on the work floor level. Curiosity and wanting to understand

the bigger structure, overall goals and operations of colleagues is something which should always be promoted since it allows Company X to take their operations and products to the next level.

The realisation of this through the addition of behaviour to the assessment of employees is the current perceived solution and would result in a stimulus to operate with a growth mindset. It is important to understand that this might decrease employee morale since some employees characteristically prefer a more self-centrered working style and focus on their work rather than the overall understanding of the company. This can be counteracted by proper explanation of the new system and with the elaboration on the intended purpose rather than the execution of a consent less management decision.

4. Application of RASCI-matrices for projects
The issue of missing structure and clarity can be resolved through the widespread application of RASCI-matrices for the projects. Responsibility-accountability-supportive-consulted-informed matrices assign the roles as mentioned in the name to team members per task. This measure, next to providing structure, also helps enforce that tasks are completed and that if they are not the right people are held accountable.

Another effect is that if during the kick-off of the project the tasks and RASCI's are defined, the communication flow is also much more refined and efficient since employees have an overview in which they can see with whom they should talk to get certain information.

5. Widespread application of the Scrum-meeting format
Scrum as a meeting format is currently applied as a pilot system is perceived to be successful and help the current projects on which it is applied; it could therefore function as project improvement to implement it on other projects for different customers as well. This will also increase project milestone delivery reliability and communications.

6. Overall problem solving
The perceived impact of certain problems is greater due to the fact the problems are interrelated (discussed in chapter 6). It is therefore also logical that solving a certain problem will cause the other problems to be perceived as less severe and make them easier to solve.

5. Key Performance Indicators

Chapter 5 presents a comprehensive list of conceptual KPI's which are afterwards reviewed based on cumulative quantitative analysis of interview data from both the employees and internal customer as well as critical review of the theory regarding KPI's. These KPI's are introduced to attempt to solve uncertainties and measure with the purpose of solving the fundamental problems in chapter 4. Section 5.1 presents the conceptual KPI's, section 5.2 explains the quantitative data analysis which is used to support the formulation of the KPI's and section 5.3 presents literature standpoints on KPI's and applies these to the NPI centre of Company X with the purpose of contextualising and reflection.

5.1 Conceptual KPI's

The following section presents a series of key performance- and result indicators, based on interview information and internal information within the company, and explains the use, purpose and measurement. These KPI's are conceptual and require critical assessment before application. Sections 5.2 and 5.3 attempt to critically review the validity of the list of KPI's. The reasoning behind presenting the concepts is due to 'Just do it' principal in Lean Management which in this research is applied with the purpose of potentially allowing some currently 'less valid' KPI's and KRI's to evolve.

The NPI centre has four principal pillars on which the future is aimed. The KPI's are presented in these categories to show how they aim to help improvement. The pillars can be found in Appendix C.1.

1. Customer satisfaction

1.1 The mean of (actual delivery date – planned delivery date):

- This key result indicator will provide a proper indication of customer delivery accuracy and will therefore help in providing better forecasting to customers.
- This KRI should in the long term be minimized since it will allow for better indications to be given to external/internal customers and for the customer satisfaction to rise due to reliability.
- This KRI can be measured by comparing the project masterplan date to the date on which the product is actually delivered and to deduce which parameters, omitting delay because of the customer, cause this difference.

1.2 The mean of (initial quoting price– real quoting price):

- This KRI will provide an indication into the accuracy of the quotation process. The more accurate this number can be made the more satisfied customers will be due certainty in their spending and a reduction of unexpected cost changes.
- This KPI is not intended to lower the price but as a measurement for the prediction accuracy. Deviations are fine as long as they are carefully discussed and elaborated with the customer.
- This difference between forecast and reality should in the long term be minimized as well since it will create customer satisfaction through reliability.
- This KRI can be measured through comparison between the forecasted price presented to the customer and the actual sent invoice to the customer.

1.3 The profit margin per project phase:

- This KRI will provide an understanding in which milestones of a project profit is generated and in which milestones profit is lost. This creates an understanding regarding which milestone steps should be more carefully managed or from which milestones can be learned for other projects.

- This KRI should in the long term be maximized; this KRI is tricky however since it is very contextual. Optimization of certain project aspects might have negative consequences for other parts of the project. Therefore, maximization of profit in some areas should only be done when there is no drawback.
- This KRI will result in customer satisfaction through the fact that it will provide transparency in the costs and value provided per project phase, which allow for catering of the process to specific customers.
- This KRI is measured by comparing the phase plan to the review of that phase (costs/revenue) by the project leader.

2. Work efficiency and measurement

2.1 The average amount of wasted resources in NPI projects:

- This KRI will properly indicate whether employees predict and calculate their resources properly which could be a measurement tool to understand employee efficiency and to review performance. This could be done with;
    - Workload calculation
    - Prediction of materials
    - Capacity (operators)
- After establishing a department wide baseline, limitations can be set and the KRI can be brought to baseline values.

2.2 The number of unnecessary deviations from Kick-Off in project X:

- This KPI will encourage members to follow the set plan and commit to the proposed plan by indicating that deviations from the proposed work planning are unwanted. This is due to deviations creating miscommunication within the project team. This increases lead time and decreases efficient working hours.
- In communication with the project leader deviations should be allowed in case they are properly explained and documented to prevent issues in the later project phases.
- This number should be minimised in order to establish a clearer process and increase work efficiency.
- This KPI can be measured in progress sessions and during review phases by the project leader.

2.3 The number of attempts at proper document formulation

- This KRI aims to reduce work inefficiency and time wasted on insufficient work.
- Minimizing this KPI will ensure that employees follow the ‘first time right’ principle of lean work and provide documents with more preparation. It is important to consider though that a lack of quality is only a small cause for revision of a document and that this KRI does not serve to dictate, but rather stimulate proper preparation.
- Measurement of this KPI can be done through the version table which is standard template in most Company X documents and supervision by the project leader.
- This KRI can be applied to many documents like for instance the revision of Workplace Instructions, or testing approval documents etc.

2.4 The current time delay on project X:

- This KPI is seemingly similar to the KRI the mean of delivery day. It provides an entirely different statistic however, since this is not a lagging measure and aims to show the current time delay on a certain project.
- This KPI should be used to inspire action in catching up to potential time delay or to indicate that a project is happening on schedule.
- This KPI can be measured by placing the progress on a timetable displaying the planning and should show an absolute number of time with which the project is delayed.

3. Current and future improvement of the department

This subset of KRI's and KPI's is presented with the intention of providing indicators for the future, after solving the fundamental issues in chapter 4.

3.1 The number of learning courses completed per employee:

- This KRI is prospective, in the sense that if a learning culture and platform are established a better knowledge foundation could be created. This KRI could be created to maintain a system in which employees follow courses which slowly take the employee through the new protocols and each other's work description which will increase Tier 4 knowledge and eliminate miscommunications.
- This KRI should have a minimum and maximum boundary after establishing a baseline, since a certain level of self-improvement should be mandatory whilst also ensuring that there is sufficient time for operational work by not exceeding the upper limit.
- The measurement of this KRI can be done through administrator access of the learning portal and administration of sufficiently completed courses per employee.

3.2 The number of coaching sessions attended per employee:

- This KRI is also prospective since it is an indicator for the future.
- In order for people to better understand certain practices on the work floor weekly coaching sessions between senior Company X NPI employees can be organized in which they explain their work activities to less experienced NPI employees and help them understand their job requirements better, in which this KRI keeps track of the progress per employee
- Maintaining this KRI at a sufficient level should serve as an opportunity for communication of best practices in which issues presented by the less experienced employees can be resolved easier.
- This KRI should have a boundary target similar to the number of learning courses.

3.3 The current number of deviations from RASCI-matrix roles in project X:

- In order to create clarity in a project a RASCI-model can be created; responsible, accountable, supportive, consulted, informed. This matrix visualizes responsibilities in the realization of a project which ensures unnecessary communication is minimized since everybody should be aware who performs what task and who to contact for help or supervision.
- This KPI will assist in monitoring KPI 2.2 since it clarifies whether or not the deviations are due to uncertainty or insubordination.
- When monitoring this KPI is important to consider one pre-requisite and that is that planned/discussed changes in the matrix with the project team are not considered as someone not following their role.

3.4 The number of “new NPI processes” implemented properly (management):

- This KRI gives an indication of the realisation of the improvement of the NPI through fundamental changes and how KPI application is realized on the work floor and on managerial levels. It serves to ensure the new policies are applied.
- This KRI should visualise the progressive growth in the department and as a reminder that the desired optimization must be performed and realised.
- The goal is to maximize this KRI after establishing a good fundament. Every improvement makes the customer satisfaction, work efficiency and overall department better. It is also important to consider that these changes should not be rushed and only implemented when the department is ready.

5.2 Quantitative analysis of interview information

As discussed previously the conceptual KPI’s and information within Company X was acquired through internal information as well as interviews with employees of the NPI centre of Company X. These interviews contained mostly qualitative information and a certain degree of quantitative questions. These questions could be placed in a numeric overview which provided the research with an indication regarding the relation between for example; position at Company X and degree of process understanding or customers in relation to perceived bottlenecks. This information was placed in an Excel sheet and analysed.

Appendix B.1 shows the data entries of certain employees (1 to 9). The top table shows the entries of individuals where the numbers indicate unique answers. So, to elaborate in column S, there are 7 people who gave the first answer. This cumulative data is shown in the bottom cumulative table. The concise elaboration of these columns and the meaning of these answers is kept confidential because of the nature of the anonymous interviews. It is importance to this report how certain aspect of employees relate to their answers, how many people universally experience the same problems or perceive the situation similarly since this can conclusive indicate significant findings. In the top table 0’s are non-entries and in the bottom table 0’s are people who did not give that answer.

The cumulative table is where conclusions can be drawn from since they indicate to what degree people agree on certain answers after which a statement can made regarding the similarities or differences between employees who answered similarly.

The following results regarding the fundamental problems can be drawn from the interviews with employees;

- 47% of interviewees perceived communication to be the main issue.
- 50% of interviewees perceived the most critical point to be the start of the project (kick-off).
- Averagely satisfaction with the NPI centre as a general department is scored with a sufficient.
- Process understanding is scored as insufficient and in one case even terrible
- Communication as part of the general NPI process is scored as insufficient on average whilst some outliers perceive it to be moderate and even good.
- In indicating how one's process is measured a great variation of answers is given, although some are in agreeance uniformity, is missing.
- Answers to questions are very person dependent and that relations between answers and positions at Company X NPI cannot be given. Meaning that some issues are perceived between functionalities and other issues are only seen by certain employees.
- Employees who primarily work on customers other than #1 perceive the process to be less clear.

The relationships between these findings and the conceptual KPI's will be explained in chapter 6.

As explained in the research design and formulation of the KPI's, secondary interviews were conducted with the internal customers of the NPI centre. This data was also quantitatively analysed in a similar manner to Appendix B.1 and can be seen in Appendix B.2

The quantitative data analysis of the internal customers is similarly designed as that of the employees and therefore the cumulative data is the relevant information for interpreting the results. It is however important with interpreting the data of the internal customers, that for the functions of the internal customers were all different, therefore the information per job function is fully coherent with the opinion of one person. This might mean that this data is not a fully accurate representation of reality since there is no frame of reference. Considering this fact research still deemed the findings important since skewed data might not by definition mean that it is inaccurate. The results from the interviews with internal customers are as follows;

- 31% of the internal customers perceived proper formulation of responsibilities to be an area of improvement in improving the work between them and the NPI centre.
- 57% perceived a gap between expectation and delivery of work from the NPI centre.
- Both reliability and satisfaction in working with NPI centre were averagely scored with a sufficient whilst quality of work was averagely scored as insufficient.
- Interaction with employees of the NPI was in communication always perceived to be pleasant but not always efficient.

The reasoning behind the extent of the quantitative analysis will be elaborated in the discussion in sub-section 7.2.

5.3 Literature on KPI's

The following section aims to contextualise and reflect on the KPI's in this chapter. Literature review supplies much needed explanations and context to the proper formulation, feasibility and validity of KPI's. The following findings were made:

From observation within Company X it becomes apparent that similarly to many, as said by Neely in his book about business performance, the management requests key performance indicators (KPI's) but actually operates on the basis of key result indicators (KRI's). It is important to understand that KPI's are leading measurements whereas KRI's are lagging measurements. Measures like customer satisfaction, net profit and return on investment are all KRI's since they are the result/consequence of many inter-related actions and according to Parmenter; 'KRI's tell you how you have done in a perspective'.

KRI's are essential in supplying information to management and from the perspective of governance they suffice a role which allows a company to keep its actions and products within desired parameters. It can be seen as initial measurement and give a perspective explanation on the current situation.

Neely expresses the importance to apply true KPI's which are measured daily or weekly at most which supply the management with a clear indication of what preventative actions should be taken since these indicators supply critical information which have a chain reaction effect through the company and should tell what to do to increase performance dramatically.

A good key performance indicator for this would be the current derivations from the kick-off schedule and planning. Logical actions implied by this KPI are the improvement of communication, the improvement of forecasting accuracy, the reduction of unnecessary changes in the plan, the improvement of process understanding and structure. Aiming to improve the NPI centre will minimize this KPI with the important theoretical understanding that this measure only serves to indicate the current level of operations and should not be considered without context.

When regarding another KPI formulated in the list literature reminds us that it is very important when speaking of accountability and responsibility to beware of fixed targets and quotes. It explains that that focusing performance measurement on relative targets and growth rather than a fixed 'top-down' amount allows for a less hostile work environment and financially is more likely to maximize profit potential since 'good work' is not being given as an absolute but the bar is constantly raised.

Literature also explains what a proper KPI is and that it is highly dependent on a proper environment. Through the words of Parmenter, which are also in line with Neely, the following is said;

"Organizations often begin to develop a KPI system by immediately trying to select KPIs without the preparation that is indicated in the twelve-step implementation plan (implementation plan by Parmenter). Like painting the outside of a house, 70% of a good job is in the preparation. Establishing a sound environment in which KPIs can operate and develop is crucial. Once the organization understands the process involved and appreciates the purpose of introducing KPIs, the building phase can begin."

For this purpose, this research aims to establish a solid foundation for the KPI's before they can be used effectively. Another finding by Parmenter is that 'winning KPI's' are KPI's which cut away unnecessary management practices, having a proper indication regarding a certain issue or topic of importance

within the NPI centre will eliminate unnecessary communication since the KPI will clearly indicate what the current situation is.

The critical view on true/proper KPI's allows a reflection on the conceptual KPI section in this report. Normally in formulation of KPI's the following is true see Figure 5.3.1.

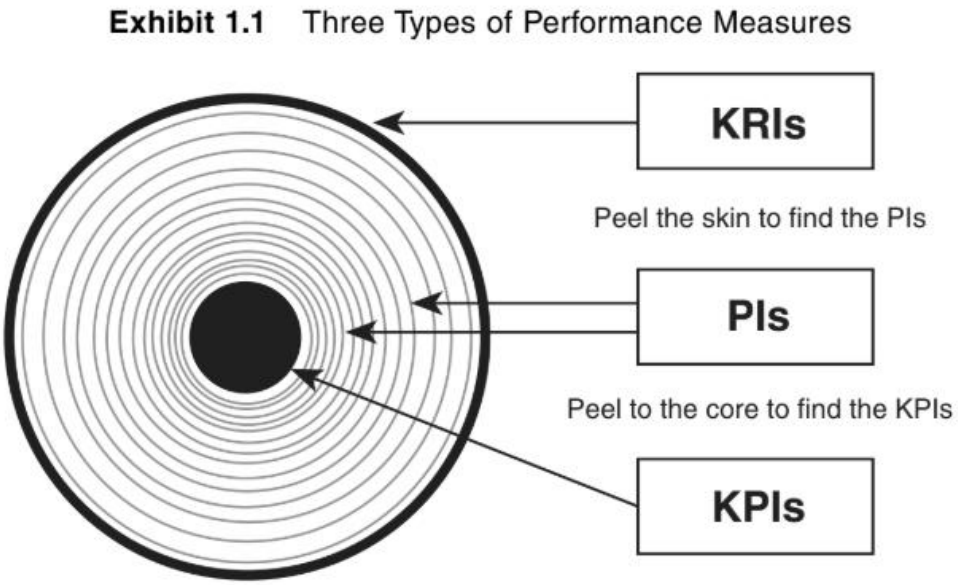


Figure 5.3.1: Types of performance measures - Parmenter

They state that in a proper performance measurement system for a company all three of these performance measures are needed. They state the 10/80/10 rule by Hope and Fraser is a suitable guideline in performance measure formulation. In which there should be no more than 10 KRI's, 80 PI's and 10 KPI's. This research has only supplied a series of KRI's and KPI's and omitted PI's, this is due to the conceptual nature.

Currently Company X does not measure anything related to the NPI performance yet and must therefore most importantly measure using KRI's first since this provides perspective. The conceptual KPI's might prove to be less significant and function as PI's along the line. The research operates on the basis of the just do it principle and believes that by starting somewhere, with the statistical foundation of the quantitative data analysis behind the reasoning the KPI's system of Company X should be very open to improvement and might along the way, through measurement of the KRI's and KPI's in this research discover better KPI's and KRI's.

6. Relationships between KPI's and fundamental problems

Chapter 6 aims to supply additional information on the previously discussed topics. Explaining how the fundamental problems and KPI's are related fulfils the purpose off visualising the connection between the issues and solutions, allows for future formulation of revision of KPI's to be done easier due to an understanding of their intended use and allows for a clear overview of the report. Section 6.1 will explain the relationships between the problems since most of them are related and exist because of, or in relationship to, one-another, these relations are the same for the KPI's. Section 6.2 aims to visualise the relationship between the problems and solutions through an overview and an explanation.

6.1 Overview of problem relationships

This section will try to explain the relationships between the fundamental problems that exist within the NPI centre, with the purpose of explaining that many of the fundamental problems either causally exist because of one another or are strongly related and affect each other.

The research will address the seven problems, mentioned in chapter 4, in order, to explain how the other problems are related to it. Starting from communication all relationships are mentioned and if for example a causal relationship between communication and standardisation/structure exists then this will only be mentioned once.

1. Communication.
Communication as a problem has different causes and results. A lack of productive and useful communication is mainly caused by a misunderstanding of tasks and a lack of knowledge. Therefore, the causes are the non-existence of the proper level of knowledge and standardisation and structure.

A lack of communication creates several issues. Non-productive communication impacts the capacity of the employees since time which could be spent on completing projects and finishing deadlines is wasted on having to understand why certain aspects of the project are delayed, why some process steps were executed incorrectly, why some tasks have to be completed. A lack of communication also creates problems in flexibility of the NPI process and employee retention. The non-communication complicates the process of introducing solutions to customers and ensuring that the desired outcome is delivered to the right party and employees are frustrated by the fact that they are continuously busy putting out fires and resolving issues due to a lack of communication which may eventually lead to an employee exiting the company.

2. Standardisation and structure.
The main perceived reason behind the lack of standardisation and structure is related to three things; the nature of the business, the problem of flexibility vs. rigidity and a lack of knowledge. The nature of the business as a contract design house/manufacturer with a great variation of customers in different fields makes the difference between the end-products vast, it also complicates making a 100% accurate business process overview since solutions for customers can vary from being the complete NPI process including volume manufacturing to being only the conceptualisation. The secondary perceived reason of the standardisation and structure issue is the flexibility of the design engineering department (development) vs. the rigidity of the manufacturing department (production) since both departments have different demands and view the processes and therefore the 'ideal' standardisation differently. This complicates the creation of a structure when no clear managerial decisions are being made on what

position the NPI centre is supposed to fill and how the balance between these two departments should be maintained. The last reason is that the fundamental issue of a lacking amount of knowledge within the employees. An understanding of the process and job description of the employee and their colleagues makes the standardisation significantly easier, since the general consensus regarding certain approaches and topics is similar and 'correct'.

The lack of standardisation and structure is most probably the creator of the most issues. Next to the previously discussed issue of communication, which is the primary issue, it also creates problems with capacity since the use of resources is much more difficult to predict due to employees approaching problems and projects in different ways. It also increases the difficulty of establishing a proper knowledge level since the lack of structure and standardisation creates a disadvantageous starting position for new employees since most of the operations are learned through experience and potential failure, which is costly.

3. Flexibility and rigidity

The issue of flexibility and rigidity mainly exists because of the nature of the business and is therefore partially unsolvable since the work format of Company X and the design of their operations creates a problem in which flexible design has to be produced within the rigid parameters of manufacturing. A secondary cause for this is that due to the lack of structure some aspects of the work description or actual work are misunderstood, further complicating the difficult job of transitioning flexibility to rigidity.

This issue creates a problem with ownership and commitment within the organisation, since some processes are deemed to not be part of the job and are not completed whilst others are completed when they are not concretely part of the job description, which further causes miscommunication.

4. Knowledge

The fundamental problem with knowledge is mainly caused by a lack of structure and standardisation and because of the non-implementation of a platform in which specifics regarding the job and day to day operations are taught. Currently employees feel like they are thrown into the deep when they start of their work, naturally uncertainties and problems occur during work, but proper instruction, insight and understanding will greatly help reduce theses. The problem of knowledge is costly problem since an investment has to be made to achieve a desired and acceptable level of overall process understanding, which will on the long-term yield much greater results and departmental growth. The problem of knowledge also flows out of a lack of ownership and commitment since this also encompasses an employee's willingness to learn and to develop themselves within the company or in this case the lack thereof.

The knowledge problem as previously discussed has a direct relationship with structure and standardisation since creating standardisation and structure requires knowledge whilst knowledge also requires standardisation and structure to some degree. Resolving the issue of standardisation should allow for a better platform to increase knowledge.

5. Ownership and commitment
The problem of ownership and commit is an issue mainly caused due to the uncertainties in the work, due to a lack of standardisation protocols for responsibility and accountability in day to day operations or project in general and is simultaneously worsened by a capacity problem. A high workload creates time stress and therefore to some degree indifference within employees since a feeling is created that when the required job is completed their work is done. The issue of commitment is created due to a lack of certainty within the company, employees have a harder time supporting the company and contributing to a better future without prospects or rewards.

The issue of ownership and commitment creates a problem with knowledge as previously discussed but also with employee retention.

6. Capacity
Capacity as a fundamental problem is caused by miscommunication, a lack of structure and worsened by a problem with ownership and commitment as previously mentioned. It is also important to understand that acquiring additional employees may seem to solve this issue but in reality, the knowledge problem creates a situation in which new employees are initially more of a time loss than they yield. It is therefore very important to take into consideration the fact that capacity problems are mainly caused by time spent wrongly due to other fundamental issues.

The only issue caused by the capacity problem which is not discussed yet is the problem of employee acquisition and retention. Capacity is the main contributor to this problem at the moment since the busyness of employees and the lack of time for development and growth creates a problem which is currently solved with employees on a loan basis, which is lost knowledge in the long term, whilst it also causes issue in acquiring new employees. This is less regarding the actual acquisition and more in the contribution to the team in general.

7. Employee acquisition and retention.
The problem of employee acquisition and retention is caused by the lack of structure and standardisation, miscommunication, lack of knowledge and capacity as explained previously. Another cause for the problem with employee acquisition is, and this is currently not considered a fundamental problem, the awareness of Company X within the academic world. Company X although currently more active then previously is still relatively unknown to students and graduates.

The issue of employee retention causes the knowledge problem to increase as well, since the loan-based employees are an outflow of knowledge.

Solutions and KPI's
The KPI's and solutions have similar relationships as the problems, since a solution/KPI which assists with for instance standardisation problem will automatically, due to the relationship between standardisation and communication, also be an indirect solution to the communication problem.

6.2 Overview of KPI's and solutions and their relation to the fundamental problems

This section will first give a visualisation indicating the relationship between the problems and then place the conceptual KPI's and general solutions in perspective, this visualisation can be seen in Figure 6.2.1. Then the section will explain this visualisation.

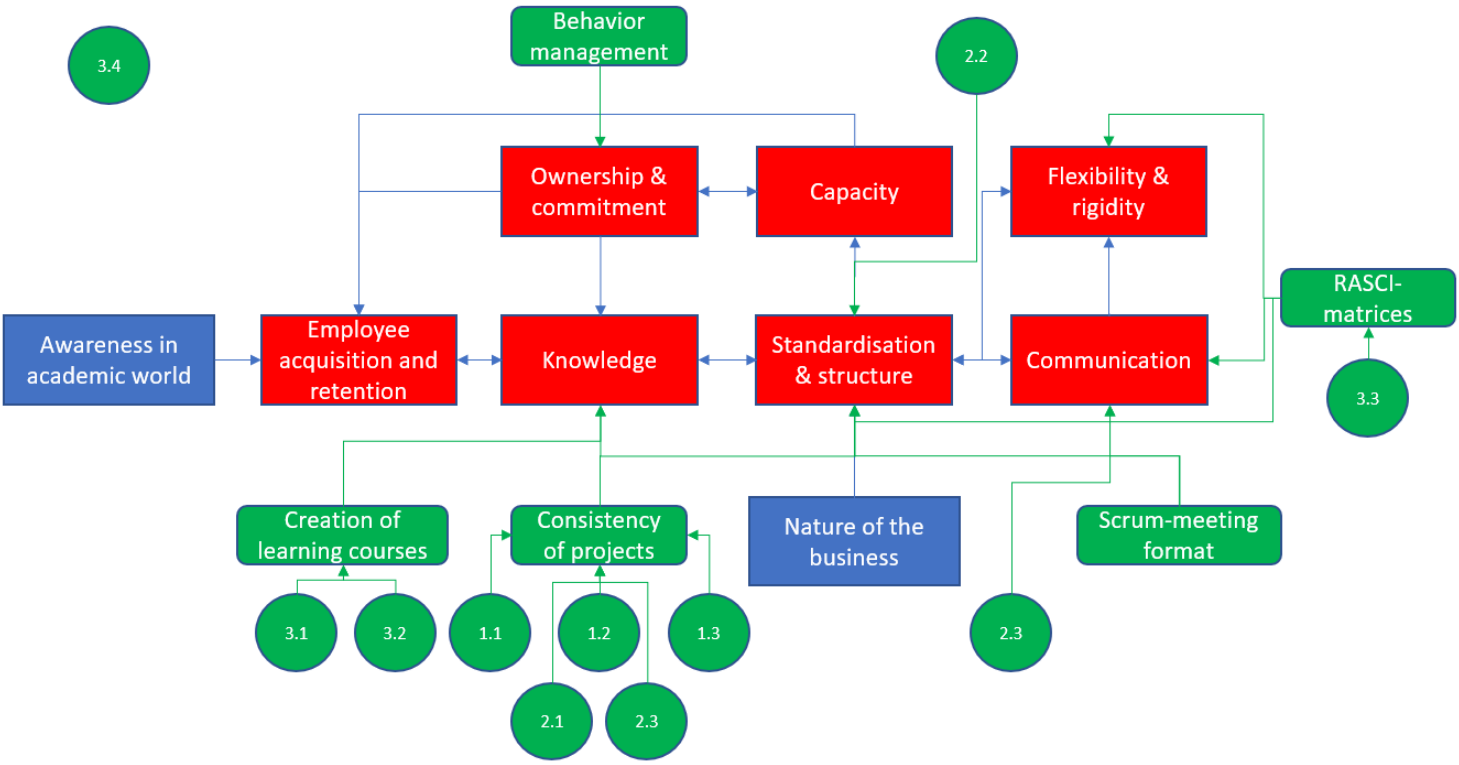


Figure 6.2.1: Relationship between problems, solutions and KPI's

Figure 6.2.1 shows the problems in red, their respective solutions/KPI's in green, with the numbers from chapter 5, and non-problematic factors of influence in blue.

The problems which are correlated linked with a two-sided arrow whilst causality is shown as a single-sided arrow. It is important to regard that solutions to problems which have a shown cause or correlation support with solving the related problem as well. As visible in the figure many problems are correlated and therefore the solutions in most cases serve to solve the collective of fundamental problems.

Awareness in the academic world is regarded as a 'non-problematic' cause for the fundamental problems since it is less of an NPI problem and more of a general problem for Company X, the problem and will therefore only be mentioned and its cause and solutions will not be mentioned.

7. Conclusions

Chapter 7 contains the conclusions of the research and aims to summarise the research. In section 7.1 a conclusion is given regarding the optimisation/improvement of Company X and sector 7.2 gives a conclusion regarding the total research, the effectivity and the limitations.

7.1 Optimization of the department

The process and perceived reality

The research established through the study and information analysis from interviews the current documentation and modelling of the NPI centre and constructed a model which combined the known information. This model helped in the explanation of the perceived problems.

The perceived main bottlenecks in the process were the (miss)communication within the department, ~50% of the employees experienced this and the perceived lack of structure/standardisation, which was a cause for confusion within the department for many.

The internal customers experienced that improvement can be made within the fields of overall knowledge, responsibility (ownership & commitment) and the translation between the flexible design engineering department and the rigid manufacturing engineering department.

The gaps between expectation and reality were summarised as a series of fundamental problems for which solutions were thought up to optimise the NPI centre in the future.

Literary theory in comparison to reality

The research established that the purpose of the assignment for Company X was originally the formulation and implementation of key performance indicators which was realistically not feasible within the current situation. This was due to a lack of primary measurement for which key results indicators are required first and the perceived use of key performance indicators in general.

The research therefore introduced the performance indicators as a conceptual solution to the problems and opinions which were discovered. Also allowing the possibility of future adaptation of improved KPI's through the understanding of the fundamental issues which they were originally created for.

Optimisation and solution to the problems

It is really important to consider the fact that the conceptual measurements and indicators function under the presumption that the business culture; employees and management, allow and accept the necessity of eliminating the fundamental problems before efficient use can be achieved.

Research attempted to clarify that the problems are nearly all interrelated, which means the solutions are too. Conclusively measurement and managerial decision making can easily attempt to solve the issue of standardisation and therefore gradually eliminate the fundamental problems.

7.2 Total conclusions, limitations and discussion of the research

Total conclusion
After gradual evolution of the research into an advisory report which addressed the main perceived bottlenecks and presented solutions for the future the total conclusion is that the NPI centre of Company X is a company which operates mostly on the competence of individuals rather than the existence of a fail prove structure.

A series of problems flow forth from the current way of operation and measurement and managerial change should be the first two steps towards improvement according to the employees.

The research presented a series of conceptual performance indicators which can be used to start measurement and addressed the fundamental problems which management can eliminate in the future.

This research therefore conclusively advises Company X to invest in increasing the consistancy of operations at the NPI centre, since this both accommodates the systematic increase of knowledge as well as establishing a structure which can be used as reference and allow for better communication. This will increase efficiency and effectivity of within NPI centre, inter-departmental and other multi-disciplinary work.

Research believes that eliminating these fundamental problems will therefore in the long term greatly increase revenue generation and overall satisfaction towards customers and employees.

Discussion
It is important to discuss the analytical approach of this research since the added value of the quantitative data might be questioned. The quantitative analysis in this report was performed to support the formulation of problems and solutions from the primary data (perspective of the employees) and to statistically visualise the reasoning behind certain KPI's.

The data in Appendix B1 and Appendix B2 aim to show that there is a commonality between certain findings. This might lead to the idea of performing a vector analysis or another quantitative analysis to analyse the relationships between for instance the 'current position' and 'main problem' within the company. Research however believes that the data for the start of solving the fundamental problems does not allow such conclusions to be drawn, since work at the company is so difference that the general conclusions regarding certain problems are either found by (nearly) all employees or noted by singular employees. Another finding which disputes the relevance of in-depth analytical analysis is that the findings regarding certain problems or solutions are not made by employees with comparable parameters; either the jobs completely differ, or the customers, or the perception of work, etc.

Research therefore perceives that views do not differ because of discrepancies between the stated parameters but because the previously mentioned fundamental problems are perceived differently based on personality, character and 'level-of-interest'. This combined with the fact that most problems are inter-related creates discrepancies, which make in depth-analysis less applicable.

Limitations
The research validity was limited by a series of parameters and decisions which had to be made throughout. These limitations imply that the research has to, to a certain degree, be critically assessed.

The first limitation is with the research population. Even though consisting of multiple employees on different and similar positions within Company X, the research population was limited and therefore potentially provided skewed information regarding the problems and processes within the company. If by chance the interviewees were mostly providing sceptical information, the research will conclude a negative outcome whilst reality might present to be different.

The second limitation is that the qualitative nature of the interviews provide room for interpretation by the research and by the reader, it is therefore important to consider that to a certain degree perceived problems might be more reported more/less severe than in reality which is a dangerous limitation to research. It is however not considered disregard-able information due to the cumulative expression by employees regarding the findings.

Additionally, the literary/theoretical support of the findings was limited due to the contextual and conceptual nature of KPI's and qualitative nature of the primary data leaving the accuracy of the KPI's to be questionable. It is however important to start measuring and therefore of relevance to provide a starting point which is supported by explanation of the causes.

8. Recommendations for future research

Chapter 8 aims to explain what future research can provide for Company X on the topic of continuing their aim of improvement and growth and how the use of this research can help accommodate this.

The original intention of the assignment was to deliver a series of measurable and optimisable KPI's. Which after the gathering of primary data appeared to be a step too far which is why this research was transformed into advice on the fundamental problems and their solutions with KPI's as a tool. Research therefore recommends that after the fundamental problems are understood and analysed future research could focus on the actual measurement of these indicators and could include an implementation plan to ensure that they accomplish the intended use.

Research also recommends that a form of information validation is performed in the future to ensure that the reality and requirements of the NPI centre can be compared again, and that in the situation in which this information is validated through interviews the research population is as large as possible. This eliminates the skewing of information as mentioned earlier in this report.

Further in the future, after establishing a solid foundation of data, a baseline can be established to which performance, operations, management, employees and processes can be compared which allows for the desired optimisation to be realised.

Another topic of further research could be the degree of involvement of higher tiers of management, within Company X or other manufacturing houses, in the realisation or non-realisation of improvement projects. This is due to, as mentioned in the report, the perception that innovation is currently partially restrained by bureaucracy and a preservative and 'old' way of thinking. Which has an interesting overlap with the optimisation of specific departments.

On the academic topic of business analysis and improvement using KPI's, future research could help further the understanding of KPI's as a tool for primary data analysis and whether specific 'general KPI's' are always applicable to companies like Company X. Similar to how there are already standard KPI's for the measurement of machining processes.

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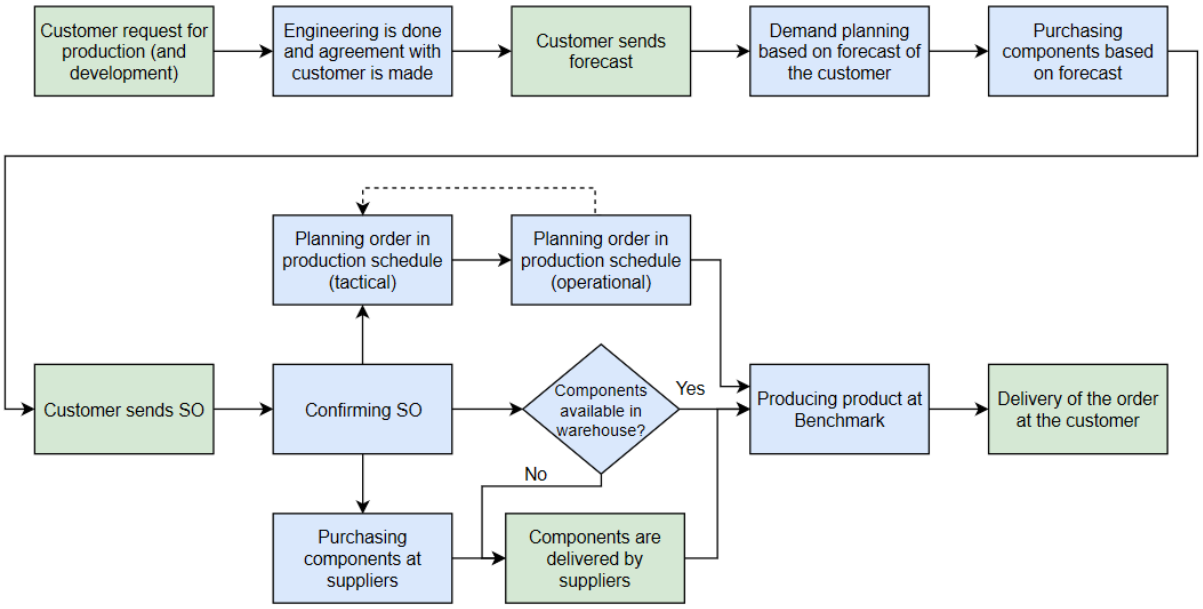
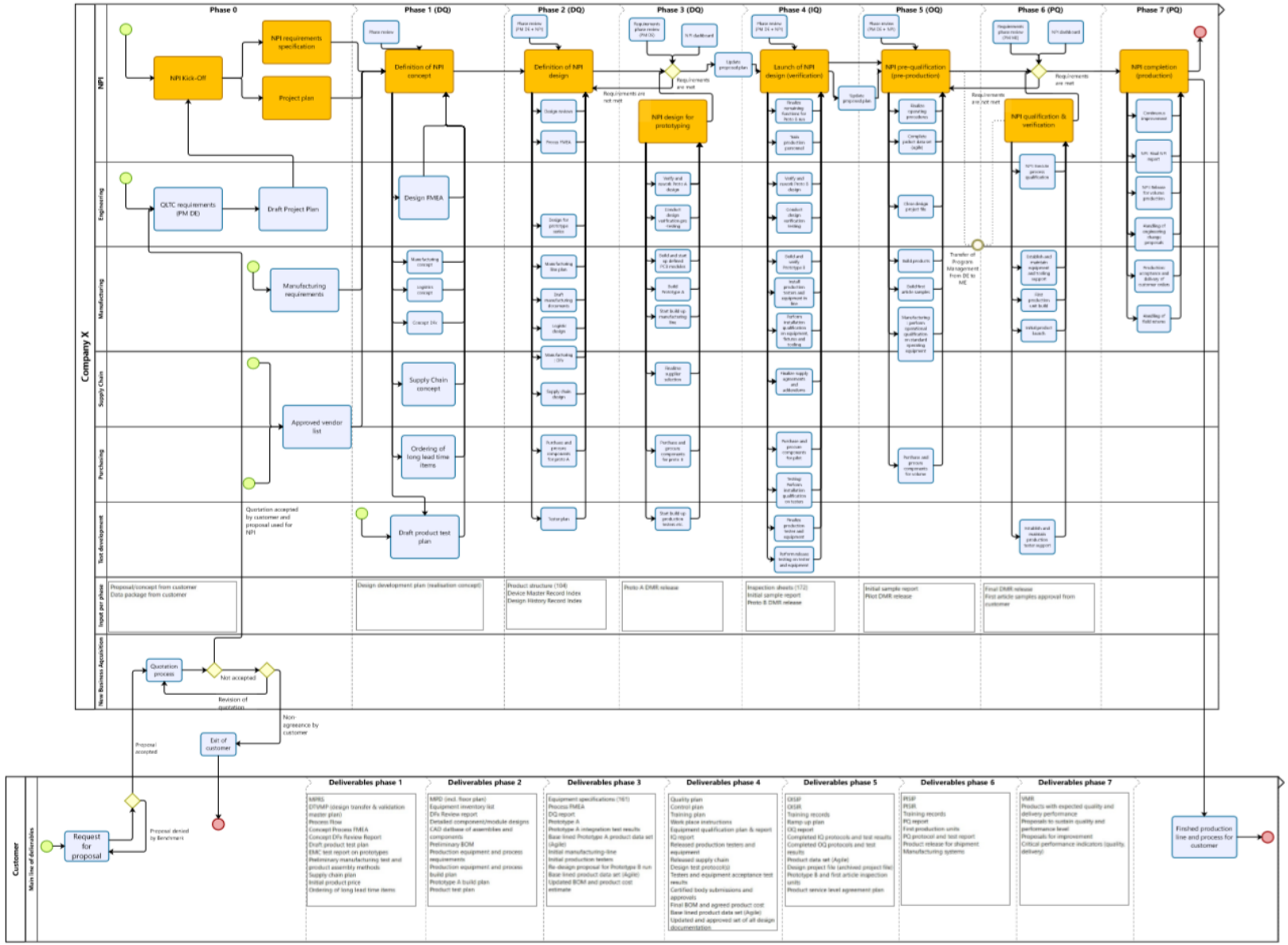
Appendix

Appendix A – Models and structures

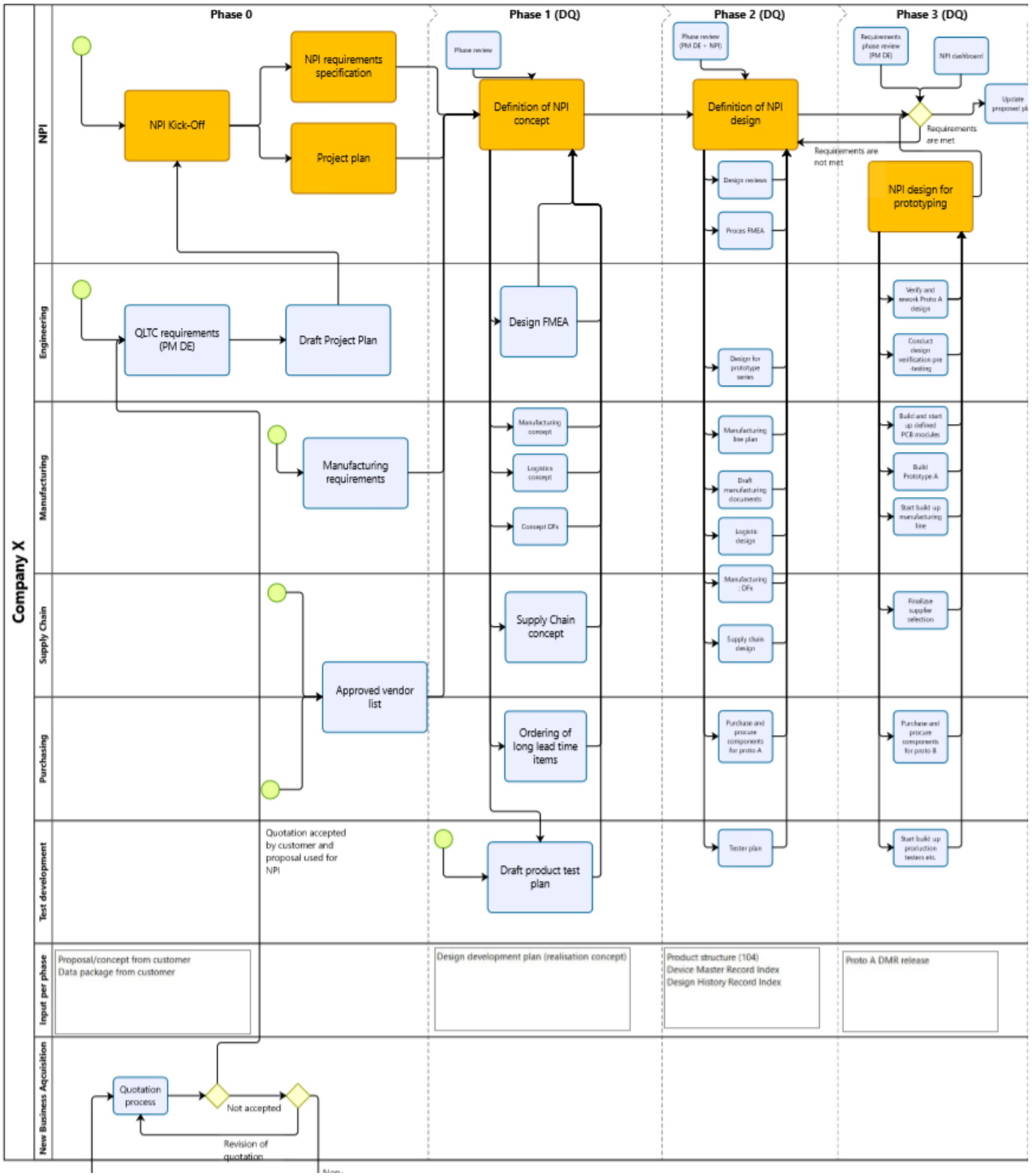
A.1: Process flow at Company X, Tijhuis (2019)



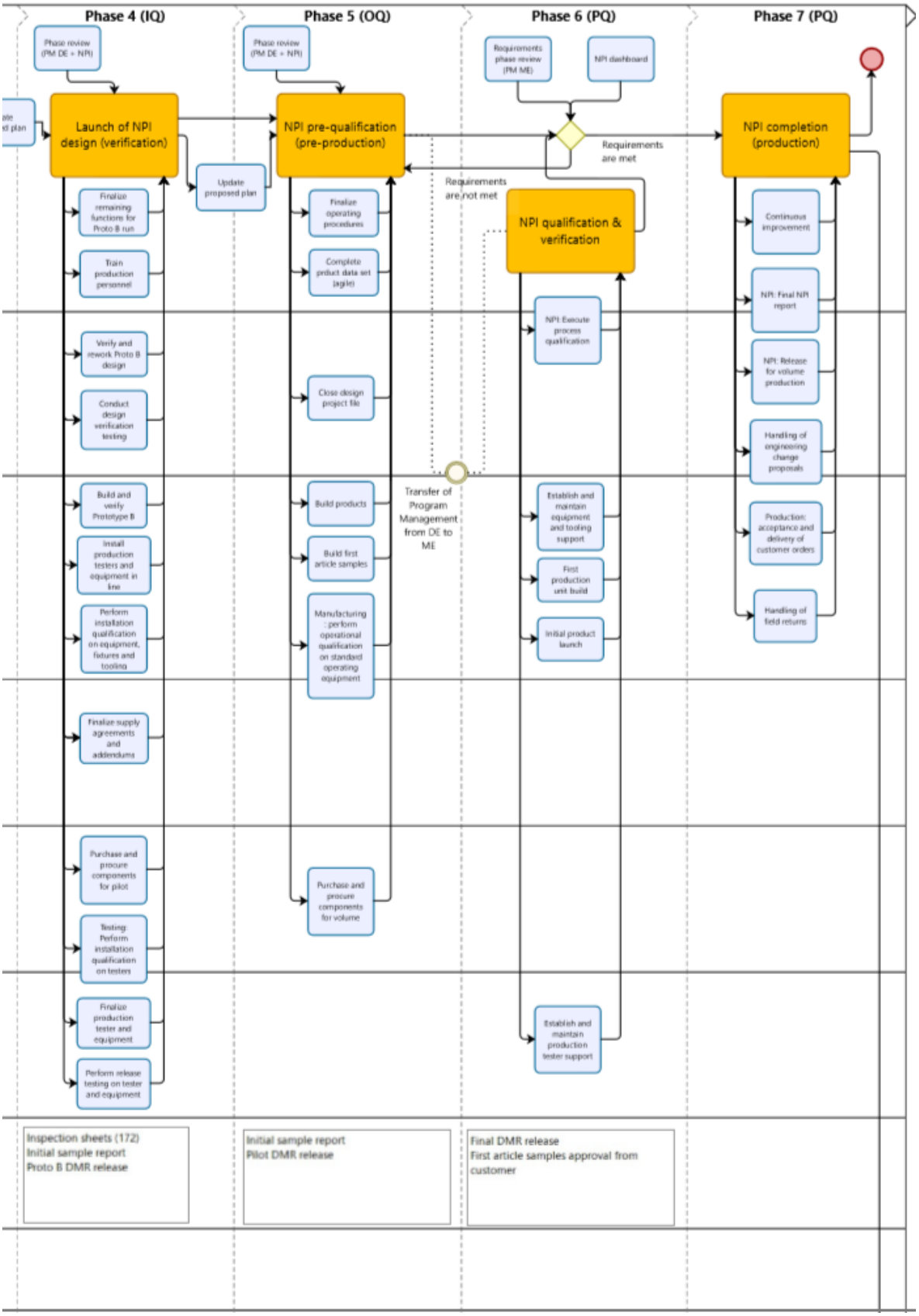
A.2: New NPI centre process model total



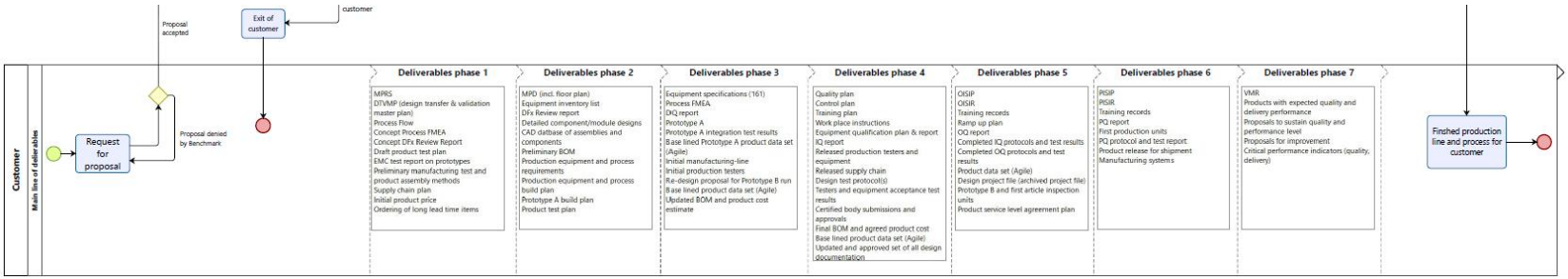
A.3: New NPI centre process Company X model left close-up



A.4: New NPI centre process Company X model right close-up



A.5: New NPI centre process customer close-up



Appendix B – Quantitative data analysis

B.1: Quantitative data analysis of employees of the NPI centre

Interview #	R	S	T	U	V	W	X	Y	Z
1	1*	1, 2, 3, 4, 6, 7, 8, 9	1, 3, 4	5	2	3	2	1, 6	1, 4
2	1	1	1	1	2	4	3	2, 3	1
3	2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 3	1	0	0	0	2, 5	1, 7
4	1	1, 5	0	0	4	4	2	0	1, 4
5	3, 4	2, 4, 7, 11	1, 2	1	3	3	3	1, 4, 6	4
6	5	3, 6, 7, 12, 13	1, 4	1	4	3	2	1, 3	3
7	3	1, 7, 13, (**)	1, 2	4	3	3	2	4	5
8	1*	1, 3, 4, 6, 7, 10, 14	1, 2, 3	4	2	2	1	2	2
9	2 (5)	1, 10	1, 4	2	2	2	2	4, 5	1, 6

Cumulative

Answer	R	S	T	U	V	W	X	Y	Z
1	4	7	8	4	0	0	1	3	5
2	2	3	3	1	4	2	5	3	1
3	2	4	3	0	2	4	2	2	1
4	1	4	3	2	2	2	0	3	3
5	1	2	-	1	0	0	0	2	1
6	-	4	-	-	-	-	-	2	1
7	-	6	-	-	-	-	-	-	1
8	-	2	-	-	-	-	-	-	-
9	-	2	-	-	-	-	-	-	-
10	-	3	-	-	-	-	-	-	-
11	-	2	-	-	-	-	-	-	-
12	-	2	-	-	-	-	-	-	-
13	-	3	-	-	-	-	-	-	-
14	-	2	-	-	-	-	-	-	-

B.2: Quantitative data analysis of internal customers of the NPI centre

#	K	L	M	N	O	P	Q
101	1	1	4	4	4	2, 3, 4	1
102	2	2	3, 4	3	3	2, 5, 6	1
103	3	3	3	3	3	1, 2	2
104	4	4	2	3	2	2, 7, 8	1, 2
105	5	2, 4, 5	3	2	2	2, 3, 4, 5, 8	1, 2

Cumulative

Answer	K	L	M	N	O	P	Q
1	1	1	0	0	0	1	4
2	1	2	1	1	2	5	3
3	1	1	3	3	2	2	-
4	1	2	2	1	1	2	-
5	1	1	0	0	0	2	-
6	-	-	-	-	-	1	-
7	-	-	-	-	-	1	-
8	-	-	-	-	-	2	-

Appendix C – Hoshin Kanri of the NPI

C.1: Hoshin Kanri of the NPI centre

REDACTED FOR ANONIMITY

Appendix D – Glossary

D.1: Glossary with English corrections

Abbreviation	Description
AOI	Automated Optical Inspection
AVL	Approved Vendor List
BGA	Ball Grid Array
BS	Boundary Scan
CAPA	Corrective Action Preventive Action
COC	Certificate of Conformity
DFM	Design for Manufacture
DFMEA	Design Failure Mode & Effect Analysis
DFT	Design for Test
DPMO	Defects per Million Opportunities
DPU	Defects per Unit
DQ	Design Qualification
EAM	Enterprise Asset Management
ECO	Engineering Change Order
ECR	Engineering Change Request
EPA	Electrostatic Protective Area
ESD	ElectroStatic Discharge
ERP	Enterprise Resource Planning
FAI	First Article Inspection
FMEA	Failure Mode Effect Analysis
FP	Flying Probe (Electronic Process Test)
FPY	First Pass Yield
GWO	Groeps- Werk Overleg
HMT	Hand Montage
ICT	In Circuit Test
IPC	Institute for Interconnecting and Packaging Electronic Circuits (Association Connecting Electronics Industries)
ISR	Initial Sample Report
IQ	Installation Qualification
KPI	Key Performance Indicator
KRI	Key Result Indicator
ME	Manufacturing Engineering
MES	Manufacturing Execution System
MPI	Manufacturing Process Instruction
MPRS	Manufacturing Process Requirement Specification
MRB	Material Review Board
MRO	Maintenance Repair & Operational (supplies)
MSDS	Material Safety Data Sheet
MTBF	Mean Time Between Failures
NPI	New Product Introduction
NPL	New Product Launch
NRE	Non Recurring Engineering
ODB	Open DataBase (file format)
OEE	Overall Equipment Effectiveness

Abbreviation	Description
OISIP	Operational Initial Sample Inspection Plan
OISIR	Operational Initial Sample Inspection Report
OOO	Out of Office
OQ	Operational Qualification
OTD	On Time Delivery
PCBA	Printed Circuit Board Assembly
PDM	Production Data Management
PER	Proto Evaluation Report
PFMEA	Process FMEA (see FMEA)
PFS	Process Feedback System
PI	Performance Indicator
PIP	Pin In Paste
PISIR	Performance Initial Sample Inspection Plan
PISIP	Performance Initial Sample Inspection Report
PO	Purchase Order
PQ	Performance Qualification
P&P	Pick & Place
PRR	Production Readiness Review
PTC	Proto Typing Center
QA	Quality Assurance
QBR	Quarterly Business Review
QFN	Quad-flat no-leads
QFP	Quad Flat Package
QIT	Quality Improvement Team
QLTC	Quality – Logistics – Technology – Cost (areas in scope of SAT)
REACH	Registration, Evaluation and Authorization of CHemicals
RMA	Returned Material Autorization
RoHS	*Restriction of Hazardous Substances*
SAR	Spending Approval Request
SDE	Supplier Development Engineer
SMD	Surface Mounted Device
SMT	Surface Mount Technology
SO	Sales Order
S&OP	Sales & Operations Planning
TAR	Travel Approval Request
TAS	TPD Acceptance Sheet
TPD	Technical Product Documentation
VMR	Validation Master Record
WIP	Work in Progress
WO	Work Order
WPI	Work Place Instruction