Nemat Dehghani

Defining Requirements Management Process for Product Development Projects

Metropolia

The Industrial management program was a unique opportunity for me to learn and update myself in many ways. The story started when I found a need to improve my knowledge from industrial production and business beside the technical knowledge that I gained from previous studies in Electrical Engineering (MSc). At the beginning it was a challenge to fit myself into the applied science university education system but at the end I learned that the applied way of learning is the best way for my age.

I would like to thank all of the instructors in Industrial management department for this unique opportunity. Dr. Juha Haimala, Dr Thomas Rohweder, Marja Blomqvist, Johanna Vesterinen and other guest lectures. Special thanks to Dr. James Collins for his effort and advice during this thesis, also Zinaida Grabovskaia and Sonja Holappa for their time and effort during the program. Without you it would not have been possible to finish the program. I would like to thank Niina Aho, Juha Sørensen, Juha Nieminen and Lixuan Feng and other colleagues for their support and help that I will never forget.

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The objective of this thesis is to create a process for managing the requirements in product development projects in the R&D department of the case company. The case company is one of world's leading companies in manufacturing business. As the content of study required to use multiple sources the case study research method have been selected for this thesis.

The first action after establishing the need to have a requirements management process was to investigate the current way of working. To identify the strengths and weaknesses of current way of working, many internal documents were reviewed and a number of interviews with different stakeholders organized during the current state analysis.

Literature in the form of academic theses, professional journals and company case studies were reviewed to find the best way to tackle the weaknesses of the current way of doing work. The proposed process defined the type of requirements clearly and introduce the steps that need to be passed for requirements in the project. Defining the requirement from the very beginning to the last step which is validation the requirement. The roles and responsibilities are introduced for each step of the process to manage the workflow in the project.

The final outcome of this thesis is a requirements management process for the case company Research and Development (R&D) department which can help the project managers, stakeholders and design engineers to manage the requirements in an efficient way.

Keywords	Requirements lifecycle managements, Stakeholders, Verification and Validation, Requirements management process

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1 Introduction

The aim of this thesis is to identify the proper solution for the case company business challenge and the outcome that will be presented to them for future and further study or implementation to the work culture. As a global company, the case company faces a massive amount of data which require processes and decisions, management of people and teams to carry out the project, suppliers, stakeholders and so forth.

1.1 Business Context

The case company is a world leader in the engineering manufacturing industry. The case company main businesses are products and solutions and also the service for maintenance, update and modernization of the product. Instead of the physical solutions, the case company provides services which the help people who are living and working in high rise buildings to enjoy smooth moving and easier daily life. Being a global brand, it has the advantage of connecting to the customers in global level and also the local market and industry requirements that should be taken into account, but these create a challenge for operating the company globally. A strong local unit in the organization hierarchy may help and give flexibility in operation. The company's new strategy is winning with customer which means putting the customer in the center of business and provide innovative solutions in a customer centric organization. The current number of employees is 55,000 and over 450,000 customers. The net sales for last year 2017 were EUR 8.9 billion.

The case company's business has been divided in two main parts. The first part is new equipment which includes state of the art solutions for all types of building. The versatile product portfolio features a wide range of innovative products including elevators, escalators, auto-walks, automatic building doors, monitoring, access and destination control system (DCS).

The second main part of the business is Services. The case company leads the industry in advanced maintenance service for elevators, escalators, and automatic building doors. The main activity is to make sure that the customer equipment performs reliably and safely. Modernized services help customers determine when and how to upgrade the equipment to ensure a lifetime of optimal operation and to maximize customers' return on investment.

The two megatrends of the business are Urbanization and Technological disruption. Continuing urbanization drives long term growth potential, for new equipment, maintenance and modernization. At the same time, new technology gives a great opportunity to learn new ways of working and serve customers and users in smarter and more exciting ways.

1.2 Business Challenge, Objective and Outcome

The global research and development office is located in Finland where most of the new product creation projects and also product development projects are implemented. Every project is created based on the needs and requirements. There are many types of requirements from different sides of the company, Business requirements which mostly should come from the people who are involved in developing the business and the related activities. Stakeholder requirements are divided between different stakeholders that have own views like instability, supply and operation, security, user experience, maintainability and so on. Business requirements are the needs for projects from the business point of view. The Business requirement creation process and the requirement management should be reorganized for the future product development projects. A clear business requirement process is a need for the organization.

The definition of a problem from the customer side is a need that the current products or services do not fulfill. The stakeholders are a diverse group of experts that see the problem from their own perspective and have their own requirements. By getting a broader perspective, stakeholders are different groups of individuals affected by the company's achievements. Thus a requirement management process is needed.

The objective of this thesis is to develop a process that helps to define and manage requirements for R&D projects.

Accordingly, the outcome of this thesis is a process that serves to define the requirements in a requirement management process for every product development project.

This thesis is written in 7 sections. The first section introduces the business challenge in the case company and also background of the business cases. The second section describes the methods and material that have been used during the study including the research design and the model to collect data. The current state analysis is presented in Section 3. Section 4 is about the literature that was reviewed to find solutions from other researches and similar cases. At the end of the literature review the conceptual framework is illustrated and which serves as the basis of the initial proposal explained in detail

in section 5. The initial proposal has been created based on the information that was collected in section 3 and section 4. This proposal includes all of the relevant information to see how the final proposal can solve the business challenge and tackle the weaknesses that were identified in the current state analysis. Section 6 is the verification and validation of the proposed requirement management process proposed in section 5. Section 7 contains the conclusion of the study, results and the suggestions for implementing the new proposed process in an efficient way.

2 Method and Material

This section illustrates the research method, materials and data collection that have been used in this thesis. First of all the research approach and the way of doing research design will be described then different way of collecting data and the method for analyzing is presented. The reliability and validity plan are the last part of this section.

2.1 Research Approach

There is not a one single way of doing research that can call it the best way and many options are available. The important part of every research is selecting the research strategy. Strategy is described as plan to reach a final specific goal. Case study approach is focusing on one phenomena to provide a deep understanding relationship or process that happens on that particular phenomena. Every research approach has its strengths, using a variety of sources and data is counted as a strength for a case study. The key point is that using case study is a strategic choice and it keeps the hands open for selecting different methods based on needs (Denscombe 2010:52-55).

Yin (2003) believes that case study is the best choice for a research which a) focuses on answering the fundamental research questions like "how", "why"," what", "where" and "who"; b) researcher cannot manage and touch the action of those who are involved in the study; c) the background condition of the situation wanted to be covered; d) there is no clear limitations. For this thesis the case study approach has been selected because the nature of study is related to many sources that can be involved in the process to answer the research question, the background needs to be studied without any boundaries.

According to Baxter (2008), a qualitative research approach provides tools for researchers to investigate the phenomena by using a wide range and multiple sources of data. Case study is not just conducting a research on simple and single individual or situation. It has a possibility to transaction simply through complex conditions and the researcher has potential to answer the "how" and "why" questions.

In this thesis, the investigation needs to be done from multiple resources and interviewing many stakeholders to answer the main why and how and what questions, therefore the case study is the right choice. Analyzing the current situation will come before reviewing

the literature to avoid leading people in the interviews. This will be explained in more detail in the next section.

2.2   Research Design

Data 1

- Interview with project managers
- Previous projects' documentation
- Company way of work

OBJECTIVE: To develop a process that helps to manage requirements for every R&D project.

Current state analysis
Understanding project milestone.

How projects are running and the way of doing.

How the requirement captured and stored.

A picture of the current way of work in case company.

Evaluation and strengths and weaknesses

Reviewing Literature
Previous theses on process development.

Books on requirement management.
Academic papers and journals.
Company documents.

Conceptual Framework

Requirement management in big industrial organizations.

Tools in requirement management process.

New ideas on process development and solution creation.

Data 2

-Interview with stakeholder owners
-Workshop for players in the process
-interview with process owners

Building the solution
Bring the Current state analysis and the current factors together.
Process key steps.
Propose a model.

An initial process for requirement management

Data 3

Workshop for project managers, stakeholders, Design engineers and process owner

Validation and Feedback
Notes from workshop

Comments from different parts and responsible persons

- Final approved process for requirement management in R&D projects
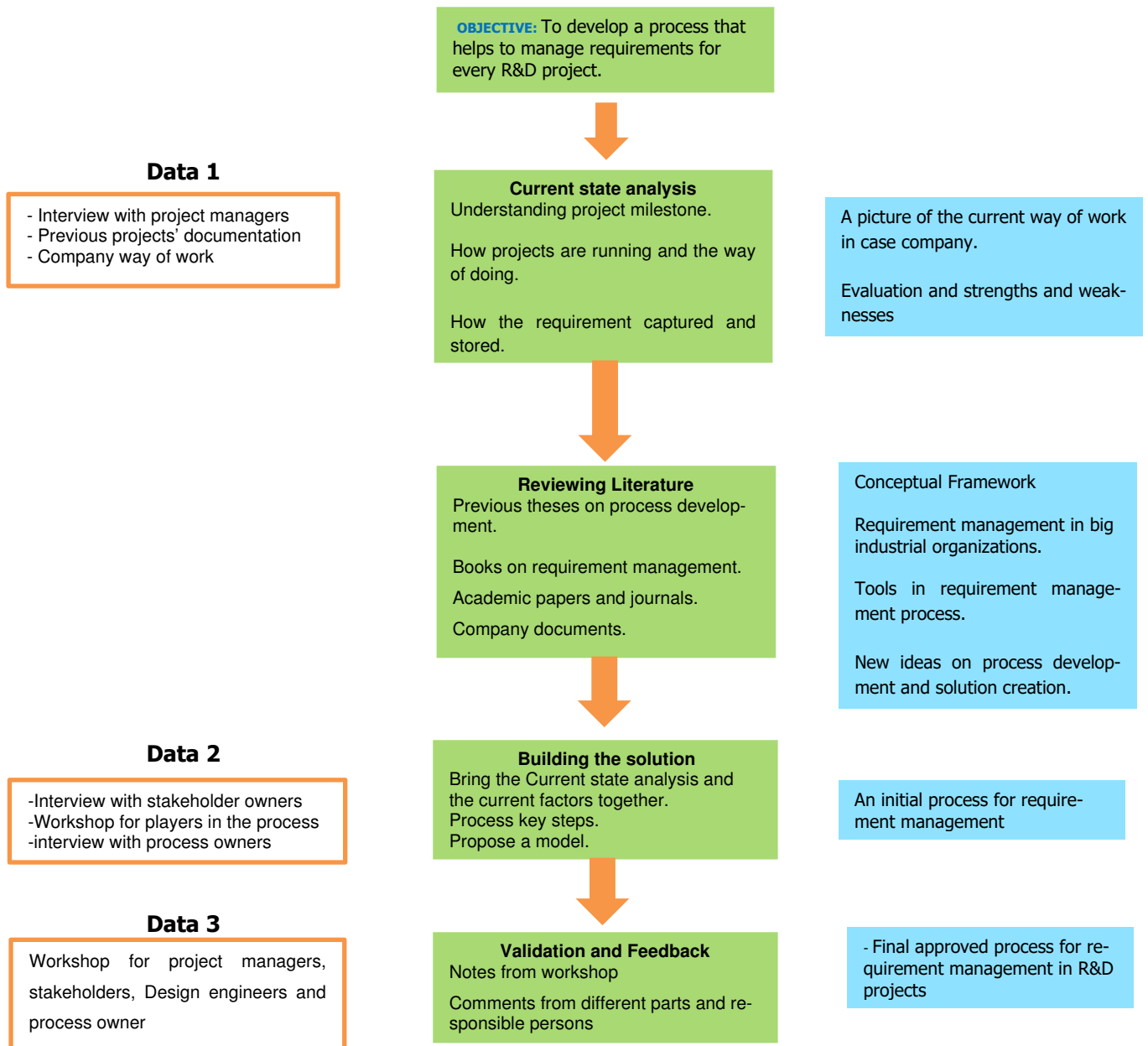
Figure 1. Conceptual framework

In this section the research design diagram of the thesis is presented in Figure 1. Generally the diagram contain the steps of study and also the output after each step which means what is the result after the step is fully done, the data base for every step are also indicated in the diagram.

As shown in Figure 1, the main objective of the study is to develop a process for the R&D department is case company. After designing the research and selecting the research approach, the first step is the current state analysis to understand what is the current way of doing and how the process works in the case company. To understand the current situation, the responsible persons including engineer designers, project managers, category managers and key stakeholders are interviewed and the past project documents reviewed. The main outcome of the current state is the advantages and disadvantages of current process. The advantages can be merged to the new process and the disadvantages are improved and developed in different way. The next step is finding the best method from available literature and review them to get the new idea and example and find the possible idea matching the objective of the thesis. By using the outcome of analyzing current situation and also the findings from literature also the new round interviews, the new proposal shall be introduced. The last step is validation of proposed solution and reviewing feedback from key players to make the proposal. The research design shall illustrate the clear step by step of the finding the new process.

2.3 Data Collection and Analysis

As there are many responsible persons and players in the core of this research work, three rounds of data collection from multiple sources have been planned which are indicated also in Figure 1. Collecting data is the input for the analyses in every step of study. The first important step is the current state analysis that needs to consider a variety of sources to understand the current way of working and merits and demerits of the current process. Face to face or online interview was a common way to hear from people who are working on their tasks with the same way of doing. Although the duration of collecting data and the work position of people who participated in collecting data process including interviews, meetings and workshops.

Table 1 shows the detailed data sources that have been used during the study. Generally the team has weekly follow up meetings to review the situation for individual nominated tasks, but it was a good opportunity to use some extra time of meeting for getting the

idea and their request which was mostly used in data 2 to consider their opinion for proposing the new solution, and also sharing the situation during the current state analysis.

Table 1. Details of interviews, workshops and discussions in Data1,Data 2 and Data 3.

	Participants / role	Data type	Topic, description	Date, length	Documented as
	Data 1, for the Current state analysis (Section 3 or 4)				
1	Project Manager-Mechanical	Face to face Interview	How projects collect requirements	Dec 2018, 1 hour	Field notes
2	Design engineers and stakeholders	Face to face Interview	Different type of requirements and how to collect them	Jan 2019 3 hours	Field notes
3	Project Manager-Solution creation	Face to face Interview	What is the process for managing the requirements	Jan 2019 1 hour	Field notes
	Data 2, for Proposal building (Section 5)				
8	Stakeholder Key players	Workshop/ discussion	Building the solution process	March	Field notes
	Data 3, from Validation (Section 6)				
9	Stakeholders Project managers design engineers	Group interview/ Final presentation	Validation and Feedback	March-April	Field notes and recording

The main difference about Data 1 and Data 2 is the way of gathering the opinions. The first round of data collection mostly starts with different list of questions that people who have been invited to interviews answered, but in round two of data collection the workshops started with a brief presentation and then every attending person tried to express their idea and write them down on paper notes during the presentations. The valuable notes were mostly from people who had an idea to improve the requirement management process.

3   Current State Analysis

This chapter of the thesis is about discussing the current way of working for collecting and using the requirements in product development process in the global R&D unit of the case company. It is important to mention that there is no existing established process for managing the requirements in the case company and specifically the R&D unit. Therefore, the source of the analyses is based on the internal documents and also interviews with experts and design engineers. At the beginning of this chapter different types of the requirements and the need for them are described. This chapter also discusses in detail the way that requirements are using during the product development project to find a general picture of the current way of working. The last part of this chapter is about finding and analyzing the strengths and weaknesses of the current way of working.

3.1   Definition Of the Requirements

The case company is one of the world leaders in the industry and has a big impact on the market and because of the nature of the product many stakeholders are affecting the final product. The company operates globally and wants to be the market leader in different areas. There are many different types of requirements that need to be considered for developing a product.

Different stakeholders view requirements from different perspectives and level of abstraction. Requirements vary depending on the solution e.g. platform, component or software. Requirements are also defined, evaluated and validated at different stages of the product development.

Business requirements represent needs from the business or operational point of view. This includes customers, users and stakeholders. Business requirements are essential requirements and usually prioritized together with the business case.

Codes and standards are regulative requirements that can be specified from different market areas. Basically codes and standards are the must to do requirements and sometimes open new opportunities from business and sale point of view but can create in same time engineering challenges for design engineers.

Stakeholder requirements are defined at platform or component level. They identify mandatory, typically non-functional, requirements to be implemented during solution development. Typical stakeholder requirements are related to many different categories, for instance the internal regulation regarding the maintenance, installation, cyber security and also more deep regulation like smooth transition environment friendly product.

Technical requirements are defined and grouped into a logical or physical structure. Technical requirements may also constrain the solution by defining what existing solution or design asset should be used in solution development. This type of constraint is very usual as most of the product development is based on existing technology. Technical requirements have an attribute to classify the type of requirement.

Technical Specifications define how the solution will be implemented. Technical Specifications take into account all approved requirements and forms a design specification for the development team. Technical specifications are a combination of different requirements and specification items which are created during the iterative development work. Definition and different types of the requirements that have been needed in product development projects have been introduced. Using multiple type of requirements crated challenges to manage the requirement in implementation phases.

3.2   Current Way of Managing the Requirements

During the current state analysis the interviewer who worked in a different position and different teams described how they managed to use the requirements during the product development process to fulfil all of the requirements. As mentioned in the last section, there are four main types of requirements that should be collected or considering to be collected at the very first step of product development. Figure 2 shows the main steps in current way of working. To determine and picture the current way of working it is better to draw the process that has been found during the interviews as a chart. Basically, the three main steps of process are collecting the requirements implementing the collected requirements in design and then reviewing the final design to find out whether it covers all of the requirements or not. It is important to mention that this process is not an established process which can be found in the official documents. In the first step which is requesting the requirements, project managers introduce the scope of the project to the core team and stakeholders. Reviewing the requirements and making prototype is a loop activity that means many version of prototype can be designed. Because the new requirements may appear even when the design is ready. To describe and open every step of the current process, it should be mentioned that the current way of managing the requirements is a simple way and can be divided in three main steps which will be described in detail in next sub sections.
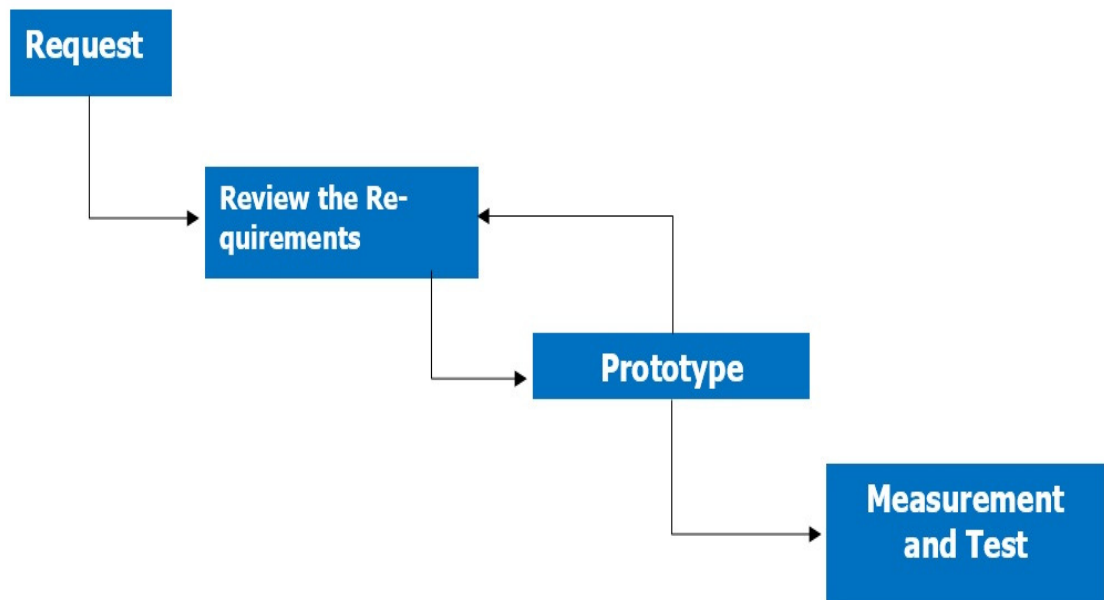
Figure 2. Current way of working process

3.2.1 Request and Collecting the Requirements

Collecting the requirements is the very first step of the requirement management, this step is almost the same for every core member of the project.

Every project has a core team that is basically a cross functional group that are responsible for implementing the project for the planed targets in cost, quality, market and business value. Figure 3 shows the project core team. Every core team member plays a role in the current way of working regarding the managing of the requirements in project which is listed in Table 2.

The Product Line Manager is responsible for business requirements because the product line manager has access to the customers' needs together with sale managers. Area sale managers are directly in contact with customers and can translate their words and make it understandable for design engineers. Basically most of the business requirements are business cases that project is planned based on them and also the new ides that will release to the market.
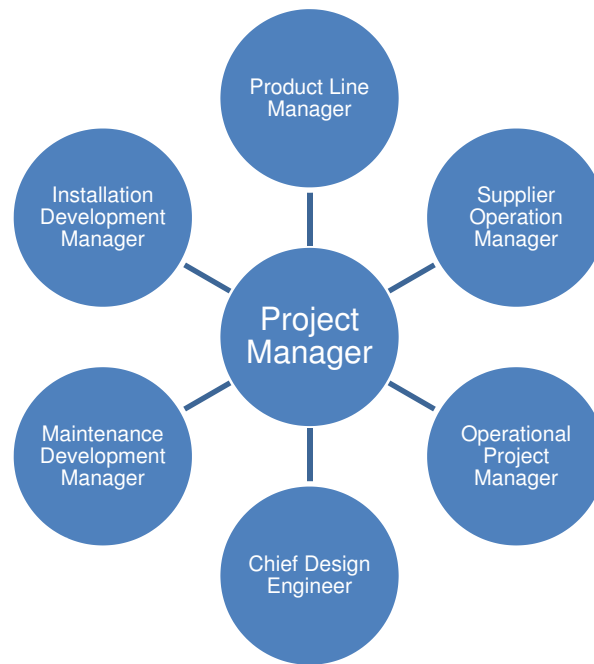
Figure 3. Project core team

Table 2. Current responsibilities in requirement management.

Core team member	Requirements Responsibility
Product Line Manager	Business requirements
Project manager	Code and Standards
Chief Design Engineer	Technical requirements
Supply operation Manager	Stakeholder
Installation Manager	Stakeholder
Maintenance development manager	Stakeholder
Operations Project Manager	Stakeholder

As shown in Table 2, every member of project core team is responsible for collecting the requirement in their own field. Codes and standards are international and local common technical agreements that every industrial organization should follow. Project managers are responsible for finding a list of all codes and standards related to the project. The chief design engineer collects all of the technical specifications regarding the project which are the technical requirements of the project. As mentioned the case company is

operating globally and the core product is a complex product which means many stakeholders are involved in the design and development of product and their requirement should be considered.

3.2.2 Review the Requirements

This step is one of the most important and time demanding part of the current way of working. Every member of the project and responsible person including the different stakeholders and designers listed the own requirements by using Microsoft Excel tools

> *Sometimes we have a list of many hundreds or even southland requirements, which make it difficult to review them. (Interviewee 1)*

Every member of core team or even engineers who are project members join a weekly requirements review meetings to check and discuss about the requirement content and decide to select the final list of requirements. Basically the project manager goes to every single line of the collected requirements and when everyone agrees and understands the requirement, then the requirement is marked as approved requirements. Similarly, the non-applicable requirements will be deleted from the list.

Some of the requirements have an effect on the other requirements for example if the product line manager removes one requirement related to selling the product in China which means the product will not be sold to the Chinese market. Then the code experts should remove the Chinese standards from the list because it is not an applicable requirement any more.

> *This is a challenging step in the project and needs to be considered carefully, approving one requirement may open many action and task in the project. (Interviewee 1)*

In the same time, adding a new feature to the final product through a request from business sale and marketing sides will open many discussion in project level, this may needs to add new codes and standards research to find whether this feature is aligned with the standard codes requirements. The chief design engineer also needs to take an action to see how it is possible to implement the requested feature from sale side and this will add new technical requirements to the list.

Stakeholders are usually invited to the meetings and their comments are valuable for implementing the requirements, for example installation and maintenance are two main stakeholders which their requirements request continue in the building prototype that will be discussed in next chapter. This means requirement reviewing is a continuing process and every project member try to put sufficient time and effort into it.

3.3   Prototype

Reviewing the requirements and making the protype of the product are connected to each other. This means design engineers using the approved requirements as a guideline in their design. Usually every engineer group makes their own action during the approval meeting and plan to fulfil the requirements. Depending on the complexity of the final product design groups are generally consisting of electrical, mechanical and IT engineers that every group focus on own art of design, but they should work in close collaboration to cover the requirements.

One of the challenges in making the prototype is different variation of the product, from one side the business has a requirement that the product should be as fit in one variant or the final product shouldn't have multiple variants. As the standards requirements are different for market areas then having a multi variant product cannot be avoided.

Due to the technical challenges or new request from front lines that are in close contact with customers, new requirement may be added in the prototype phase to the final requirement list, so basically there is a loop between the final approved requirements and the prototype. This means the first prototype is not the final one and is not the best, this may happen due to not covering some of the requirements or even some of the requirement that is related to for example both electrical and mechanical may be considered just from the mechanical point of view.

Some of the requirements need many laboratory tests to reach the specification that is targeted but it may be time demanding because if the item needs to be supplied from a third party then supply chain management team should be involved to find the right supplier. Quality is also an important aspect in selecting a third party supplier, different samples from different suppliers should be ordered and engineers decide and choose which sample can cover all types of the requirements regarding the price, availability and ability of supplier to fulfil the case company supply chain management internal requirements.

Making the prototype based on the approved requirements is one of the main steps in the product development project and also managing the requirement. The project manager and engineer have a clear picture of the final product.

3.4   Measurement and Test

Measuring and testing are the only ways to find and understand the performance of an engineering system. There are many required test by case company R&D that every product should carried out during the developing phase, for example reliability test, environment test.

As mentioned in the previous sub-sections all of the technical requirements need technical specification that are supporting the technical requirements. Every innovation idea or high technology achievements during the developing of the product should be measured carefully in the test environment and also in the real tine situation to be sure that they can cover the targeted requirements.

For instance if the targeted project includes electronic boards and also mechanical structure, communication and software interface, then it may create many technical challenges when every part wants to work together. Based on the case company design guidelines (Test plan 2017) there are a list of functionality and reliability tests that must be carried out, for example dynamic impact final product test, static force test, functionality test, lifetime test, activation test and UV test. Some of the tests are depending on the using purpose of the product, for instance cross-cut test, tear test, chemical resistance, abrasion, contrast, viewing angles which are mostly visuality and appearance tests.

Every successful test is a second approval for the requirements and also may be good news for the supply operation team to inform the supplier that they will continue with their supplied part or material. In this line, every failed test means requirements related to the test should be considered again and reviewed again to see whether the project will continue by selecting the other supplier or may repeat the test. It may be possible that the project core team decides to even postpone the requirement for the next generation of the product.

Measurement and test are the final steps of the managing the requirements which means after approving the tests that shows the prototype fulfils the approved requirements, the product will be ready for large scale production and release to the market.

3.5   Key Findings From the Current State Analysis (Data Collection 1)

This section discusses all of the strengths and weaknesses about the current way of managing and implementing the requirement management. There has been an on-going discussion from starting the interviews regarding what the advantages and disadvantages of the current way of working are. Table 3 shows that the advantages or strengths are not many and most are weaknesses that need to be improved.

Table 3. Strengths and weaknesses of current way of management the requirements

Strengths	Weaknesses
Easy to fill Excel and Word templates	Low level quality of requirements
Low cost (doesn't need new tools, training , service fee)	**No Coaching and discipline for writing the requirements**
The product development process works satisfactory	Multiple documents for project documentation
	Not customer centric requirements
	No systematic review process
	High potential to miss the requirements
	Low level of traceability
	Not available for future use
	Low data security
	Not Considering special budget for requirement management for every project
	Requirement review time
	Requirement responsible person in project level

To describe the content of Table 4 more clearly, the strengths which are not many can analyzed. As mentioned before one of the most common ways of collecting the requirements is to write them into Excel files. This means that every group creates their own template and then every member of the group can add and fill the requirement, at the end before reviewing meeting every group merges their own template to one and sends it to the project manager. This is a fact that writing on Excel file is easy and some of the group members have been doing it for any years, therefore it should be considered for the future proposal or development. The other important fact is that using Excel template is the most low cost solution and this can affect the decision making level, because adding new tools to the organization will require service cost, training cost and other related general costs. That is why everybody agreed that Excel is a suitable solution. The product development process is a well-designed and stablished process that is familiar for every person in global R&D. This means on the proposed process this shall be considered that the process is somehow mergeable to the current product development process.

Regarding the weaknesses there are plenty of items that need to be considered. The first thing that can be found from the interviews is that there is not good understanding for definition of requirements. This leads to writing requirements that are not understandable for the whole team and or people out of team and third party. Using Excel files is easy but it will lead to have multiple versions of the same document and increases the project documentation. This may also decrease the security of data in the whole project. One of the important facts is that the final product should meet the customer's need, but in the current way of doing there is not a clear way to communicate to the customer that needs to be considered for future study.

Reviewing the requirements is a vital step but there is not a clear way of reviewing and most of the requirements review meeting are discussion meetings which is time demanding. In addition, it is a high potential to miss some of the requirements in the implementation phase.

By looking to the whole way of doing and considering every step can have a big picture of the whole process and understand the level of challenge, but the weakness from this big picture is that for every project the whole process should repeat again, which is

time and cost demanding. If the process is designed in the way that can be usable for future projects then it will increase the efficiency of work and save the cost and time.

As requirements are coming from different sources it may happen that some of them overlap each other or are in some cases even against each other, but it is not possible to monitor them from the starting point to cover it better during the implementation or reviewing phases. Without treatability, the reviewing and implementation and even the testing step would be more difficult.

The other weaknesses that can be considered are mostly from the higher level of decision, for instance managing the budget to have a specific budget for requirements management in case of using new tools.

It is not possible to cover all of the listed weakness in the future developing process but the blue colored weaknesses in table 3 are the important ones. By covering the blue covered weaknesses the process will change and can improve the performance. It is important to note that the blue colored strengths have a positive impact and they should be kept in the proposed process.

The next section is very important in the whole study. In the next section, many high level literature will be reviewed and the conceptual framework that the final proposal will be presented.

4 Best Practice on Requirements Lifecycle Management

One of the tasks for business analysts is to manage and maintain the requirements from the beginning of the design to retirement phase. This task is called requirements lifecycle management which include creating a suitable relationship between the requirements and design, play the key role when a change for design proposed from different parties and make a common agreement on proposed changes. The main purpose of the requirement lifecycle management activity is to be sure that every side which contribute in the activity like stakeholders, design and requirements are working in the same line. To reach to this goal, a level of monitoring and control shall be made on how requirements will be use in actual implementation, also it will confirm the availability of information for future use (Babok 2015). Based on the NASA system engineering handbook, requirement management means managing the expectations from stakeholders, customers and component technical features. These can be included the common effects between system and external objects like environments. Basically people who have stake in the system called stakeholder, which usually are in two groups, internal like the engineers and designer and external stakeholders that are user or the owners. From the bigger picture, stakeholders are the individual persons who are affected by the organization (Maciaszek 2005) (Freeman 1984).

The first step of requirements lifecycle management is defining the needs for business and continue to develop a solution for mentioned needs. At the end, a requirement goes to the retired phase when the solution that has been created based on that requirement is retired. But the management does not end after implementation, the solution continues generating value through the proper requirement management.

The requirement management life cycle includes the following areas: trace the requirements, maintain and prioritize and approval which will be discussed in more detail through the requirement management process in the following subsections.

4.1   Define and Trace the Requirements

Some of the literature argues that in product development there are two different terms, the needs which are on the problem side and the feature and requirements which are on the solution side. Basically, this means needs describing what customers, stakeholders or even standards wanted. Needs can also be translated as raw requirements or the language of customer (S. McEwen 2004). The IEEE Recommended Practice for Software Requirements (1998) mention that the raw requirements is not a proper rounded requirement. One of the characteristic styles is to classify requirement as functional and non-functional requirements (A. Abran 2004). But generally the key purpose of the investigation is to determine what is really required, that means requirement (Aarama 2017).

It is obvious that business and technology are changing, and reusing the experience to avoid any risk in cost, quality and time is essential. Tracing the requirement is a solution that acts to fill the gap between requirement management and changing in stakeholders needs. In other word, requirement traceability can be distinct as the capability of following the requirement background or basically where the requirement is coming and the future effect of requirement. Tracing can link conceptual objects to each other, for instance connecting a requirement to the component design requirement. The human cooperation others also is important in the final tracing phase. Finally traceability is the core of activity for creating possibility to find the connection of requirement to past and even future in requirement management process (M.Jarke 1998). NASA system engineering handbook defined that traceability the connotation between many units which are reasonable such as requirements, system elements, verification (Nasa 2007). Traceability also used to find the potential missed function that system can handle or even the implemented function but requirements have been missed. By traceability the analysts will be faster and simpler, and the duty to confirm which requirement already covered and not will be easier. More reliability will be on covering the gap between the requirements.

Usually it is not easy to connect needs and solution without considering the links that have been existed among them. Business analyses can get benefit from traceability by balancing the relationships and also get advantage of them in release planning, because it will provide a direct connecting from requirements to what was expected from needs. Figure4, represent the requirement traceability example in soft wear industry.
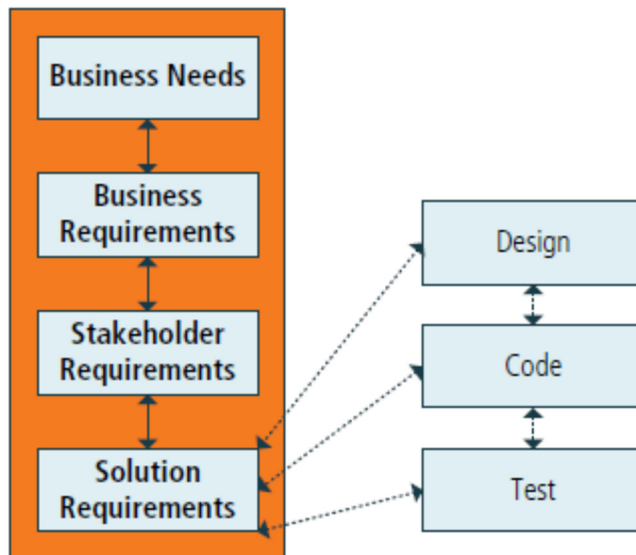
Figure 4, Requirement traceability example

Requirements and design are two input parts of trace procedure, requirements including all of the business goal and stakeholders can be traced to solution or component and design can be traced to the requirements. Basically the business analysts are looking for the value that will deliver by tracing and the effort will be increased when the number of requirement increase. Two main types of relationships between requirements are Derive and Depends. When two requirements which has a relationships are in different level those requirements are driven from other. For example a component requirement and business requirements. Two requirements can be depends to each other, when it seem right to add a requirements if the other requirement also fulfilled or even this may make it easier. The dependency can be related to technical situation and one requirements can be depends on the test result to ensure that a solution can cover the requirements. A requirement management tools can be used to store the requirements and relationships, this will have befit for different stakeholders. Stakeholders can trace how the solution has been implemented and how this solution fulfills the business cases. It will be easier for the project manager to manage any change in a project. The output of tracing activity are traced requirements and also traceable design. (Babok 2015)

4.2   Freeze and Approve the Requirements (Maintaining and Prioritization)

Maintaining the requirement will help to sustain the accuracy of them and it will support the possibility of using them again in other projects. Some of the requirements are based

on ongoing needs and may change during the development. Maintaining the requirements is a need to keep those requirements valid. In this line, requirements should be optimized, reviewed, approved and be available for use. In some situation, requirement can be reused. It is important that those requirements categorized, named and stored in right way that it would be easy to reuse by stakeholders. Requirement may be used by the present parallel projects or by different department in the same organization. Some of the requirements are specified to a component, product or solution which make it difficult to reuse them. Generalized requirements that written without detailed specification and link or reference has more reuse capability. The next step is to prioritize the requirements. Prioritization means ranking the requirements based on their importance. The purpose of this vital action is to get high level of value.

In product development projects when the customer has high expectations, the time and resource are limited, a solution can be delivered with high priority features with limitation in each scope of release (Lehtonen 2004). Many projects experienced the situation that due to the time limitation not all of the requirements can be implemented, which means some of the requirement should be overlooked for current release. Wiegers (2013) believes that this will help the project manager to do better project planning. However, the customer may not be happy to get the product or solution with just prioritized requirements and engineers not wanted to acknowledge that they cannot develop the requested features. Many technics such as backlog management, interviews, workshops and risk management can be used for prioritizing the requirements (Babok 2015).

The approval of the requirement is basically an agreement between the core players to continue the process based on the project plan and strategy. Usually business analysts makes sure that there is a common understanding between stakeholders and designer to approach the approval. A typical way to approval is only when the it is possible to implement a solution to cover the requirement. Avery important part of the approval the requirements is to understand the role of the project core team in approval. Not all of the stakeholders may have the right to approve the requirement, but they may have influence in the final decision. It is a task for business responsible person to give the authority for the final approval. Business analysts or requirement responsible person has a responsibility to ensure that stakeholders understand clearly the approved requirements because the approval means that a solution will be created and value will be delivered. Key persons need to be discussed with to review the requirement, even a full agreement from

everyone may cannot be achieved but the related risk needs to be considered. Documentation the status of the requirements needed to keep tacking and the current status of current of the requirement and also connecting to the stakeholder to consider the implementation of requirements approved. The techniques that can be used in the approval step of requirements can be for example using the acceptance and evaluation principles to define the approval criteria. Review meeting and workshop is the other option to enable the evaluation for finding approval agreement (Babok 2015).

4.3 Verification and Validation of the Requirements

The verification process is the first priority in the verification and validation process which is directed to the end product (Nasa 2007). Verification testing that maybe completed in different phases are mostly related to the approved requirements. These tests are recorded to show that the design, prototype or product are meeting the approved the requirements including all the specification. During the verification engineers may use different measurement equipment. The validation happens in the real or simulated situation to find the efficiency and steadiness of the product when operated by the users. Basically it is to see that the system functions in a normal environment as expected (Nasa 2007).

4.3.1 Verification

The main purpose of verification is to make sure that the approved requirements and the design specifications are in same line and they can be served to deliver the value (ISO15288 2008). One of the techniques that is usable in both verification and validation for evaluation is testing. Based on BABOK requirement, verification is a task to business analysts and stakeholders to specify that the approved requirements and design specification are deliver enough data for the next step which is validation the requirements. Verifying is to make sure that every requirement and design selected correctly and the specifications are clear with high quality, the designed model or prototype is also follow the standards. The most important point is that requirements and design should be usable by stakeholders and cover their needs, stakeholders are the only reference that can approve the quality. The important action in the verification process is a verification plan that should be defined (ISO/IEC15288 2008). This action needs a verification method based on the way that requirement has been created. The verification method indicate How , Where and When every single requirement submission can be accepted. A good

verification method intend to define the verification method, classify the responsible persons in the organization to do the verification and also create a timetable that the verification to be done including the venue and environment (ISO 29148 2011). Four main standard method to identify and approve that the requirement rewarded which are inspection, analysis or simulation, demonstration and test. Inspection is basically checking the documentation and the delivered item to confirm the agreement. In practice is using the documentation and drawing and compare to find the difference between the requirement and the inspected object.

An analysis method which includes the simulation tools and also analyzing data can be used in the situation in which it is not possible to do the actual testing or for considering cost point of view. Analyzing and simulation may also be used when there is a common agreement that that the requirement and specification are match with the delivered solution. In practice, a general analysis like failure modes effect analysis, analyzing tools and method can be agreed by every parties.

Demonstration is like an exhibition to show how the design and specification works, it may include simulation of the system to show how the features are implemented and operators use those features when using the product. Stakeholders can observe and compare the features with the specification. Using the statistical information in demonstration can make it more proper and to the main purpose. In practice it is important to document the data during the event to ensure that how the audience interact to the demonstration.

Test method is an action to measure the operability and performance of an object or system. Usually testing is required to use special equipment and tools to measure accurate data that needs in test analysis. In practice the test need special resource that can cover the facility and also qualified person that can run the test (ISO 29148 2011).

4.3.2 Validation

The main purpose to validate the requirements is to validate that all of the requirements and designs are in line with stakeholder requirements and specially business requirement and are providing the promised value. The goal for implementing the requirement

is to reach the point to make stakeholders satisfies, validation the requirement an approval for the stakeholders that they can see the future state after meeting their requirements. Validation is required for approval by the key stakeholders and also project core team and expert. Validation needs a review process of stakeholder requirements and also approval criteria to approve that the requirements are a reflection of stakeholders needs. In addition, If any requirement or design cannot be validated which is mostly because of not delivering benefit to the user or other stakeholders or not fitting to the final solution. These unvalidated requirements can be recorded as a change for the current design and considering the future release phase (ISO15288, 2008).

4.4   Conceptual Framework of This Thesis

This section describes the general conceptual framework of the thesis which is based on the analysis of the current state and reviewing different literature. The literature that has been used form the main references to create the conceptual framework. As it is illustrated in Figure 5 this conceptual framework consists of three main parts. Some parts contain sub-sections that help to build the final proposal more usable in practice. Figure 5 shows the input and output for each part of the conceptual framework.
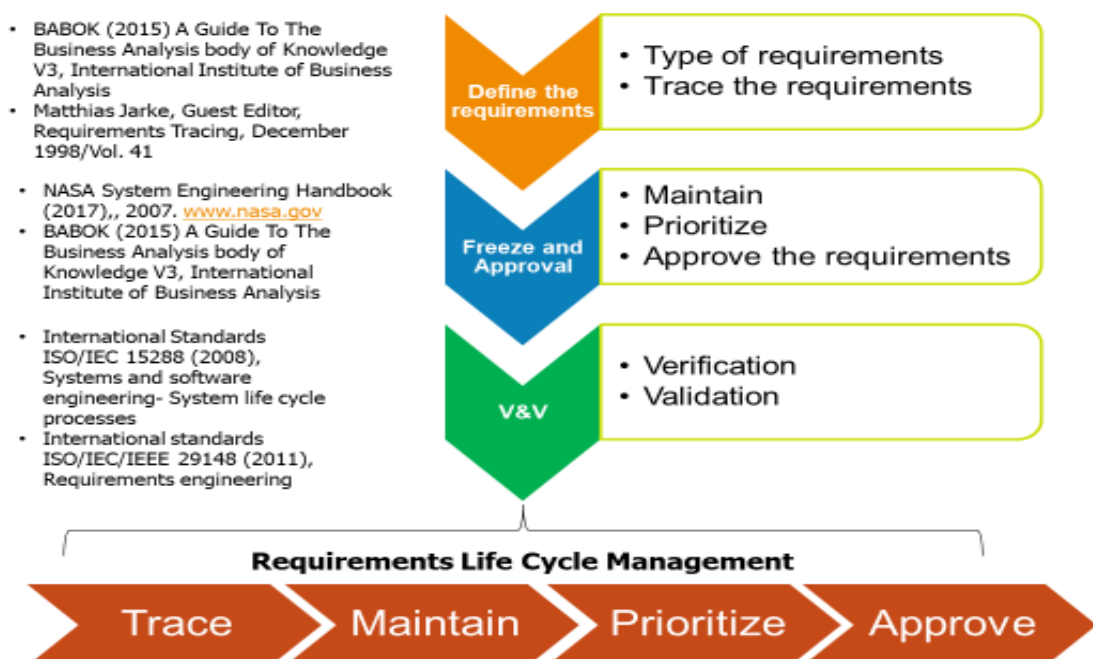

Figure 5. Conceptual framework

The first part of the conceptual framework is defining the requirements. The requirement as a terms does not give enough information for future steps. Categorizing requirements in different groups help the analysist to use a proper technic to manage the requirements. Requirements are categorized in four different types. This dividing the requirements helps to avoid misunderstandings and save time in the next phases. Tracing and maintaining the requirements are two acts from the requirement lifecycle management that regardless of type of requirements can start already from the beginning of the first part. In Figure 6 shows that the input of the this part is all of the documented requirements and at the end requirements categorized in different types based on the project. The main references for the first part are (Babok 2015) and (Aarama 2017).
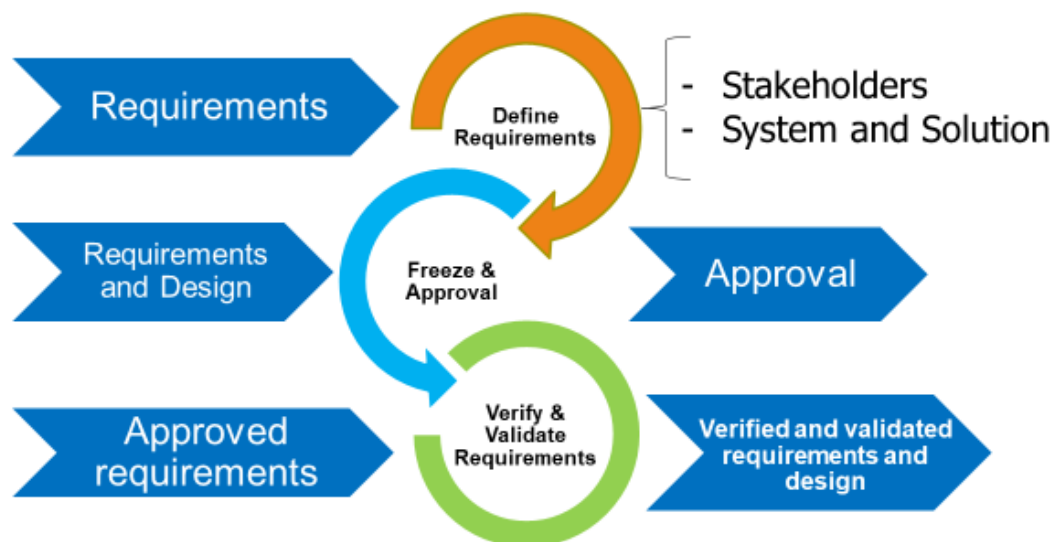

Figure 6. The input and output of each step in conceptual framework

The second part of the conceptual framework is freezing and approving the requirements. In this section, the requirement acceptance criteria which are the terms that requirement can be considered as approved requirements will be discussed. Also importance of continue maintaining the requirement explained. After approving the requirements, it is time for designer to focused more on designing the specification. Generally approval means that the feature or the needs can be fulfilled during the first release. Prioritizing of the requirements can be done during this phase which is mostly dependent on the project manager core team. To make it more visible, Figure 6 shows that the input

for the second part are categorized requirements and design or prototype which at the end approved requirements based on the acceptance criteria are the output. (Babok 2015) and (Nasa 2007) are the main literature references.

The third part is verification and validation of the requirements. Verification and Validation include number of activities to ensure that requirements and design are match to each other and supporting stakeholder needs. These activities are planning, measuring, testing, inspection, reviewing and etc. Figure 6 illustrates that the output of the last part is validated and verified requirements and design. Two literature references for this part are (ISO15288, 2008) and (ISO 29148 2011).

The next section of this thesis presents the initial proposal based on the current state analysis and the conceptual framework.

5   Building Proposal on Requirement Management Process

This chapter describes building the proposal for the requirement Management process based on the information collected from the interviews in current state analysis and also by reviewing the literature. The information from previous chapters analyzed to build the proposal for requirement management process. The first subsection is about overview of current state analyses and the second subsection is describing the final proposal.

5.1   Overview of the Proposal Building Stage

The current state analysis which reported in chapter three, described the weaknesses and strengths of the current process. The first general challenge from the CSA was missing an established process for requirement management process, and engineers try to manage the requirements based on trial and error. The second problem was using multiple documentation for collecting the requirements which makes it difficult to find the right sources. This lead to the next problem that was low level of reusing possibilities. During the interviews it was mentioned many times that the possibility of missing requirement is high and it needs to be considered during developing the new solution (Data 1).

One of the main goal in literature review was to find the right solution from the literatures to solve the weakness and keep the strength powerful and stable. Interviews also gave the idea to find the places that needs to be improved. Indicating different types of requirements and helps to categorized requirement in different ways. Case company documentation also reviewed to get the newest data from the way of working and also company's internal rules and strategy (Data 2).

Building the proposal started based on available way of working and also the conceptual framework to find the way to combine these two to each other or learn from each other. This step started by drawing all of the available information on the table and try to find the connection from each part. More detailed pictures related to building the initial proposal can be found in Appendix II. The second step was to build the requirement lifecycle for the product development project. The case company has a special process for handling the product development project and managing the requirement is one of the important steps of the product development process. In the next subsection, the solution proposal can be followed and each part of it described properly.

5.2   Proposal Draft

The proposed process is based on the Current State Analysis (CSA) and reviewing high quality literature. This proposal was presented to the stakeholders and many experts from different team were involved by attending the workshops, face to face meeting and made their feedback during the development of the proposed process. As mentioned before the requirement management process is a sub-process of the solution creation process, which is shown in figure 7.
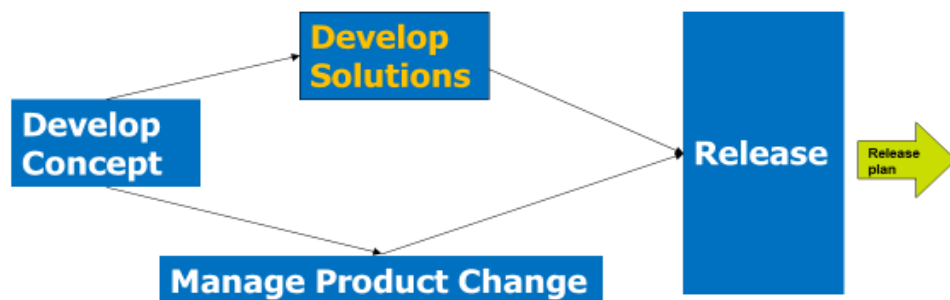

Figure 7. Development structure in case company R&D

As shown in Figure 7, every development is categorized in develop solution, develop concept and product change which the requirement management process is counted in develop solutions.
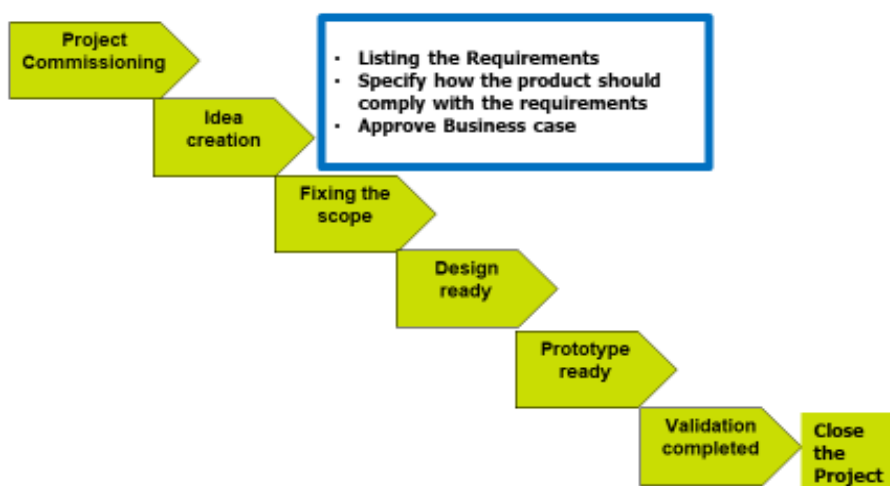

Figure 8, Solution Development for product development process

Developing the solution has its own steps and processes for product development projects in which specifying the requirements is one the main steps of the process. Basically, based on the case company way of working, every product development project should follow this process and the second step of the project, i.e. idea creation, should specify their requirements. Proposed solution in this thesis is an established process for this step in the product development process. That means the final proposal helps the project managers to pass the challenges for this step. It is important to mention that the final proposal is an on-going process during the product development and continues based on the project plan. For example the verification and validation of requirements which are introduced at the end of final process description can happen in the last step of the project when the prototypes are ready.
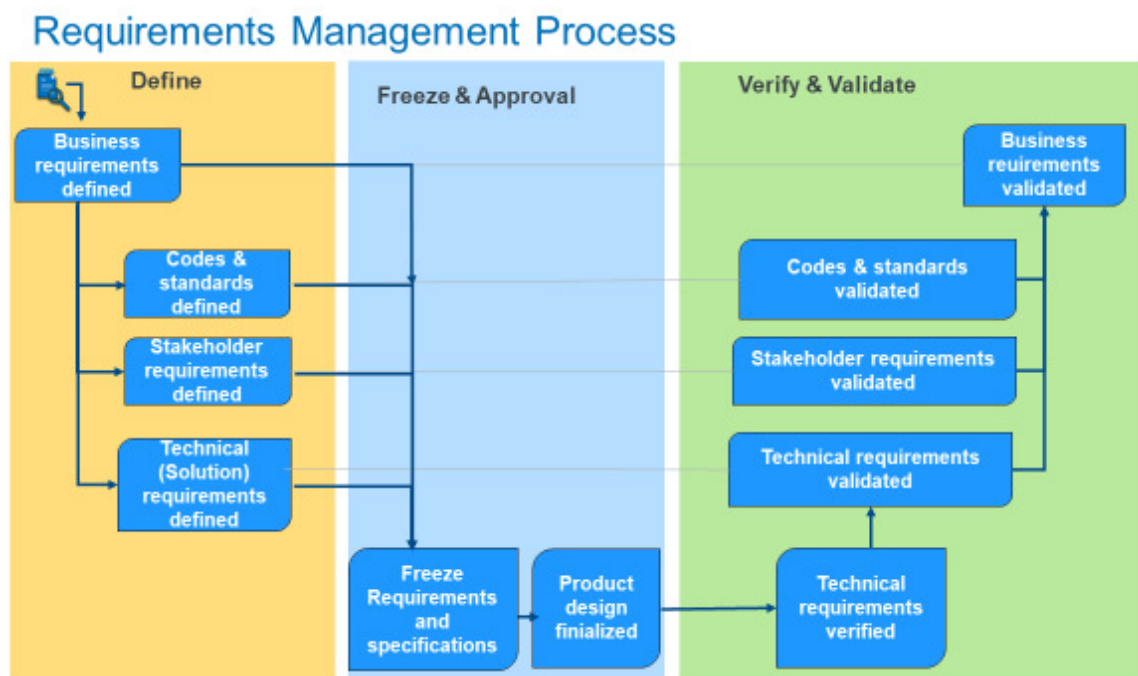

Figure 9. Final Requirement Management process

As illustrated in Figure 9, the three main steps in conceptual framework have been implemented in the final process. The Develop a Requirements process defines how requirements and test management activities are connected to each other and other processes. Develop a requirements process includes actions and responsibilities which are needed to implement requirements management. Define is the first step in the process because it is important for the core team members of the project to understand the business need and target, and to create a common understanding of the scope of work.

5.3   Define the Requirements

Defining the requirement is the very first step in the requirement management process. Basically, defining means finding different types of requirements. In the product development project, four types of requirements are available, namely Business requirements, Codes and standards requirements, Stakeholder requirements, System and Solution requirement (Technical). To increase usability of the requirements it has been suggested to store the requirement in requirement libraries. This means alongside of the requirement type, that every requirement type has its own library. It is also important to make it clear for the organization who is using the library and who is updating the library. Creating the library is the first step but keeping the library up to date and basically managing the library is more important. It will increase the trust among engineers to use it regularly. Figure 10 shows the defining requirements in details. The input of this sub process are new requirements. New drafted requirements are coming from two main sources, one of them is list of drafted requirements from different stakeholders and the other one is reusing directly from libraries which will be explain in next sub sections.
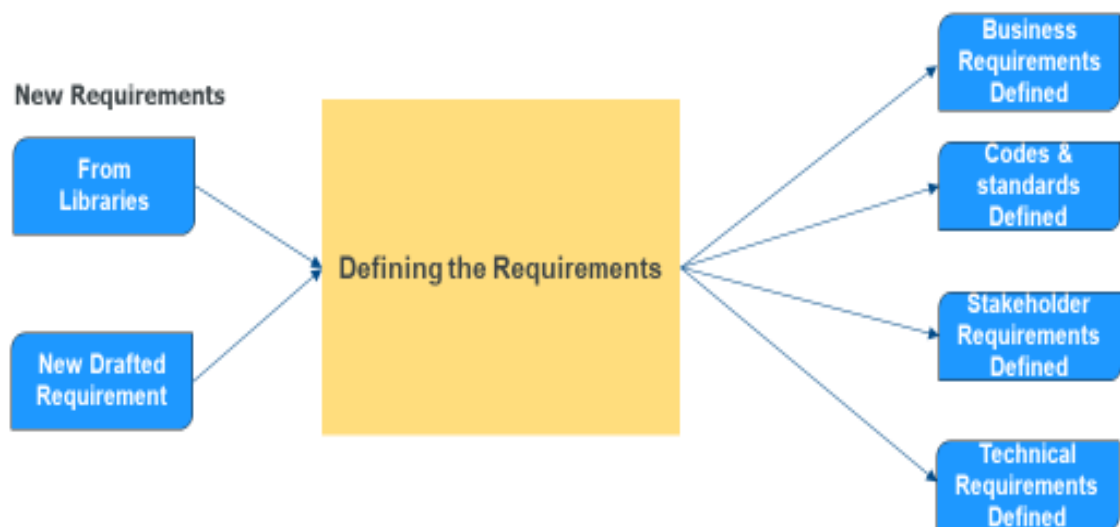

Figure 10, Defining the requirement sub-process

The output of this sub system is categorized requirements which are four main types of requirements. These categorized requirements and their related library which are Business, Code and standards, Stakeholders and Technical requirements will be described in next sections. As mentioned in section 3 from current state analyzes, Microsoft Excel is one the easy use tool to create list of new drafte requirements. Figure 11 shows an example of requirement template for filling new requirements draft. It include requirement

name, description, value reference and a place for owner of requirements. There information from each requirement helps to manage requirement easier and more efficient.

Figure 11, Template for drafting new requirement

5.3.1   Business Requirements

In the product development and solution development projects the first step to start a new project are usually prioritized customer needs, change in codes and standards, offering improvement or new system requirement. These critical requirements managed as business requirements include the business case and information about product scope, market area, volume, supply unit and cost target of the project. The business requirement library described in Table 4 that represents the important information regarding why a requirement management process needs a business requirement library. The main users of this library are product line managers and project managers because they are the experts who create the business cases for project. Business line manager are in close contact with front lines and sale team and their information from the market situation is always new and fresh . This is why product line manager are responsible for updating the business requirements and also has the right to approve the business requirements in the project. Business requirement library needs to be updated when a major change happen to the market or new strategy and vision defined by the company.

Table 4. Definitions for business requirements library

Topic	Description
Why needed?	Business requirements library provides generic requirements definitions to all new products and solutions e.g. platforms and components. Focus is in the business case elements to which projects and programs need to answer or define a value. Typical business requirements definitions are market area, range of use, customer value, offering development, cost target and technology.
Used by	- Core team members of project produst line manager and Project manager or - Product Change Manager
Maintained by	- Product Line Manager(s).
Approved by	- Product Line Manager
When updated? (examples)	- New business requirement defined - Major change in business environment - New generic customer need identified - New strategic theme defined - New vision defined
How updated?	1. Create or update requirement in Requirement management tool 2. Review and comment 3. Approve the requirement 4. Retirement of the requirement
Notes	Business requirements are generic, and they are typically part of the business case. This means that they do not have value in the library. Value for business requirements shall be defined in the project.

5.3.2   Codes & Standards

Codes and standard requirements need to be identified and analyzed at the beginning and starting phase of the development process. This can be done based on the defined business requirements. There are many specific standards which might be applicable when developing a new product. This means that there are always on-going changes in standards in national or international level which need to be followed and managed. Some of the changes might have a bigger impact and require interpretation.

Table 5 shows the information related to the codes and standards library. The purpose of this library is to store the codes and standards requirement to be useable in the future for similar product development projects. Design engineers and other stakeholders are the main users of this library and local codes expert and international code owners are responsible for keeping the library up to date. The library needs to be updated when a new version of codes is released or any modification and correction takes place in the international codes. The first step for design engineers who are working to develop a product is to create a list of applicable codes and standards. This list needs to be created from the codes and standards library. During the next phase of codes study, codes list needs to be categorized based on the project features to gain a clear common understanding for stakeholders and design engineers.

The codes need to be reviewed with code experts and designers together to find the relevant clause from codes that needs to be implemented in the design.

Table 5. Definitions for Codes and Standards library

Topic	Description
Why needed?	Codes and standards library provide list of applicable norms to be used when developing new products and solutions e.g.
Used by	- Core team members - Design engineers - Product Manager
Maintained by	- Codes & Standards team - Code owner - Code manager
Approved by	- Project Manager or nominated person.
When updated? (examples)	- New code requirement defined - New code requirement published (e.g. Directive, legislation) - New requirement defined - New requirement published (e.g. ISO, IEC or EN standard) - New amendment published
How updated?	1. Create or update requirement 2. Review and comment 3. Approve 4. Retire
Notes	There can be several versions of the same standards in use at the same time.

5.3.3 Stakeholder Requirements

As mentioned in the previous chapters (3.1) and (4.1) stakeholders are persons who are using the final product or solution and getting benefit from it. The stakeholders are acting as a bridge between business requirements and other requirements. It is highly recommend that library requirements are utilized and reused as much as possible to create Stakeholder Requirements Specification. The visibility and traceability can be increased a great deal by reusing the requirements. Stakeholder requirements library describes the needs that a given stakeholder has and how that stakeholder will interact and impact with a solution. Some of the stakeholder's activities are connected to each other and a cross-functional cooperation is needed to have a good enough stakeholder library. Table 6 indicates the stakeholders library related topics that need to be considered.

Table 6. Definitions for the stakeholder requirements library

Topic	Description
Why needed?	Stakeholder requirements describe the needs of various parties that have an interest in the solution being developed.
Used by	- Core team members - Project manager - Product designer
Maintained by	- Senior experts
Approved by	- Project manager or nominated stakeholder or responsible person.
When updated?	- Change in applicable codes & standards - Change in existing methodology - New production technology - New or updated strategic theme - New or updated product strategy
How updated?	1. Create or update requirement 2. Review and comment 3. Approve 4. Retire

5.3.4 System and Solution Requirements (Technical Requirements)

Technical requirements of a system and solution are the technical issues that are needed to fulfill the business, code and stakeholder requirements. System and solution requirements are the core of solution development. Technical requirements get direct influences from high level business requirements, codes and standards and also stakeholders which are listed according to the priority point of view. Based on the hierarchy when a single business requirement is drafted as new requirement, the following action is to find the standards that are related to this requirement and in same line find the requirement by stakeholders that wanted a similar request or supporting request. The next is covering the technical challenge that faced the project to fulfill all of the requirements from high level business.

It is important to note that maintaining relationship between technical requirements and other higher level requirements helps to establish traceability and to ensure requirements coverage. Specifications are the supporting detailed information to support the requirements and make them clearer and specify the technical details. The system requirements specification will be consistent, accurate and traceable.

The detailed information on how to manage the technical requirements is listed in Table 7. Mostly engineers and designers are the users of the technical requirement library and they are responsible for keeping it updated for future use. The project manager is responsible for approval of the technical requirement in cooperation with stakeholder design engineers.

Table 7. Definitions for technical requirements library

Topic	Description
Why needed?	Technical requirements are a type of item that concerns the technical details of the solution.
Used by	- Project core team - Design Engineers - Project Manager
Maintained by	- Design Engineers
Approved by	- Project Manager
When updated?	- New or updated code or standard - Change in stakeholder requirement - Improved description - New technology implemented - New technical requirement
How updated?	1. Create or update requirement 2. Review and comment 3. Approve 4. Retire
Notes	Technical requirement has directly on design and can be reused for new design. Generic information, quality, interfaces and other technical requirements of the product.

5.4   Reviewing and Approving Requirements

This step is one of the important steps in the requirement lifecycle. The reviewing and approval step is the same as freezing and approval step which was already presented in literature review in section four. Reviewing is one of the best technics that project manager can take into account to find any maintaining in the requirements. Periodizing can also be done in the same line during reviewing the requirements. The project manager invites all of the core team member to the review meeting and discusses the decision to approve or reject the requirements. Reviewing is also a typical way in other steps including requirement defining, approval and also the next step which is verification and validation. The approved requirement can be moved to an applicable requirement list and also stored in own requirement library, but rejected requirements maybe based on requirement prioritization moved to the requirement draft list or deleted permanently from the requirements list.

Table 8 describes the requirement lifecycle for the proposal. The first status is draft which is in idea generation phase of the requirements. In this step, all of the requirements are listed by different parties. The status of the requirement can be changed between draft, ready and review many times before the review meeting approval.

Table 8, Requirement lifecycle

Status	Description
Draft	First capture of the requirement
Ready	Completed definition of the requirement
Review	Status for requirements under review
Approved	Approved requirements
Rejected	Rejected requirements

Figure 12 shows the input of reviewing requirements which are the defined requirements from last step. After reviewing the requirements, there are two main final decision Approve or reject. Approved means the requirement has been reviewed and is in scope of the project. An approved requirement will be used for current design and also needs to be stored in own library for future use. Rejected requirements after approval can be stored as a draft requirement for the future review use or deleted from the list.
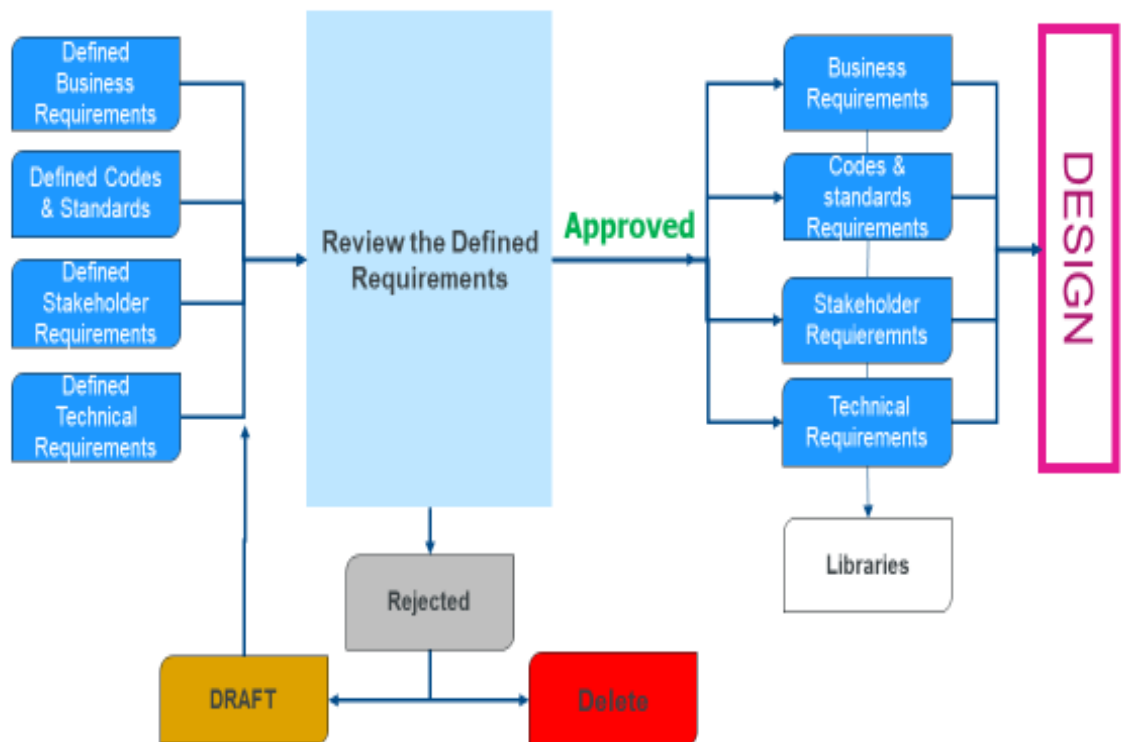
Figure 12, Reviewing requirement subprocess

5.5 Verification and Validation of the Requirements

Verification of the requirements and design and then validate them is an important part of the whole process. These are used to ensure compliance to the design, requirements, specifications and align to the business cases and stakeholder requirements. Table 9 shows the activities that need to be planned for the verification and validation process.

The test cases need to be planned before hand and have direct connection to the requirements which means it will be possible to trace the test and requirements and find the relation between them.

Table 9. Planning of verification and validation

Planning activity	Content	Notes
Design verification Focus in design	Design verification plan - Technical calculation - Design FMEA | Risk analysis - Other verifications	Test plan (if required) Test cases
Integration testing	Integration testing plan - Software integration testing	Test plan (if required) Test cases
Security testing Focus in security	Security testing plan - Security testing	Test plan Test cases
Functional testing Focus on functionality	System and release testing plan - System testing - Release testing	Test plan Test cases
System verification Focus in system (black box)	System verification plan - Performance tests - Usability & accessibility tests	Test plan Test cases
Manufacturing verification and validation Focus in Manufacturability	Manufacturing verification plan - Production prototype - Supply unit readiness for pilots - Validation through pilots	Test plan Test cases
Installation verification and validation Focus in install ability	Installation testing plan - Prototype installation test - Installation manual - Validation through pilots	Test plan Test cases
Maintenance verification and validation Focus in Maintainability	Maintenance testing plan - Prototype maintenance test - Maintenance manual - Validation through pilots	Test plan Test cases
Product certification Focus in compliance	Product certification plan - Conformity assessment - Certification testing	Test plan Test cases

5.5.1 Test Plan and Test Cases

Test activities need to ne planned with the information about the scope, objectives and time schedule of the test along with the information about the testing facilities, testing environment and resources. It is mandatory to include all of the major activities of the project in the test plan.

Traceability is the activity that continues even after approval to the verification and validation. Traceability between requirements and test cases is important to make sure that product performance in test cases are in line with the requirements that are coming from different stakeholder needs and business purposes. Test cases can used from the library as well to find the latest approved test cases and verification processes. Some of the tests are just to find the weaknesses or the improvement needs in the prototype but some of the tests are fail/approve which are basically standardized tests. These tests need to have acceptance or approval criteria which needs to be prepared during the test plan.

Some of the tests include many sub-tests for a single component or basically called individual tests. These tests can be grouped separately to keep the test plan in track regarding the timetable and schedule. For instance environment condition tests are required group tests to consider different type of temperature conditions like high or low temperature or extreme conditions and humidity to measure the performance of prototype in those conditions.

5.5.2 Reporting and Analyzing the Test Results

Every test case and also the tests for unit verification need to be completed based on the created plan by senior design engineer or test manager. There are verification and validation phases that need to be covered in final test reporting and analyzing documents.

Table 10. Verification and validation phases in Requirements process

Verification phase	Validation phase
Unit verification	Stakeholder requirement
Design verification	Code compliance
System verification	Business requirements

Table 10 shows the different phases in verification and validation of the requirements. Unit, design and system need to be verified by using the test result and then every unit needs to be validated by stakeholders based on their requirements. Design can be validate by using code compliance to ensure that all of the codes are covered and system level validation is needed by business requirements. The final report which includes the result for each test case needs to be reported with a clear description of the test and result. An acceptance criteria is also needed to regulate if the test result is accepted or not.

In case the test result cannot pass the acceptance criteria, the senior design engineer needs to analyze the result and report it as defect. The purpose of this reporting is to analyze and clarify the defect and do necessary correction. At the end, the core team member needs to decide regarding the approval of the defect report and plan to handle the correction action in reasonable time.

6   Validation of the Proposal

This chapter describes the feedback to the initial proposal that was received from stake-holders and other management team. At the end, the final proposal is presented based on the feedback.

6.1   Overview of the Data Collection and Feedback

The implementation process was based on the pilot projects and also presenting the initial proposal to the audience from a different part of R&D. This implementation and getting feedback is an ongoing procedure which needs more time that will help people to get used to the process in their daily work. The new tools also have been ordered to help the requirement management which has its own challenge to organize a training session for responsible persons in an efficient way and timetable.

The most effective feedback was collected during the feedback session organized by R&D department. During the event, the participants divided in different group from different backgrounds and responsibilities. Every project had its own stand and the group made a round and stopped at each stand. The initial proposal was presented in detail to every group even though some of the pilot users were familiar with the process. The participants wrote their feedback on colored paper notes and attached them to the feedback board. Figure 13 illustrates the feedback board.

Figure13. Feedback board from the workshop

Table11. Summary of requirement feedback workshop

Requirements
Business Requirements are essential part of the requirement management and need to be considered
"Who" is defining and prioritizing the requirements?
How to consider customer needs and customer co-creation?
Link to Portfolio Management
Deployments
Clear decision from management of the usage of the process needed!
What is the requirements content coverage in the requirements libraries?
Who is owning the requirements? **Suggestion:** Product Manager to own the product related requirements
What is requirements, How to recognize a requirement? **Suggestion:** Training how to write requirements needed?
Quality of the requirements? **Suggestion** How this is ensured?
Process
This requirement management process is for product development process but What about Change Request Process?
What are the freezing points of requirements?
Unclear requirement hierarchy
Where are interface requirements?
Overlap with other tools
Where specifications are managed

Table 11 shows a list of the more frequent and common feedback that was written by the participants during the requirement feedback workshop. The feedback was categorized in three groups. The first category is requirement related feedback. That means feedback related to the requirements themselves and not the proposed process. The second group of feedback is deployment related feedback which needs to be considered. And the last group is feedback related to the process which is closer to the aim of the workshop.

6.2   Review Feedback for Final Proposal

By analyzing the feedback, it is clear that most of the feedback from Table 11 is already implemented in the process and there is no critical feedback from the different steps in the process or any request to change in the process. This shows that many people who participated in the feedback event are not fully familiar with the process yet. For example business requirement, requirement prioritization and requirements owner are already implemented and explained in the process. The action that can be planned is that the process description for the case company internal documentation needs to be clear enough to be understandable for everyone.

Some of the feedback like considering changing request or portfolio managements are not in the scope of the objective for the thesis. The freezing usually happened after requirement approval, but it needs to be considered that requirement can be changed even in the freezing phase of the requirement. About owning the requirements, a suggestion was made that the product manager needs to be requirements owner. As the aim of this thesis is to find a requirement management process for product development project, the project manager is the default owner of the related requirements. Also the core team of project can decide about the ownership rights.

Generally as there is not any negative feedback and request to change the process, there is no need to change the process and the initial proposal for the process is the final process. It is always possible to give feedback regarding the process for the internal stakeholder and external. However, depending on the product development projects the roles and responsibilities may change but the core concept of the process can be used for a variety of projects. The next chapter describes the final conclusions on the process and the requirement management.

7   Conclusions

This section presents a brief summary of the thesis and discusses the findings during the work process. It also includes suggestions for the future related topics, thesis evaluation and also the final words to close the thesis.

7.1   Executive Summary

This study started based on the business challenge and common understanding in the case company that an established requirement management process was missing and it was a need. The objective of the study was to create a process to manage the requirement in the product development project. The research design was selected based on the case study model. This means the first step after initiating the context for the thesis was to carry out a current state analysis to understand the current situation and current way of working in case company. The key stakeholders and responsible persons including design engineers were interviewed and the outcome was documented. The case company internal documents were collected and studied to determine the current way of working. The result of the current state analysis indicated the weaknesses which were mostly related to the lack of a systematic way of working and possibility to reuse the requirements. During the next phase of the study, literature from high quality academic and industrial research was reviewed based on three main categories, namely defining the requirements, requirement life cycle management, and at the end verification and validation of requirements.

By observing the findings of the current state analysis and the literature review results, a requirement management process was proposed. The requirements were categorized in four main group of business requirements including high priority requirements, code and standard requirements, stakeholder requirements and solution requirements which are basically technical requirements. Requirement tracing was introduced as one of the main parts of requirement life cycle management. Tracing indicates any relation between two or more requirement categories. This activity needs to be continued till the end of the process. After tracing and prioritizing the requirements, the approval process begins in order to review and decide whether to approve or reject the drafted requirements based on the acceptance criteria. The acceptance criteria helps the core team of the project to understand when and how a requirement can be accepted. Requirement libraries are a vital part of the process which enable reusing the requirements for future projects. Approved requirements need to be stored in their own categorized requirement

library. Requirement lifecycle management verification and validation are the next steps to ensure that the requirements and designs cover each other. Verification and Validation requires specific tests which need to be planned beforehand by an appointed test engineer or senior design engineer.

The proposed process covers most of the weaknesses of the current way of working in the case company. For example, requirements are traceable till the last steps of requirement management, and reusing the requirements have been implemented by creating libraries. The workflow during the process was and roles and responsibilities were clarified. This will increase the efficiency of the process.

7.2 Thesis Evaluation

The evaluation of the work can be started by describing the starting situation. When people work in the same way for a long time and even if they know that it is not the most efficient way, making a change is a challenge. There was a common understanding that an established process is a needed during the current state analysis and even before that. But not everyone wanted an actual change to the way of working.

Much literature was reviewed from academic theses, journal papers and books. At the beginning, the researcher spent most of the time on pure academic researches rather than case study based literature. This was not a smart way to focus just on specific literature. The literature review continued but a new challenge was that most of the cases were software related business whereas the case company for this thesis is a manufacturing company and the thesis was done for the R&D department. At the end, all of the mentioned challenges were part of the learning process for the researcher and other people who participated in the study during the interviews, implementation and feedback workshop. The general evaluation of the thesis is that managers, engineers and stakeholders are satisfied with the output of the study.

Also finding detailed information from the case company business was not easy. During the verification and validation maybe it would have been better to make sure that people who participated in validating the proposal had been totally familiar with the proposed process.

7.3   Validity and Reliability

Validity of the thesis is to find or estimate whether the final results of thesis dependable to the objective of the study. The people who were involved in the study were familiar with the process and also people who were working in the pilot project. The new incomers to the organization or new product development project need to know clearly every step of the process. Creating a clear and easily understand able guideline which describe the roles and responsibilities is the most necessary action for the next phase of implementation. Libraries are playing a vital role in increasing the process reliability and also decreasing the work load. A person is needed to keep libraries updated and make sure that the old and unnecessary information is not stored in the library. It is recommended that Project Mangers keep their eyes on requirements during the review session to avoid low quality requirements with misspelling and grammatical mistakes.

To make sure about the reliability of the study, the internal case company documents and also other process which are connected to the product development process reviewed. This reliability study was to get a proper understanding of the case company R&D department strategy. Reliability study help to make sure that the final proposed process is not overlapping with other sub-process and will help to accelerate the product development projects. It must be underlined that this process is implemented just for the case company R&D project and other organizations and industries need to modify it and find their own requirement management process.

7.4   Closing Words

This study is one of the most important topics for the R&D department of the case company. The majority of benefits is for project management team. Requirement types and also roles and responsibilities for the requirement management is clear and it will save time, reduce workload and ultimately the cost of the project. Like with every other new step, people need time to get more familiar with the steps in the process and match it with their daily life in the product development project. This study can be a good reference for a similar case study in the manufacturing industry.

The study managed to define an established requirement management process for a product development project in the case company which can benefit from the process in many ways.

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Interview questions

Interview questions for the first data collection:

- Please describe your role in the project

- Can you explain the structure of your team

- Are you the team leader or team member?

- Can you explain what is a requirement in your word.

- Where (based on what) the requirements generated in your team?

- Are you aware of different type of requirements?

- Haw you ever collect requirements for a project?

- How you collect the requirements?

- How you use the collected requirements in your design?

- What is common tools for collecting the requirements?

- What happen after collecting the requirements?

- What is the challenge in using the requirements in design?

- What is the advantage of current way of working?

- Do you have any suggestion?