Eero Putkinen

Improving System Quality by Transition from Individual Part Ownership to Shared System Ownership

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My Master's year was exiting and intensive. I met lots of new people and made great new friends.

I would like to thank all my colleagues, instructors and classmates who were encouraging and involved in making this thesis for their support and interest.

I would also like to thank my managers in the case company for the challenging topic.

Finally, I would especially thank my instructors, Dr. Satu Teerikangas for her contagious enthusiasm, my process instructors Zinaida Grabovskaia and Sonja Holappa and all the wonderful lecturers from whom I learned so much.

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Instructors	Satu Teerikangas, DSc (Eng), MSc(Eng), Head of Industrial Management Master's program Sonja Holappa MA , Senior Lecturer

This study focused on improving the system level quality of products in the case company by transition from individual part ownership to the shared system ownership. To achieve this goal, this Master's thesis investigated relevant factors affecting the system level quality of products that the case company designs and produces.

The study was conducted in five steps where first business problem was defined, then the current state analysed and the existing challenges identified related to the system level quality of products. Then the existing knowledge was studied focused on finding best practice to address the identified challenges. Then a proposal was built together with company employees and finally presented for feedback. The study used qualitative research methods and interviewed stakeholders and employees from different positions and teams.

A proposal was built that suggested a new flexible ownership, a more collaborative environment and support tools for the System Owners to use and manage quality issues.

A proposal was built with steps suggesting how the case company can change from the Individual product ownership to a Shared system ownership work model. The transformation will create the basis for an improved system quality design as well a more systematic way for recording and solving quality issues on a system level.

Keywords	System Thinking, System ownership, Product ownership, Collaboration, System level quality of products, FRACAS, Lessons learned

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Acronyms

CA,	Corrective Action
Callout,	A maintenance callout to repair the system
CDE,	Chief Design Engineer
CF,	Conceptual Framework
CR,	Change Request, a design change in part or product
CSA,	Current State Analysis
CtQ,	Critical to Quality
FMEA,	Failure Mode and Effect Analysis
FRACAS,	Failure Reporting and Analysis Corrective Action System
HW,	Hardware
Part Owner,	Owner of the part related to a system
Product Owner,	Owner of a System or module consisting of parts
SW,	Software

1 Introduction

Recently, product change management for a product owner can be challenging in larger global companies. Electronic control systems are especially challenging. There are many factors involved such as software and different electronic modules and parts which the system consist of. Surviving in the competitive market requires for the continuous improvement in the system to be ever faster and significant in quality, reliability and features. It needs to respond to competition and customer demands.

Change requests come from many different sources: Complaints from the customer, quality improvements, additional functions, etc. At the same time, certain quality checks need to be done to validate change before implementing to production.

All these need to be synchronized with the bigger picture. The product can be divided into many different parts each having its own owner. Software and other components related to the whole system can be dependent on the change the part owner is holding in the change queue. High priority items will usually cut in front of minor items.

This thesis studies how product change management is practiced from part or product owner's perspective and system perspective in a matrix organization. The challenges in implementing quality improvements and the different factors affecting change in the system are analyzed. The goal is to find a work model to improve quality in system level and bring system level focus in quality improvements.

1.1 Case Company Background

The case company studied is a globally operating industrial company. The main business area of the company are industrial machines and systems and their services, maintenance and installation. The study focuses on a research and development unit of a global technology company. The case company has R&D units located in Europe, China, US and India. In these research and development units, equipment designs are managed, developed and created. Electronic systems at the case company are complex and built from different parts. These systems can consist of various parts such as mechanics, motors, inverters and electronics. The case company also offers services

and maintenance for their products. The organization structure is a typical matrix model where different categories are responsible for the parts for technology systems.

1.2 Business Challenge

The primary business challenge for the case company R&D unit is to design electronic systems that meet the requirements for volume production, secure and reliable assembly, -installation and -maintenance. The current trend in the field is that the complexity of the systems is increasing. Therefore, dependency of the parts fitting and working together is ever more important for quality. As a result, the handling of issues affecting the system's quality has become the main challenge for a product owner.

1.3 Objective and Scope

To tackle the business challenge of the case company the objective of the thesis is:

> *to identify factors affecting system quality and create a work model in product change management and continuous improvement process to achieve better electronics system quality.*

The model can be used by the product part owner, product owner and relevant stakeholders for faster and more efficient implementation of change requests related to quality issues. The outcome of using the model should lead to improved system quality.

The thesis is structured as follows. Section 1 contains the introduction and describes the business challenge and the focus areas for the study. In section 2, the research design model and research approach is discussed. The first section also describes the business challenge and the focus areas. In section 3, the current state analysis is done to map the strengths and weaknesses of the current practices in the product change management process. Interviews are conducted with different stakeholders in the process such as product part owners and platform managers. Viewpoints are studied and analysed from various perspectives in change process for the system product.

The current state analysis suggests a focus area where improvement to the process is needed. In section 4 the existing knowledge is explored to pinpoint significant factors

and identified challenges affecting the process. In section 5, a work model is created to improve the challenges in the current state analysis. In section 6, feedback from the proposed work model is gathered and analyzed. Model is then fine-tuned according to the feedback suggestions. In the last section, a summary and evaluation of the thesis is presented and discussed.

2 Method and Material

In this section, the research method is presented and discussed. The research approach selection and research design is visualized to display how the study is conducted. The section also analyses the data sources and how the research is validated.

2.1 Research Approach and Method

This study is a case study. A case study investigates a single or multiple cases to answer a specific research question. Cases can be individual a group or organizations and institutions. Evidence can be explored from a wide variety of sources (Gillham 2010).

This study will use qualitative methods as the research approach. The qualitative methods focus on what interviewees tell as the evidence and data to understand and make sense of what is currently happening in the organization or group studied. A qualitative method is considered as a strong way of studying human behaviour (Gillham 2010).

Qualitative research approach was selected because the themes of the study are related to collaboration and human behaviour in the case company. To get a holistic view what the current state is from different perspectives informants were selected from various teams.

The case study approach was selected to investigate a particular unit and how they function. The selected unit is the Research and Design unit of the Case Company. The process of the research is described in section 2.2.

2.2 Research Design

A plan how the research should be conducted was created. The research design is visualized in Figure 1 to clarify the process flow and steps of this study.

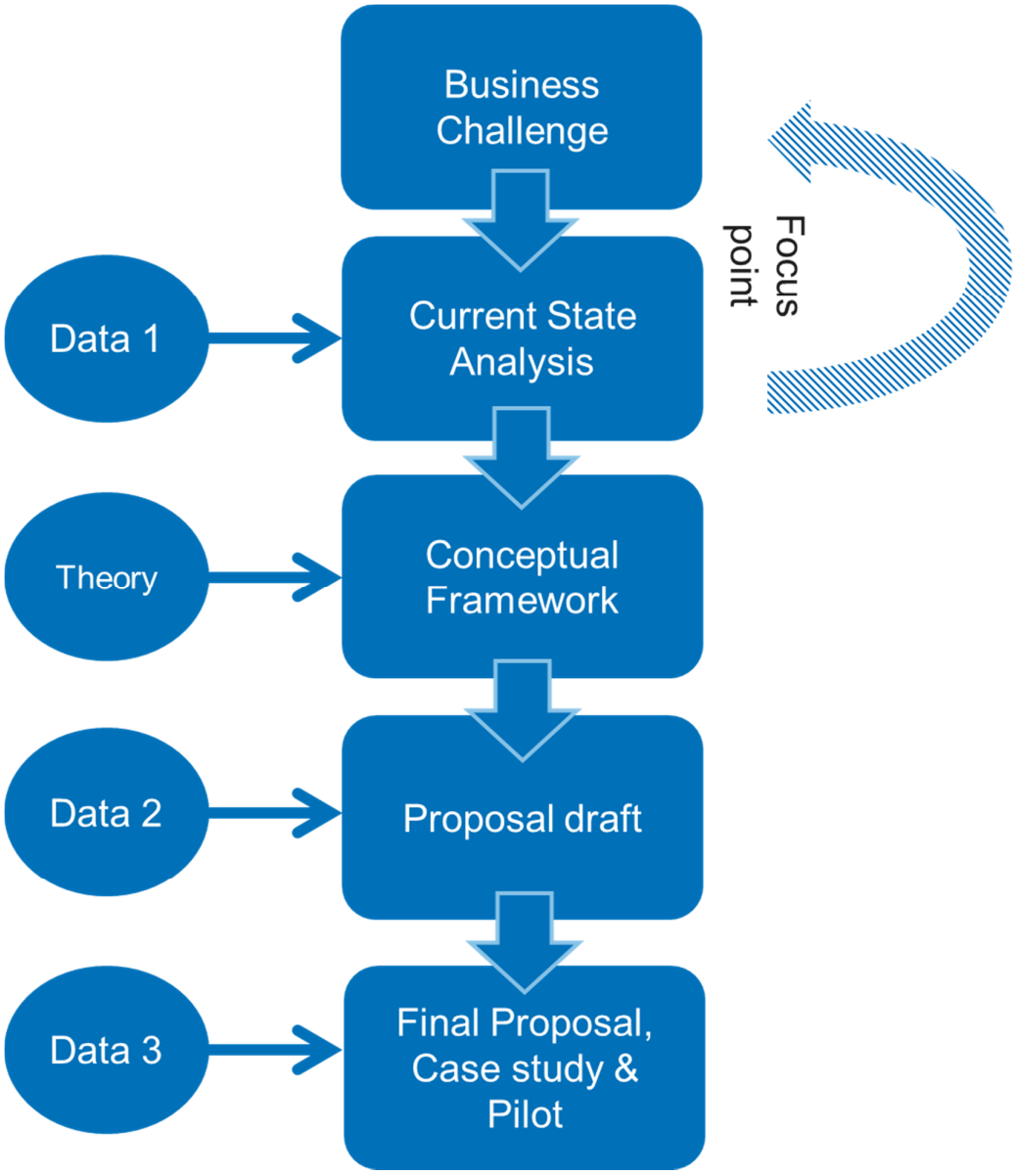

Figure 1. Research design of this study.

From the Figure 1, we see the progress steps of the study. In the first step, the Business Challenge was suggested by Supply Sourcing and Head Quality departments. Then a rough plan how to proceed in the study was conducted. Topics and questions for upcoming interviews for Data 1 were drafted and ideas of what existing knowledge and theory are needed to take into account in the conceptual framework.

In the second step, some interviews for Data 1 were conducted to get a good understanding of the current state. From the current state analysis some key themes were selected to be tackled in the conceptual framework. After the current state analysis, the business challenge and focus were reviewed, and the focus of the study started to differentiate. In the third part the theory and existing knowledge was studied and selected based on these themes to create a conceptual framework.

In the fourth part, the interviews for Data 2 were conducted in one to one and small group co-creation sessions. This data was then collected to create a proposal for the case company. Details on how the Data for the study was gathered are described in section 2.3.

Finally, the proposal was presented and feedback of the process and the proposal was collected and analysed. This was then used to fine tune and finalize the proposal.

2.3 Data Collection

Data is collected in three rounds: first Interviews for the current state analysis, secondly for creating a proposal and finally for feedback from the piloted process.

In the first round, the data is collected by interviewing stakeholders in different roles and responsibilities. Eight interviews were conducted in total.

The main informants are Chief Design Engineers who are product part owners from the system point of view. The part owners and CDEs are responsible for the performance, quality and the design of the part they own. Other relevant informants are Product Owners, Product Managers and Platform Managers. They have a product or a platform that they are responsible for. The platforms are usually is built using different parts from different owners.

These informants are selected for two main reasons: First reason was the experience in product ownership and product change management in chief design engineer and product manager levels. The second key reason was that they are from different teams even though the system might be dependent on various parts from all the teams.

SW testing Managers and Visual Design Managers were selected to be interviewed to have more holistic and diverse viewpoints of various stakeholders and for verification purposes. In addition, a process specialist from Project process development has been chosen.

A list of interviews and topics are summarised in Table 1.

Table 1. Interview conducted for Data 1 collection.

Data	Interview	Duration	Topics
Data 1	Component Manager	55 min	Quality issues and collaboration
Data 1	Platform Manager	55 min	Collaboration, Silos, Quality
Data 1	Design Manager	50 min	Quality improvements, Silos
Data 1	Chief Design Engineer	50 min	Collaboration, Projects, Change process
Data 1	Project Manager	50 min	Projects, Platforms, Change process
Data 1	Process Specialist	40 min	Collaboration in Projects, agile methodology
Data 1	Quality Manager	50 min	Collaboration, Silos
Data 1	SW Reliability Manager	1h 11 min	Silos, system reliability

As seen from Table 1, the topics discussed included elements of quality issues, collaboration, change process, silo effect and transparency and visibility of quality issues. A Full list of the items and topics discussed in the interviews can be found in Appendix 1.

The interviews were conducted to get a holistic view of the change process and how a quality problem and actions are processed and eventually solved. The information from interviews is the basis in creating a current state analysis and pinpointing the strengths and weaknesses of the current process. Also, a focus point in the study was to be selected after current state analysis since the initial topic and business challenge was wide.

In the second round, three one to one sessions and two group sessions were conducted. Some of the co-creation sessions were held together with some of the managers responsible for defining the original business challenge and focus. Also some Quality

managers were selected because of the topic's relation to quality. Current state analysis was reviewed and strengths and weaknesses were discussed. Some Key challenges topics recorded to be tackled in the proposal. A list of the proposal co-creation sessions can be found in Table 2.

Table 2. One to one and Group co-creation session for Data 2 collection.

Data	Interview	Duration	Topics
Data 2	Category Manager	30 min	FRACAS, Silos, Collaboration
Data 2	Quality Manager	30 min	FRACAS, Engagement in Owners, Silos
Data 2	Quality Manager	15 min	FRACAS, Structure of Quality issues
Data 2	Three person group with Quality Managers	30 min	FRACAS, Change process, Collaboration, Process harmonization

As seen from Table 2, the topics that came up in the discussions, were then recorded to be used in building the proposal.

In the third round, the feedback was collected from the presentation of the draft proposal. The process was discussed and the challenges that had come up from review were discussed and how they could be taken account in the final proposal. A list of the feedback can found in Table 3.

Table 3. Feedback interviews for Data 3 collection

Data	Interview	Duration	Topics
Data 3	Quality Manager	70 min	Product development, lessons learnt, project ownership, product ownership
Data 3	Quality Engineer	40min	Product structure, Quality organisation, Teams' seating arrangements
Data 3	Category Manager	40min	Organisation structure, Teams' seating arrangements

All of the one-to-one interviews in Table 1-3 were conducted anonymously. Many issues off-topic were also discussed and sometimes there were challenges getting back on track with the preselected topics. The interviews seemed open and sincere. New ideas came up during the interviews, and the informants were interested in the topic of the study. Some meetings were calm and a few were intense when certain items were discussed.

Data collected from the three different interview rounds were then analysed in three different sections. The first part was the analysis of Data 1 is summarised Table 1. Field notes of these interviews were used to get a good view of the current state of the system quality. Data was analysed to create the current state analysis and find the main topics to take forward where to focus in the existing knowledge.

In the second part, the current state analysis and conceptual framework were presented to get feedback for developing the proposal. This was recorded as Data 2. This data was then used to co-create a proposal draft.

Finally, the draft proposal was presented to the relevant stakeholders for feedback, and final comments were collected for piloting the proposal.

2.4 Validity and Reliability Plan

Informants used in this study are selected from different teams and positions all somehow affected by the business challenge of the study. Informants in Data1 were from two groups: Firstly Product and part owners and secondly other stakeholders from Design, Quality and Reliability. Two clear different processes arise during the interview and these processes were benchmarked. This is why Project design process engineer was selected to be interviewed.

Based on the interviews a current state analysis will be created to visualize different factors in the process. This will be combined with a conceptual frame work to co-create a proposal which will then be piloted and validated. Feedback from the pilot case study will be recorded and analyzed after piloting is finished.

The analysis and finding will be validated with a Case study related to a product part that I, the author own. I am in a role of a product part owner and will utilize the outcome

of this study in my daily work. My preconceptions about the study are related to challenges in collaboration, system design, system thinking and silos between teams and units. Whit theses preconceptions identified, the interviews and the study is aimed to be from an objective viewpoint.

3 Current State Analysis

This section discusses the Current state analysis of the study. The aim is the make sense of what is the current reality in continuous improvement, what are the best practices and weaknesses and which are the main important points.

3.1 Data 1 Collection for Current State Analysis

Interviews were conducted to get an understanding of the current state in the case company. Interviews were conducted one-to-one and confidentially. Questions and topics for the interviews were pre-determined and are shown in Appendix 1. The interviews were recorded and summarized in field notes as the example seen in Appendix 2. This data was then was then analyzed to find the strengths and weaknesses in the current process.

The informants were selected for their experience in product change management in different teams. Also design and reliability managers were interviewed as well as process engineers.

3.2 Overview of Product Development and Product Life Cycle

In this section the product life cycle developed in the R&D unit of the case company is studied. The process relates to electronic systems that consists of different electronic and electomechanical parts and can be applied to the individual parts as well.

A product's lifecycle in an electronic system can be divided roughly into two parts. First, the project phase where the product is created and then developed to a product. The project phase prepares the product to be sold to the customer.

Figure 2 displays the Product Life Cycle model is displayed

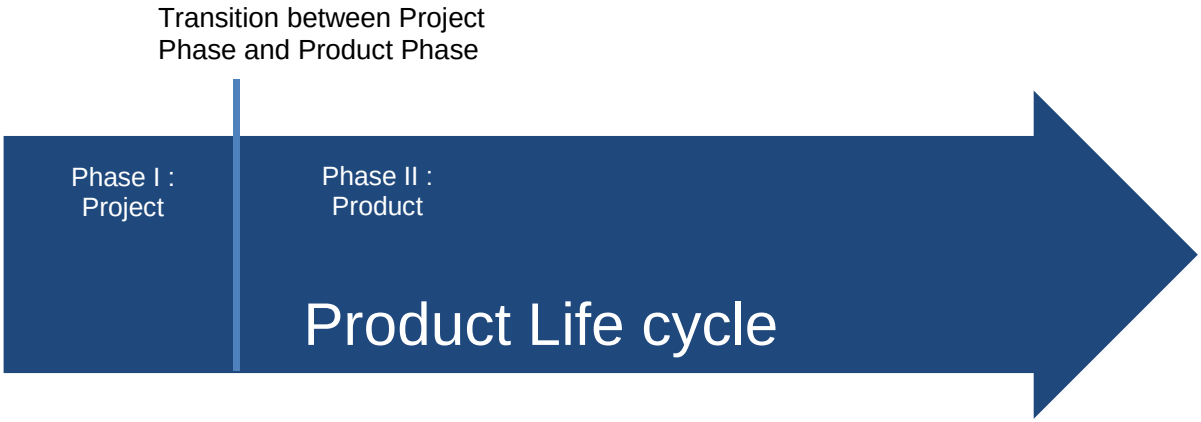

Figure 2. Product Life Cycle in an electronic system

Depending on how the project is executed the product will me more or less ready when sold to the customer. This is the transition from the Project phase to the Product phase. At this phase, all the lessons learned and previous issues should be communicated clearly to the new owner.

Processes between the two phases are very different and different tools are also used.

3.2.1 Phase I: Project Phase

To finish a project successfully, the right specialists need to be involved. These are different part owners, software developers and the project manager leads them.

The working style in Projects is seen as faster compared to product changes and also prioritized more clearly. Usually, clear ownerships of components and product is defined. Secondly, the tools are available for Product Change Management, Corrective Actions and Agile method of working is promoted. Scrum meetings are held when needed to get changes and quality issues forward. A FRACAS tool is used by the project manager in project phase but not utilized in continuous improvement.

From the interviews, it became apparent that collaboration between individuals was usually working, and problems can be solved if the right specialists are involved and personal relations are ok. In Project phase the specialists are usually assigned and selected.

At the end of the project, the Project Manager hands over the project to the owning category. This could mean that that the part owners and project manager start a new project and previous ownerships are no longer clear unless handover is done properly to the new owner. Figure 3 visualizes the collaboration between Project team members.

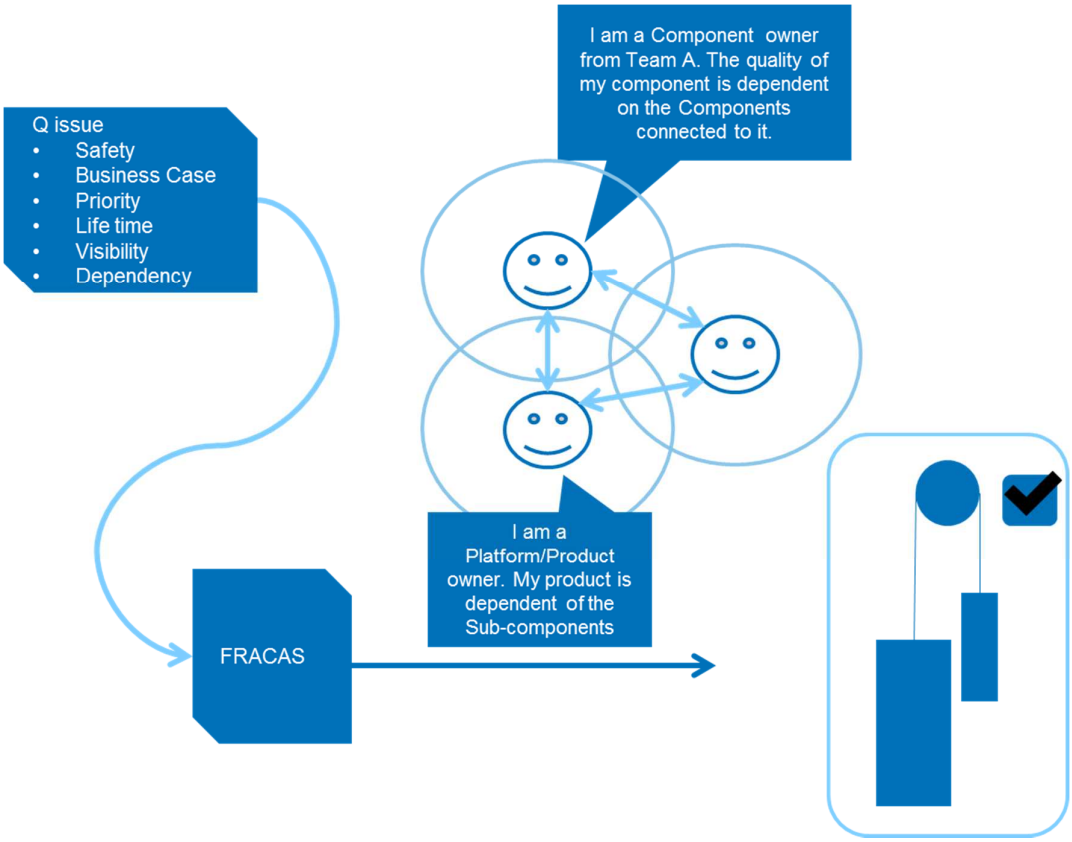

Figure 3. Visualization of collaboration in Project phase. Modified from: Agile Product ownership in a nutshell by Henrik Kniberg (2012)

As we can see from Figure 3, the quality issues are managed by the Project Manager in a Failure Analysis and Corrective Action system or list. The team is tight and solves issues efficiently. In a Project, clear roles are defined and communication between owners is established.

3.2.2 Phase II: Product Phase

When the project is finished, the product ends up as a new offering to the customer. The project manager can start a new project and the product gets a new owner. The owner can also be just a category until a person is defined to be the owner. For products that are seen less priority, there might not be owners for all the parts or no clear ownership. Someone might have many products under his ownership and less time to govern all of them.

This transition brings up some issues. Firstly, information might get lost during transformation between project and product phases. Secondly, known problems might re-appear and need re-analysing and waste resources. Thirdly the project phase uses different tools compared to product phase and continuous improvement. The fourth issue is that Project phase is usually better managed by having more priority and thus having a clear product- and part owners defined.

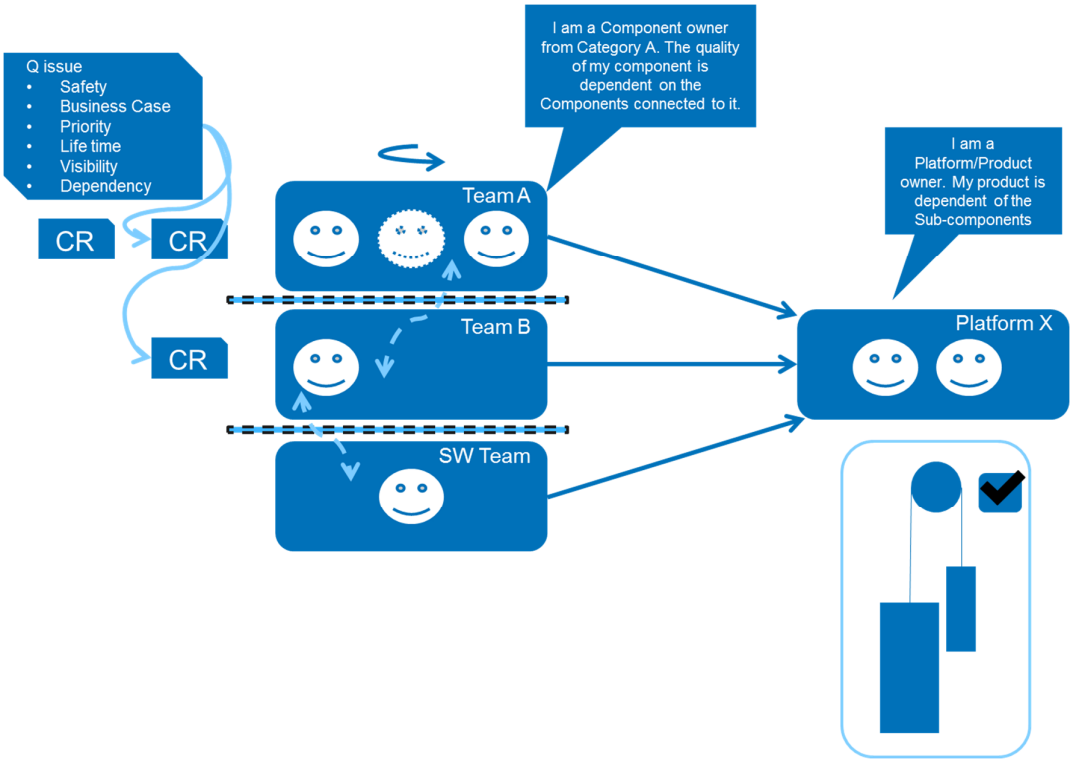

Figure 4. Visualization of collaboration in Product phase. Modified from: Agile Product Ownership in a nutshell by Henrik Kniberg (2012)

As seen from Figure 4, the collaboration between teams is more difficult in continuously improving products, especially if no owner is available. it is seen that quality issues in continuous product improvement process swim into the Change Requests that are assigned to different teams and handled by an “owner” if available. From Figure 4 the division of the teams is also visible. The structure of the electronic system of the case company consists of various parts. The teams are divided into teams specialized in these different parts. Responsibilities and ownership are heavily fixed on the product structure.

Figure 4 shows that Change Request are assigned to individual teams. By default, the change request’s visibility is restricted. Restrictions are to ensure confidentiality and that sensitive information does not leak to the wrong hands. This suggests that other teams do not know about other teams change requests by default and can cause collaboration issues such as overlapping in the work done. (Case company internal documents 2016)

Quality issues are not systematically followed in a FRACAS tool. This difference between the two processes: Project and Product, causes issues. In product phase Teams are divided according to the speciality related to the parts in the system. This coarse allocation creates silos between teams.

> *“If we cannot determine right away whose responsibility [the quality issue] is then we guess and start bouncing the issue around [between teams]. Because nobody wants to take it, then we play ball with it. “*

Found quality issues are seen as extra work and teams seem to get defensive on the topic whose responsibility to solve it should be. Challenges come in predicting the impact that will create the business case.

Additionally, the quality issues or problems are not transparent to owners and stakeholders. Dependency between products is unclear and may confusion. Silo effect is a matter both between organization units and teams. Communication between the silo-effected teams needs to be established preferably through product owner to be effective.

3.3 Tools for Change Request and Continuous Improvement Practices

Based on the results from the interviews, clear drivers for changes were found. Primary drivers are related Safety, Quality and Business Case

From the interviews results, three explicit types of failures could be identified. The most critical failures are those related to safety. The next critical failure is the ones resulting in a callout. A callout is when the system has a failure and maintenance is called on the site to repair the system. From software and system verification point of view in the project phase, these main issues need to be fixed before “a green light“ to go forward is given.

Secondary issues are failures affecting long-term reliability and cosmetic problems that do not affect usability. These failures usually get lower priority to be fixed. All found issues found from SW verification are reported to the project manager and he reports

them to the project FRACAS file (Failure Reporting and Analysis Corrective Action System).

From prioritization point of view the three themes are suitable and safety seems to be the main driver in this kind of categorising. It might be too general for a more holistic system quality fault categorizing.

From the interviews, it was also seen that not all the available tools are used in continuous improvement compared to project phase. Especially FRACAS tool would be beneficial for component owner and product owner to record issues and lessons learned for future reference.

> *”The faster the issues are found and the better they are fixed then it is better [for us]. And if we were to start developing the next version where we have fixed the lessons learned“*

Usually the owner changes when transferring a part of product from project phase to the product phase. Lessons learnt in this transition are easy to lose and a smooth handover would be needed. Tracking and communication of resolved and unresolved issues could be communicated better between teams and units:

> *”For us, the visibility is lost after we have communicated the issue onward. Actually, it is a little bit sad that we don’t have visibility. And even if we had, I don’t know if we can insist that “hey you need to fix this”*

It also means to engage and define the owner or when an owner is even needed is alternating. Sometimes there is no owner available for a product either through resources or other reasons. A clear and transparent list or system of open items and needed changes for a product would bring more ground to move resources and priority to a particular product.

Tools are available for the owners. The only issue is that there is overlapping of the tools, and their functions could be harmonized between project phase and product phase.

Lessons learned have many opportunities to be lost during processes. A tool needs to be available and used as lessons learn database or Product Lifetime FRACAS.

3.4 Ownership in Quality Improvements

An apparent owner for system level quality is not found. A clear product and sub-component hierarchy ensures that a stakeholder will eventually come up higher in the hierarchy, but the responsibility of solving the quality issue is assigned to the part owner who is seen as the responsible to fix the problem.

The key findings in the current state analyses are that working in project phase is usually better resourced and prioritized. In project phase, the part owners are clearly defined the needed specialists taken onboard and the project might have the highest priority to solve quality related issues. The project is run by a project manager who coordinates the activities, tests and meetings. He is also reporting the progress to management. Also, silos in project phase seem to be less significant because resources have been allocated to the same project team.

3.5 Collaboration between Teams and Units

The main weaknesses in the current state analysis are the silos between teams and units.

> *" We have silos [between teams] from side to side and lots of [different] component that we should understand how they communicate [and work] together."*

From the interviews, it became apparent that some emphasized the silo effect between teams and units that created separation between targets.

> *"When we save costs [in a part] it should not increase cost somewhere else. That is exactly the silo effect where categories are separated with their targets and cost objectives. This is sector optimization."*

During the interviews, it was also highlighted that teams compete in lowering part costs but it might increase overall system cost.

The second main weakness was related to tracking and transparency of quality issues.

> *"What we can do, as a project, we can just send the lessons learned, but the component owner needs to take into account what are the following specifications. It just goes to the project folder not necessarily in someone's hand."*

The quality issues and lessons learned found during Project Phase of the product life are recorded in a FRACAS file. This way of working is not continued in continuous improvement phase. When all the quality issues are not recorded into a system or list then it is hard to measure the impact of improvement to the cost of poor quality and estimate clear business cases for the improvement items.

The quality issues found in In Project Phase are also quite coarsely divided into three categories: issues related to safety, issues resulting into a callout and long term reliability and cosmetic issues.

3.6 Summary of the Current State Analysis and the Key Themes

A summary of the key findings was built based on the Current State Analysis. The key themes from the interviews were categorized and analysed. Figure 5 summarizes the main findings and the themes that emerged.

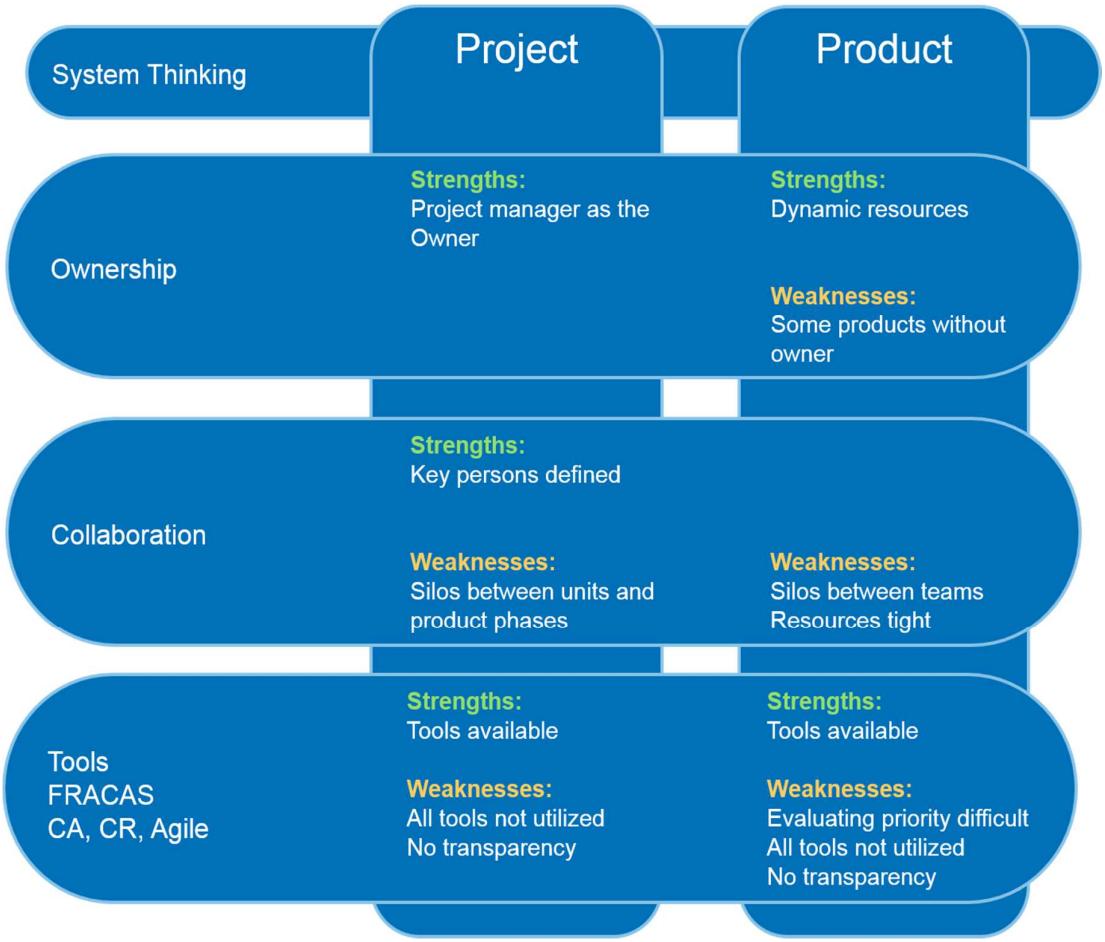

Figure 5. Summary of strengths and weaknesses from the current state analysis

As seen from Figure 5, the key issues can be divided into three main themes: The first theme is the Silo Effect between units, teams and between phases in the product lifecycle and how it affects collaboration. The second theme is the Ownership of the parts and actions when an owner cannot be assigned for every part. The third theme is the Tools utilized to manage quality issues, bring transparency between teams and units in the organization and categorizing the quality issues. Tools should also support the two other themes Ownership and Collaboration.

Summing up, the three main themes, Ownership, Collaboration and Tools were taken as a focus for selecting and studying existing knowledge and finding the best practices for improvements.

One main approach behind the current state analysis is systems thinking. The products are complex systems and how to handle quality issues with them needs a system thinking approach.

4 Best practices in Ownership, Collaboration and Tools to support

This section studies the existing knowledge of the key themes found from the Current State Analysis in previous section 3.6. The aim is to find the best practices related to the identified main themes. A conceptual framework is prepared from the study to summarize the findings.

4.1 Systems Thinking

Systems thinking describes how the properties of the whole system are affected by the dynamic interactions between the parts. Sheffield, Sankaran and Haslett argue that the main focus in system thickening is to tame complexity and make the handling and managing of complex systems more simple. They note that system thinking techniques require interpersonal skill over technical skills (Sheffield, Sankaran and Haslett 2012).

In an interview conducted in 1997 Russel Acoff explains system thinking in the following way:

> "The dominant mode of management in the Western world is divide and conquer. Take each department or division or function of an organization, and operate it as well as possible. The belief is that the whole will then also operate as well as possible. A simple example will show why that belief is absolutely false. Look at all the various automobiles available and pick the one with the best motor, say the Rolls Royce; the one with the best transmission, perhaps the Mercedes; the best brakes, for example, the Buick; and so on for each part for an automobile. Then you remove these parts from the cars of which they are a part and try to put them together to create the best possible automobile. Not only don't you get the best possible automobile, you don't even get an automobile, because the parts don't fit. Performance of the system depends on how the parts fit, not on how they perform separately. This is a very critical systems principle that applies to management." (Russell Ackoff in an interview by Finnie 1997).

This quote summarizes the idea behind systems thinking. The system cannot work properly if the parts are not compatible. It emphasizes the dependency of the individual

components to another. It also highlights the performance of the system over the performance of the individual parts.

The parts of the systems are usually managed by the product owners and part owners. System innovation is more promoted in an environment with various actors or owners. This kind of setting supports distributed cognition and coordinated action. This is because the owners have their own perspective in matters. In contrast in groups of homogenous actors more collective cognition and collective action can develop (van Mierlo, Leeuwis, Smits & Woolthuis 2010).

In summary, systems thinking relates to integration of people and systems working, interacting and functioning together. The overall functionality of the system is defined by the interaction between the parts of the system.

4.2 Product Ownership

Product ownership defines the responsibility of the product, its quality and design changes.

4.2.1 Agile Product Ownership

Agile is a method how to develop a product. This is mainly intended for software developers. Agile methodologies main function is for the product owner to forecast the time needed to implement selected features. The main concept is to have a Backlog of requested features as input for the team. Then the development team then has a constant development time for implementing changes. The Product Owner can then decide which features to implement and which not to. To decide on the changes to implement requires good communication between the product owner, different stakeholders and the development team (Kniberg 2012).

Agile product ownership is a model where design change rounds are divided into smaller and frequent change rounds. The Agile develop process is presented in Figure 3. Full image of Figure 3 is found in Appendix 3.

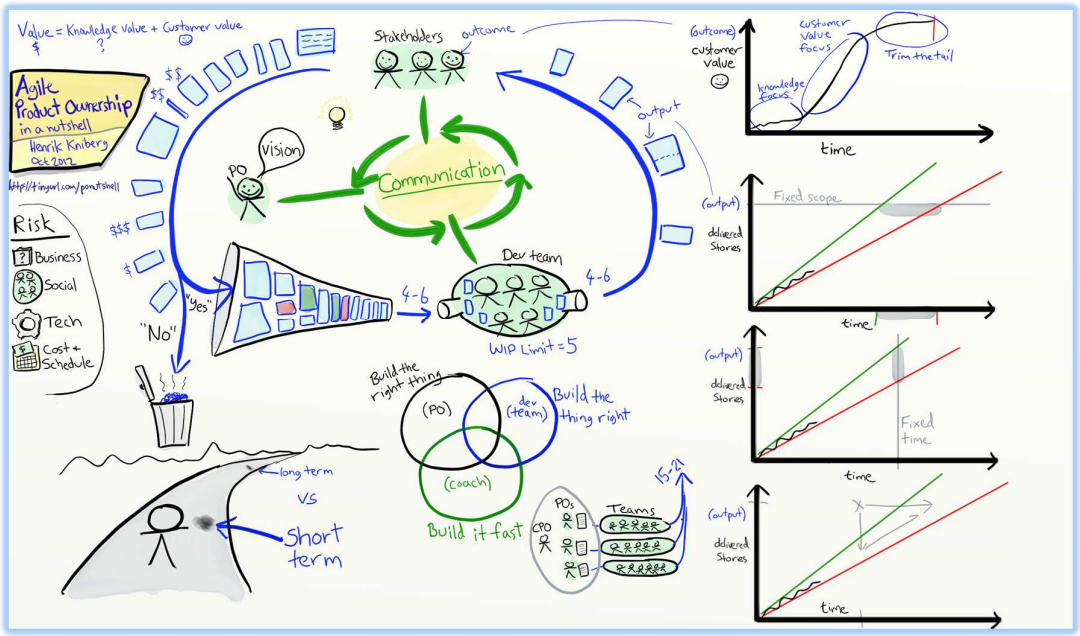

Figure 6. Agile Product Ownership in a nutshell (Kniberg 2012)

As seen from Figure 6, the Product Owner is in the key role of defining what changes are taken into account in the product. The main driver of the action is working communication and collaboration between the Product owner, Development team and various stakeholders.

For hardware developers, the agile methodology can bring more challenges because producing prototypes is not as fast to do as software is. Change cycles in hardware can be rarer than in software. This is due to need to manufacture and test physical prototypes and pilots.

From Figure 6 it is also seen that items that are not for some reason selected to be implemented go into the trash bin. This does not mean that a quality issue, for example, would not go away even if they are not taken into account in the next change round. These items could be used as lessons learned in new product development or saved for a more suitable time to implement in the product.

4.2.2 Agile Testing and Adaptive V-model

Testing and verification can be a bottleneck in product change process. Traditionally testing is done in a V-model where test are done in parallel at different levels. Figure 7 shows the V-model of software testing and validation is presented.

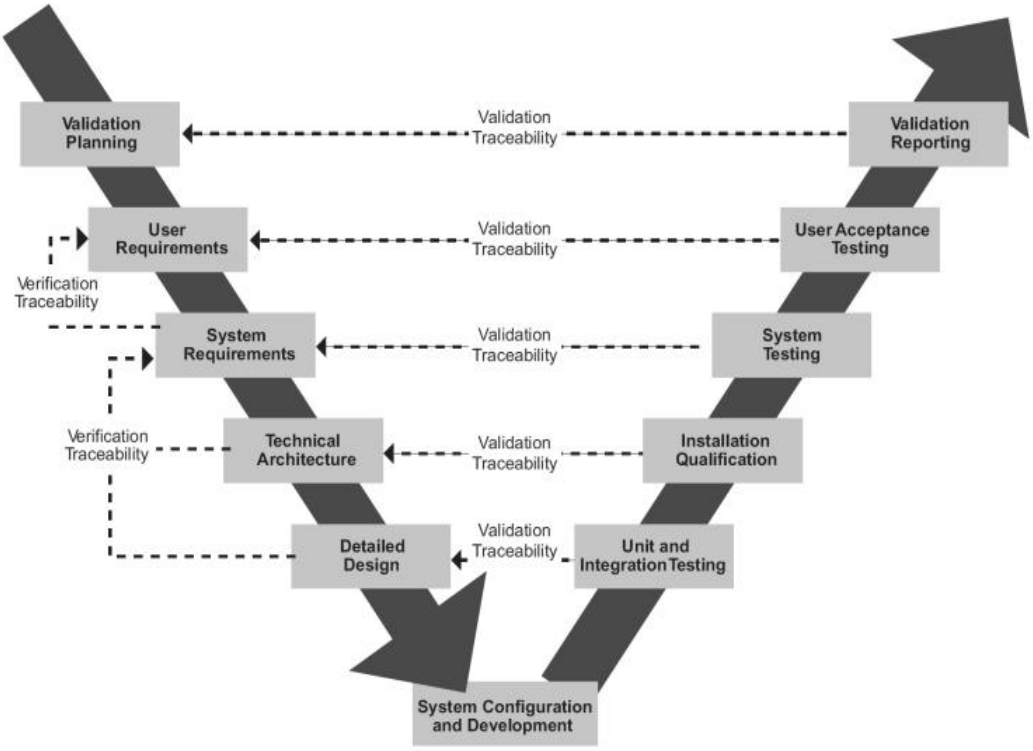

Figure 7. V-model in software testing (Ghahrai 2008).

Figure 7 shows the different levels of verification is presented and hot the change flows through all of them. The key item is transparency between the levels, teams and units. From an Agile perspective, the testing time can be reduced with risk-based and case based testing. In case based testing the test preparations are done already in the planning phase (Ghanim 2015).

The V-model can apply not only for software testing validation but also for corrective action validating and hardware changes validation. This kind of validating done in dif-

ferent levels needs a suitable system, transparency and healthy collaboration between levels e.g. units and teams.

4.2.3 Expanding Ownership

For better collaboration and sudden problems like quality issues ownership can be extended. Ah Bee Goh suggests applying ROFO principle. Responsibility, Ownership, Focus, On-time corrective action is empowering everybody to take responsibility for quality in an organization. In practice, the employee needs to generate on-time corrective actions to fix the issue and expanding the employee's role's responsibility so that the employee will own the whole process. (Goh 2015)

The ROFO principle emphasizes the role of the reporter of the corrective action. It gives him the responsibility to solve the corrective action measures on time so that more significant damage cannot happen. The challenge in this is if the corrective action is not reported in any system, then no learning might not become of the incident. A corrective action is more efficient when preventive measures that the problem cannot appear again. More preventive measures will usually need collaboration with other teams and units.

4.3 Collaboration

Tamm (2015)) argues that an organization cannot effectively compete externally if it cannot first collaborate internally. The reason for this is because teams and units that cannot collaborate are internally competitive, highly conflictive, and adversarial. In contrast, employees and organizations that are highly effective in collaboration are supportive, co-operative and collaborative (Tamm 2015).

Tamm argues defensiveness to be the main area where to focus on improving collaboration. Main fears triggering defensiveness are related to lack of competence, one's significance and one's likeability. Usually, these fears are then quickly turned to blame. This type of vulnerability and defensiveness decreases the ability to solve problems. Tamm suggests the solution to this is to monitor your behaviour and manage you own defensiveness (Tamm 2015).

In summary, increased collaboration helps in solving problems and increase effectiveness. This can be prevented by trying to eliminate the needs of defensiveness.

To manage your defensiveness most effectively the environment might also need to be supportive and eliminating the need to be defensive. Environments, where teams are competing e.g. in cost savings, available resources or bonus targets in the expense of other teams and units could be one cause of challenges in collaboration and one cause of silo effect.

4.3.1 Leading Collaboration

Leading collaboration is important because it has an impact on how efficiently you implement changes and solve problems together with others. It is important to have a strong hand in decision making so that over analyzing the issue does not paralyze the process. Usually, a group consensus is not possible, so at the beginning of the process, it is important to specify the leader the collaboration and the decision maker. He can then stop the discussion and proceed with the made decision (Ibarra and Hansen 2011).

If the reason why the decision that was made is not communicated correctly to the collaborating party, there is a risk that someone can take the decision personally against him and decrease motivation. This can then affect future collaboration and why clear communication needs to be taken into account.

4.3.2 Silo Effect

Silos describe the barriers between teams and organisations that block the flow of information, collaboration and ability to work together. Silo effect is teams looking too inwards in what they are doing and less taking account the whole system.

> *“Silos are the cultural phenomena, which arise out of the systems we use to classify and organise the world.” (Tett 2015)*

This will bring issues such as employees who are categorized in teams specialized in a certain topic can cause damage by wasting resources, not communicating and overlook risks. Silos can also block innovation (Tett 2015).

Tett calls controlling of the silo effect as “Mastering silos”. It is never finished and always needs fine tuning. Tett lists some lessons learned about her studies about Silo effect. First is to keep teams flexible by decreasing the borders between them. Secondly, job rotations between teams and units are seen beneficial. Thirdly, silos can also be battled by creating an organizational atmosphere that supports the encounters and collisions of different teams and specialists. Finally, organizations need to reward their employees more from collective performance than individual team performance. Otherwise, this can lead to internal competition between teams and units (Tett 2015).

By categorizing employees into boxes based on their specialty can be challenging while trying to master silos. From the Current state analysis in section 3, there was clearly categorization of part ownership into different parts of the system. This might cause the silo effect that has emerged. Silo effect also has a negative effect on collaboration.

4.4 Failure Reporting, Analysis and Corrective Action System (FRACAS)

The FRACAS is a Quality process to report and control failures in a system or a product. By identifying and classifying failures, reporting them into a database and eliminating the causes of the failures increases reliability and quality. This is a continuous improvement process and target, in the long run, is to move from a reactive process to a preventive process (Smith and Keeter 2010).

A FRACAS system is basically a system where you can record your failures and categorize them in any way you wish. The system can bring visibility and transparency of open items between teams and units. In a good FRACAS system, it is easy to categorize and classify different types of failures.

4.4.1 Transparency

Transparency describes openness of the reporting or discussion at hand. It gives the possibility for everybody to contribute and bring up items that they feel are necessary for example in quality issues or a FRACAS system.

Transparency is seen connected to organizations' success and effectiveness. More open communication promotes trust and supportiveness among other things. Transparency can also help in minimizing the effects of unexpected crises. Transparent leadership supports the leader's and follower's relationship and motivates the follower (Norman, Avolio, Luthans 2010).

Listing the found issues in FRACAS and promoting transparency might help in motivating the team.

4.5 Conceptual Framework of the Thesis

This section summarizes studied theory and highlights the key findings from the studied existing knowledge in section 4.

In Figure 7, the conceptual framework is visualized. The key items are divided into same themes as found in Current State Analysis in section 3.

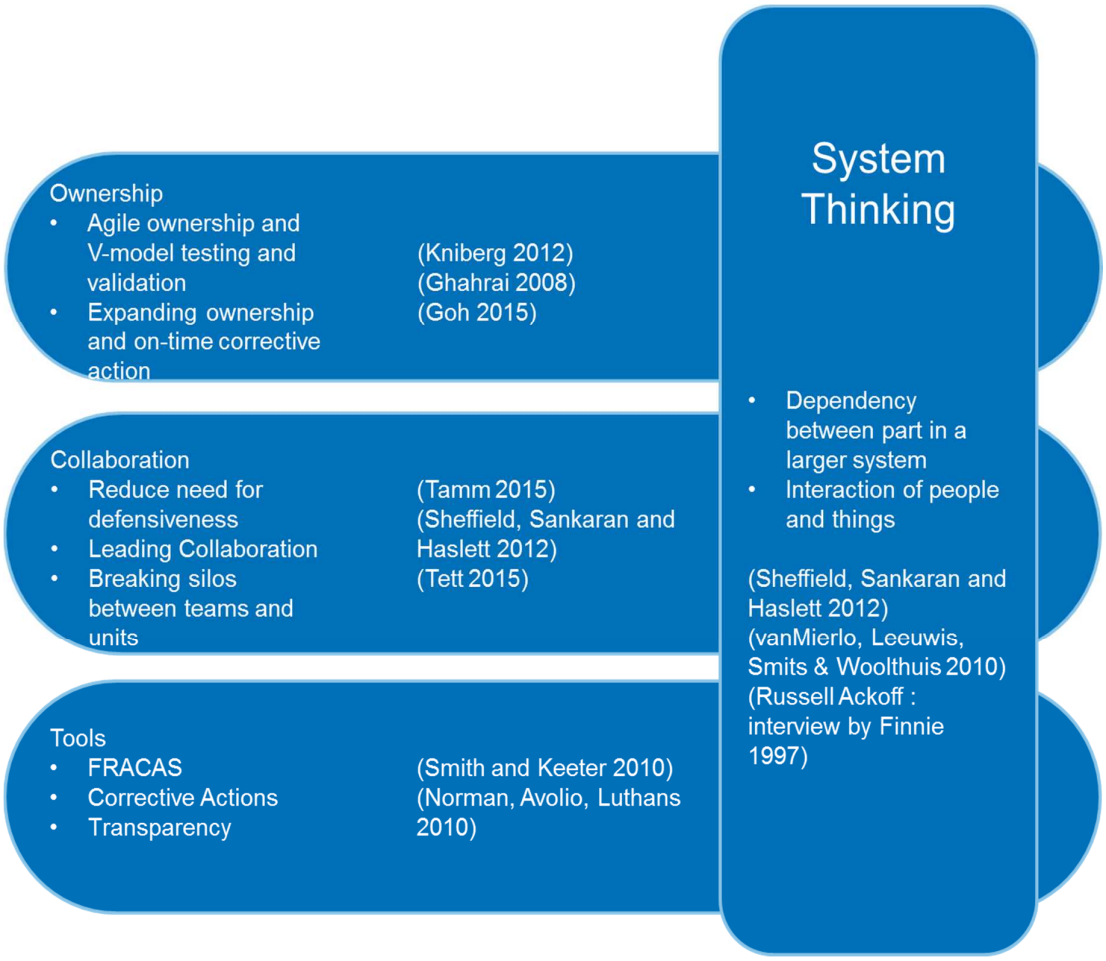

Figure 8. Conceptual Framework for improving quality with shared system ownership.

As seen in Figure 7, the main findings from the conceptual framework can be divided into the same three themes as was identified in the Current State analysis: Collaboration, Ownership and the Tools.

As shown in Figure 7, the key items in Ownership are related to how Agile product ownership works and how ownership and responsibility can be expanded to create on-time corrective actions and improve quality. Agile ownership lists the changes needed and categorizes them according to priority, needs and business case. The Agile method requires good collaboration between product owner, development team and stakeholders. Verification V-model can bring transparency between teams and units. Expanding

ownership to fix the found issue with an on-time corrective action bring flexibility to the concept of "ownership".

As presented in Figure 7 the key items in Collaboration are how to break silos between teams and reduce defensiveness among employees to increase collaboration and how the working environment and used tools can support this. Silos between teams and units can be mastered with actions such as flexibility, job rotations and rewards in collective performance rather than individual team performance.

The key items in Tools are how FRACAS can support collaboration between teams and units and expanding ownership while recording quality issues to a reporting system for more transparency. A V-model type of transparent corrective action planning and validation may improve collaboration between the units and teams.

From the conceptual framework, the key items can be analyzed and taken into the building of the proposal for the case company.

5 Building the Proposal for the Case Company

This section describes the process and the sessions held for developing the proposal for the case company. When creating the proposal first the results, themes, and key items from the Current State Analysis and the Conceptual Framework were taken and analyzed. Then the some co-creation session were held where these findings were addressed. Finally, the proposal was built.

5.1 Development of the Proposal

From the Current State Analysis in section 3 and the Conceptual Framework in section 4, the three most important themes were taken as the basis of building the proposal. The fist theme is Collaboration and breaking the silos between teams, units, Project Phase and Product Phase. The second theme is the Ownership of the product and Quality issues. The third theme is the Tools utilized to support ownership and collaboration.

These themes were presented and discussed in the one-to-one and co-creation session for building the improvement proposal. The goal was to create a proposal for improving system quality. Feedback and key challenges from the one-to-one and co-creation sessions were recorded for building the proposal.

The sub-processes related to the three key themes were finally summarized in a main process and final proposal.

5.2 Overview of Data 2

The one-to-one and small group co-creation sessions were held to go through the key findings from the Current State Analysis and the Conceptual Framework. These sessions started gradually to form an idea about the proposal for the Case Company

Some key challenges and topics were discussed during co-creation sessions for the proposal. The first key item is how to engage owners in using the proposal and how it will benefit them. The second Key item was related how to merge the new proposal aligned with the current product change processes. The third key insight was that there

needs to be a focus in the handover and transition where the product moves from Project Phase to the Product Phase. Finally, the bottom line cost and benefits in the system need to be evaluated by the system owners before going forward with the design changes.

5.3 Building the Proposal

The three themes were selected as the basis of the proposal. Also, the main challenges found in the Current State Analysis and the Conceptual framework were discussed in the co-creation sessions

5.3.1 Step One: Ownership

From the current state analysis, it was studied that the concept of ownership is one of the key themes. One solution would be taking into use a system-level quality ownership approach and have a system-level owner responsible for system-level quality. This kind of approach though would not help in breaking silos and even increase silo effect. A System Quality Owner, in-between teams, might result in that person being the only communication channel between the teams.

The System Quality Owner approach presents a risk that quality issues are solved only by starting a new project. Starting a new project for solving quality issues is logical since in chapter 3.2 it is recognized that in the case company the Projects usually get more resources and priority. This is not the intention in this study. But rather building a more collaborative solution in product and quality issue ownership.

As suggested by Goh in section 4.2, a more collaborative approach might make everybody responsible for system quality. Quality issues should be recorded in a standard way and be transparent to all product owners. Ownership is then expanded beyond team borders to solve those quality issues that affect your product (Goh 2012).

This approach can also be used to invent new solutions and pinpoint the already known challenges. These outputs can then be utilized in the development of new product even if changes to old products are implemented.

Figure 9 visualizes the expansion of responsibility and ownership.

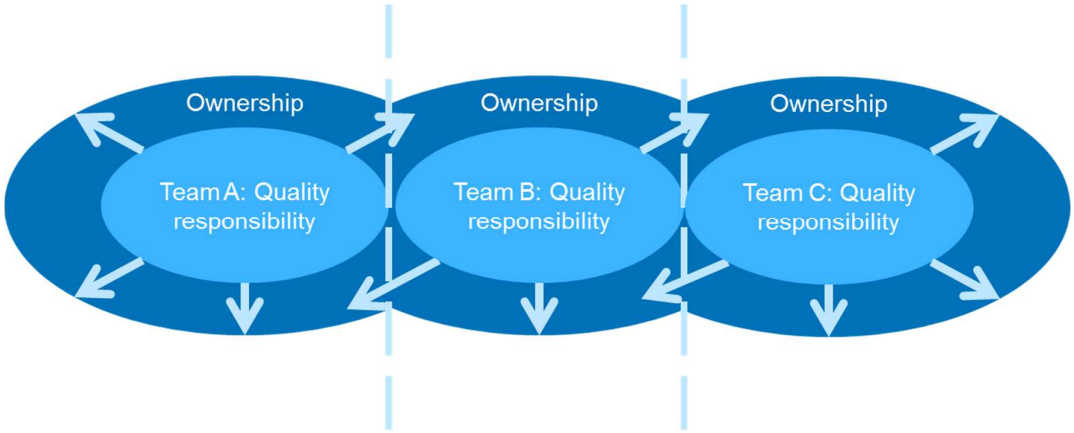

Figure 9. Expanding ownership beyond teams and units. Modified from: (Goh 2012: ROFO principle) analyzed in the Current state analysis in Section 4.2

As shown in Figure 9 by expanding the quality responsibility over the team borders it will overlap and expand to a shared system quality ownership. The goal is to disperse the boarders between teams and create opportunities where by solving a quality issue on “another team’s turf” you improve overall system quality. This would eventually begin to change individual part owners into system owners and transform the ownership model in the organization.

5.3.2 Step Two: Collaboration

From the current state analysis in section 3.5, it became evident that teams need to compete for resources, and this is not ideal to build collaboration. Even if you don’t have resources to spare it is beneficial to report the found issues transparently. System quality would benefit so that if other teams know of an item critical to their area it can be taken under study and prioritizing changed accordingly if needed. A system to record these issues could be a system Lifetime FRACAS discussed more in section 5.3.3.

The main target is to reduce the need of being defensiveness and fix the recorded issues together as suggested by Tamm studied in section 4.3.

Proposal for the company to improve this is to increase system thinking and build a more collaborative environment to work. At the beginning of the transition, some incentives for change could be created. A way to measure the change would be in measuring Change Requests and Corrective Actions more in system level than in part level. Bonus incentives could be focused on solving corrective actions and change requests from other parts and teams the same electrical system.

This step combined with step one in the previous section would start the chain reaction and start fading out the borders of ownership and silos in between the teams.

5.3.3 Step Three: Implementing supportive Tools

The tools used are the key item for kind of transmission from individual part ownership to shared system ownership. The target is to utilize available tools so that ownership issues and collaboration is supported.

Lifetime FRACAS:
It would be beneficial for product owners and product part owners to start keeping a record of the open, ongoing and closed quality issues concerning their product. The record keeping should be done in a systematic, transparent way in every team so that anyone can find the item in the system and to what products or parts it is related to. Since the Change Requests need to be restricted by default, it forces to use another more transparent tool to follow quality issues. One solution would be to use a Lifetime FRACAS system to keep records of the quality issues. This kind of system would be utilized in the beginning of a project and maintained through the project and handover to the product owner in Product phase.

The information stored in the corrective action is important to identify the products related and to determine priority and classification of the failure. Figure 8 shows an example of the information layers of a corrective action.

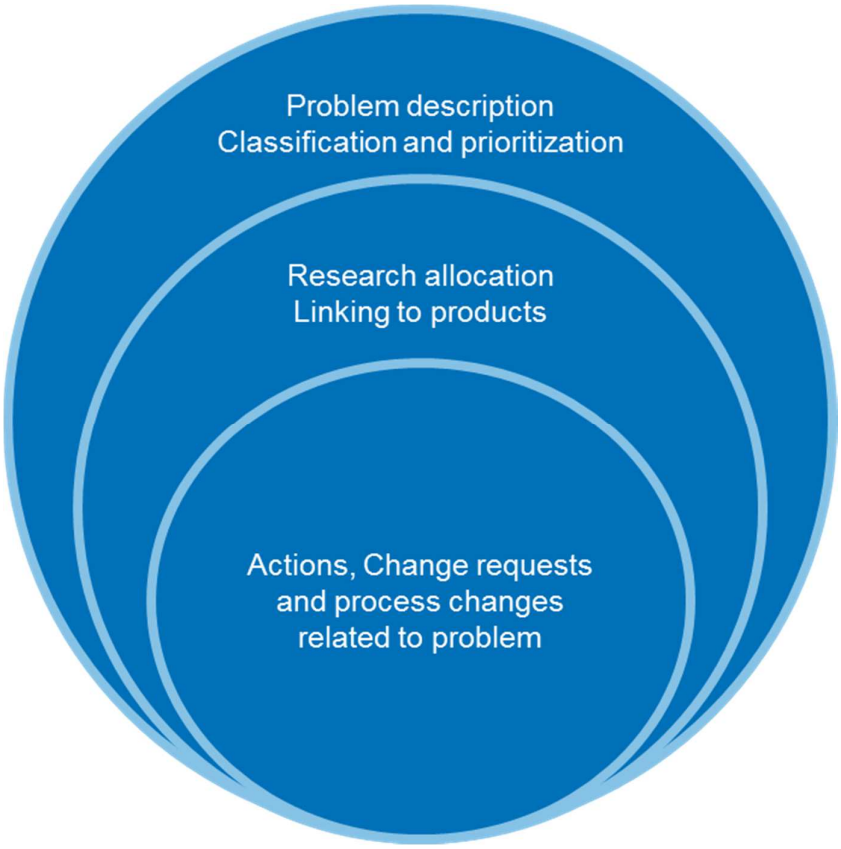

Figure 10. Visualization of a corrective action and its information layers.

As seen in Figure 10, the corrective action can have several layers of information. The outmost layer contains a general problem description related to the quality issue. In this layer, the quality issue is classified and prioritized accordingly. In the next layers, resources are allocated, linking to parts and products is done. Then the root cause needs to be defined, and actions, product change requests and instructions and process changes are recorded.

Transparency and Confidential information:

This kind of information layers as shown in Figure 10 also helps to keep sensitive Change Requests restricted and possibly sensitive information not visible to everyone. Restricted change requests can be linked inside the corrective action and they will still be restricted and shown only for those intended. This solution still gives some transparency to follow-up on quality issues if the general description, the outermost level, is kept transparent.

Validating the Corrective Action transparently through organization:
The corrective action can be verified through a standard V-model where the corrective action can be initiated at any level: customer, field, platform or part. Actions started at any level would they be changes in instructions, changes in part design or SW can all be linked to the same Corrective Action where the outer layer is describing the general level issue. The finally the Corrective Action is validated on all levels.

Figure 11 shows the Corrective action V-model for the owner.

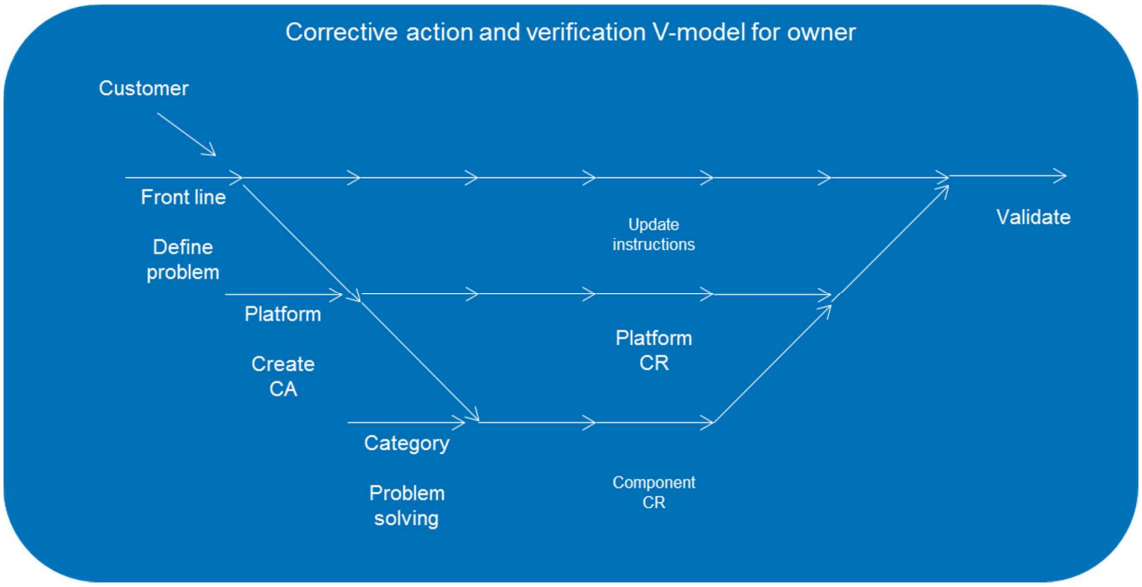

Figure 11. The corrective action and verification V-model for the owner.

Figure 11 shows the different levels and units, are seen, where on time Corrective Actions can be generated, planned and how they can be validated. The goal of using the validation V-model is to bring transparency to the organization for the recorded Corrective Actions and quality issues.

Categorizing and Analyzing Corrective Actions
When all the quality issues are recorded with its unique Corrective Action number then the analysis of the quality issues can be done. In Figure 12 the analysis of corrective action is visualized.

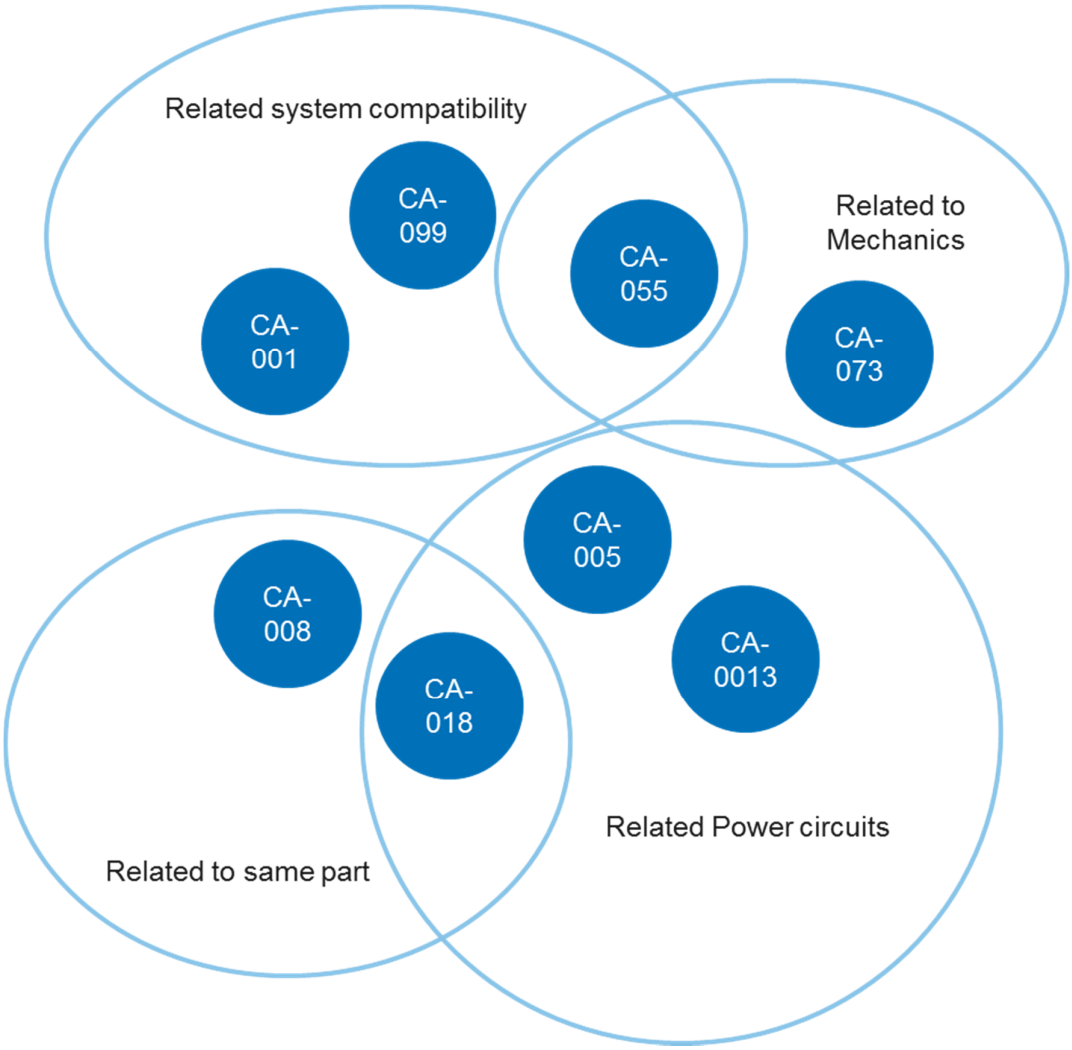

Figure 12. Example of categorizing themes Lifetime FRACAS.

As seen in Figure 12, the after recording all the corrective actions they can be analyzed and classified into different topics. This helps in creating a plan which states what themes should be taken into account and to prevent when creating a new design. The goal of categorizing the Corrective Actions is to identify most valuable business cases and lessons learned to be implemented and taken to the next design.

Using Lessons Learnt From Lifetime FRACAS:

When the Corrective Action system of Lifetime FRACAS is utilized for all products and parts in a systematic way, then all the lessons learned can be directly found in the sys-

tem. In reviews related to design changes or new product development such as Failure Mode and Effect Analysis -reviews and Critical to Quality reviews these items can be used for identifying potential risks.

5.4 Summary of the Propposal

As a summary, a general process can be created from the three key themes from previous sections and the smaller sub-processes. The summary can be presented in three general steps related to Ownership, Collaboration, and Tools. Figure 13 shows the summary of the proposal.

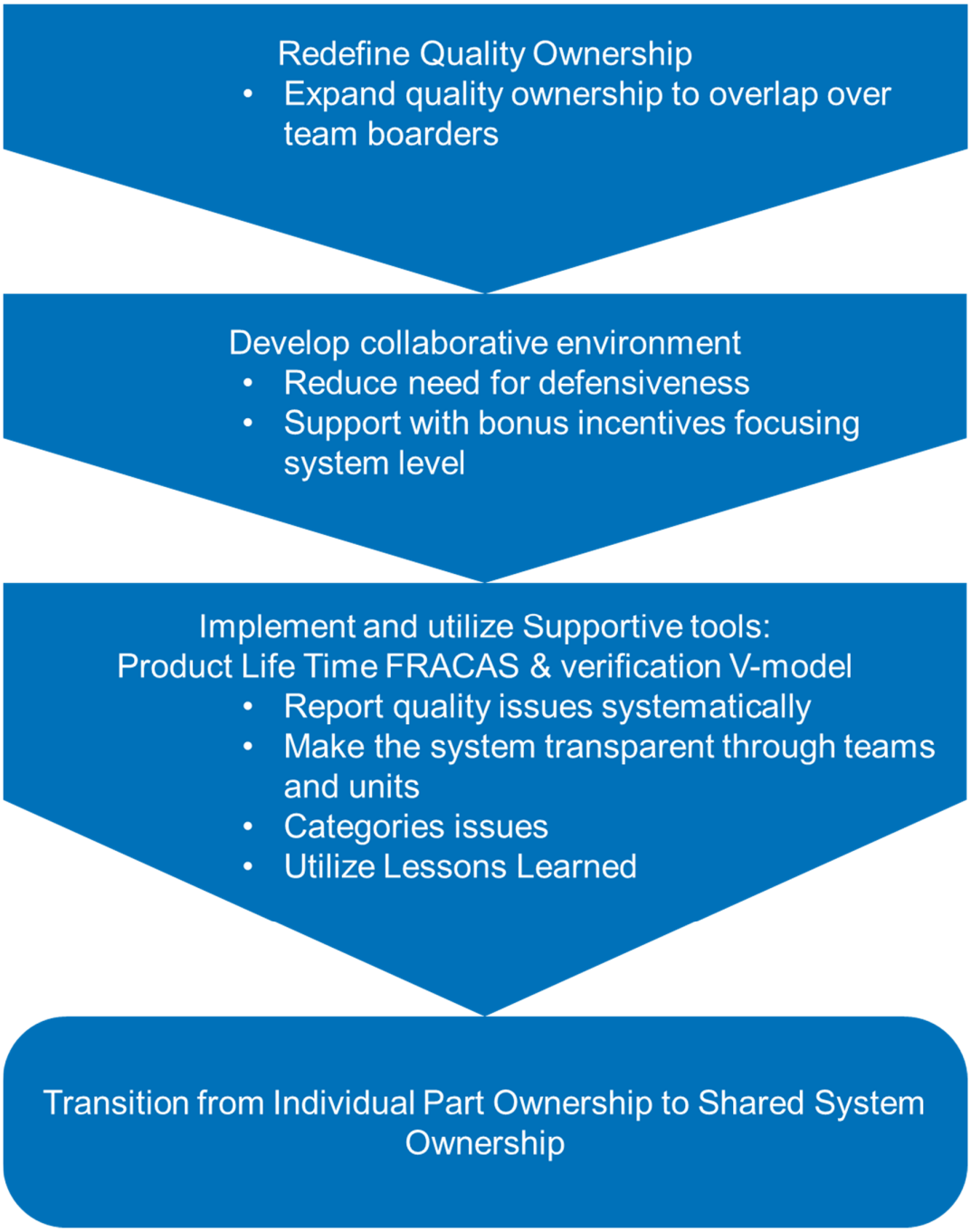

Figure 13. Steps of the transition from Individual Part Ownership to Shared System Ownership.

As presented in Figure 13, the main steps in the transition from Individual Part Ownership to Shared System Ownership are divided into three main steps.

The first step is *Redefining Quality Ownership*. In this step quality ownership is expanded to overlap over team borders. The goal is to make the boarders and silos inconstant and variable which are dividing the teams' responsibilities.

The second step is *Developing a collaborative environment* in which and the need to be defensive about the found quality problems is eliminated, and the issues and findings are encouraged to find, report and solve collaboratively. Bonus incentives should be set accordingly for reporting and resolving the items, focusing on system-level transparently and not in individual part levels.

In the third step, *the supportive Tools* are taken into use. A Product Lifetime FRACAS collects all the corrective actions related to parts and products and systems. The FRACAS needs to be transparent through teams and units. The confidentiality of some items can be ensured by linking sensitive and restricted Change Requests under the general level of the Corrective action as discussed in section 5.3.3. The system is finally used in lessons learned by picking the items straight to the FMEAs and Critical to Quality reviews.

5.5 Expected Outcome after Implementing the Proposal

The expected results of using the proposal are divided into short-term expectations and long-term expectations.

5.5.1 Short-term Effects and Expectations

By utilizing the FRACAS the short term effect is going to be the ability to recognize needs in resources and prioritization. Secondly, the slow change from reactive process to a more preventive process will start. By reviewing what types of faults are possible in a new project they can be more easily prevented. The recordings create a database where inputs to Lessons learned and items Critical to Quality can be looked for in the start of a new product design project.

5.5.2 Long-term Effects and Expectations

Long-term outcome will be an improvement in system quality. This is because when quality issues related to different parts and products are communicated openly and transparently, it will eventually diminish individual ownership and transform ownership to a more dynamic shared ownership. Improved collaboration doe to shared ownership and open transparency will eventually start breaking the silos between categories and lead to better system design in the long run.

6 Validation of the Proposal

This section analyses the feedback from the presented proposal in section 5. The feedback was used to finalize the proposal and create an action plan to implement the proposal. Also, piloting of the Corrective Action process was started and results studied.

6.1 Feedback for the Proposal and Findings of Data 3

The proposal and sub-processes were discussed in three one-to-one meetings with Quality managers, Quality engineers and Category managers. The discussions revolved around Product development, project ownership, product ownership, lessons learned Product structure, Organization structure, and Quality organization structure. The original business challenge was defined with the same managers as the managers included in the presentation of the proposal.

During the one-to-one discussions some risks, concerns and suggestions came up to improve and modify the proposal.

Firstly, there was concern that the project manager does not want to list all or solve all the quality issues into FRACAS during the project phase since he intends to finish the project on time.

Secondly, there was concerns related to the product structure. The Lifetime of the whole system is decades and this heavily affects the structure and specialization of the units. A realization occurred during the one-to-one discussion that current product structure might be one cause why team hierarchy is so fragmented. When the product lifetime is long, and the organization is used to making the things the same way for decades, it blurs your system level view.

When going back to the Interviews done in the current state analysis, the following quote came up:

> *”No body wanted to comment on what to do [for the quality change]. We dwell on it for so long until we got a third team on board. No body commented on the solution so we just went with it”*

This citation suggests that the product structure could be one reason why the teams have molded into the specialties they are now in, and do not even want to comment on the changes done in any other team, even if it might have impact on the system level to their parts.

A radical way of forcing this change in system thinking would be to dismantle the current teams but the current product structure might be difficult to re-structure because of old habits. This is also one of the reasons to start recording the system related issues to FRACAS to identify where the old habits and ways of working do not apply and might cause issues.

Some ideas came up in breaking the current norm. One idea was that the current owners would be dismantled into a pool of resources that will take the next issue and solve them. Also the current seating was discussed. The teams are currently seated in the teams and breaking the normal seating distribution e.g. making an open seating office might disturb the current norm in a positive way from breaking silos point of view. It would also bring more “coffee table” type of discussion and might result in new innovations and support renewing the old product and the system.

Also in the discussion, a more moderate solution for organisation change was suggested which could start with the quality organisations dismantle and expanding ownership over the current team silos. But in the discussion it was highlighted that this could lead to the System Quality Owner as being the only contact between teams and thus increasing silo effect as discussed in section 5.3. It was identified that giving tasks for quality engineers and product and part owners outside of their own specialization would give a new point of view on system thinking right away.

As a summary, the current teams would need a little push out of their comfort zone and open their eyes to new possibilities in solving the issues a little higher in the system level rather than deep in the specialized part level.

Overall, the feedback on the proposal was good, and many new ideas and discussion started blooming. The feedback was taken into account when drafting the final proposal and changes to the original proposal draft.

6.2 Piloting

As a pilot for the proposal suggested in this study, the Corrective Actions recording of the quality findings was started extensively in the team responsible for PCBAs in the case company. Already some themes when categorizing the corrective action can be found. The part owners in the PCBA team are usually the owners also for the opened corrective actions and follow up on the measures to solve the issues. The use of the corrective action system will be continued and extended in the PCBA team in the case company.

6.3 Final Changes to the Proposal

From the feedback some changes to the proposal draft were made. First change was that the Organization Structure in part ownership could be radically modified for better support. This could be studied further when the process recording the findings to the Lifetime FRACAS has been done for a while. Also how the natural expanding of ownership could be measured before radical organization changes.

A visualization of the new pool of system owners and how they solve the issues was created. In Figure 14 the old and new type of ownership is presented. In Figure 14 the main suggestions from Section 5 are also summarized.

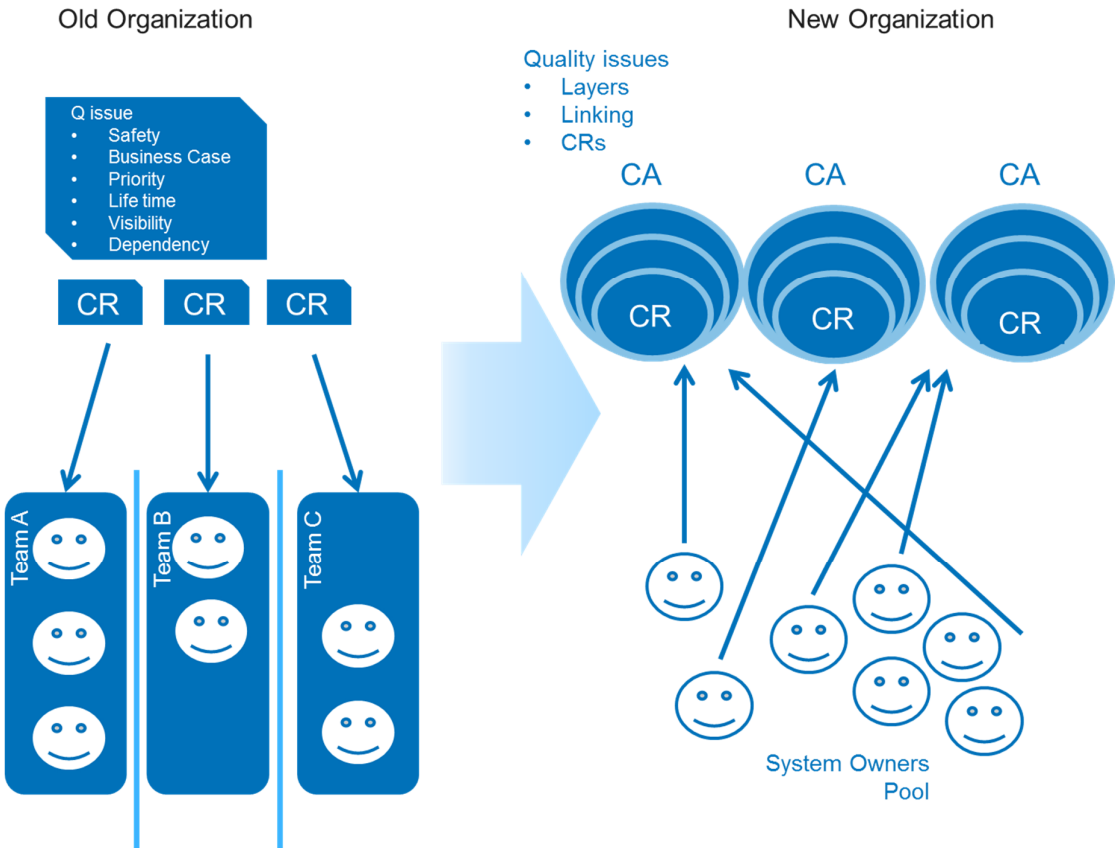

Figure 14. Draft Organization change supporting transition from Individual Part Ownership to Shared System Ownership

As proposed in section 5.4, the main proposal is The Transition from Individual Part Ownership to Shared System Ownership. In Figure 14 the organization change proposal is presented to support the transition. In the new organization, the Quality issues are presented in the Lifetime FRACAS system as individual cases and the System Owner Pool solves the issues taking into account the whole system. The FRACAS layers the information of the quality problem and links to the related CRs as described in section 5.3.3.

6.4 Recommendations

For putting the proposal into action and taking next steps to improve system quality, the following recommendations need to be taken into account.

First, for a better system visibility, the use of the Lifetime FRACAS system should be extended to other parts to see correlations in quality issues in different teams. The use of the Lifetime FRACAS is already started and can be used in parallel with other actions.

Second, the next priority is improving collaboration between teams and developing KPIs for supporting this.

Third, the final step is Ownership shift from Individual Part ownership to Shared system ownership. The transition can anyway started with smaller groups at the beginning like e.g. Quality engineers, as was discussed in the feedback of the proposal in section 6.1.

Finally, from the study's point of view, the use and visibility of the Lifetime FRACAS and corrective actions should be opened transparent to other teams as early as possible. Also, the KPIs planned for the process should be on the system level to support collaboration between the teams and dismantle silos.

Additionally, it should be noted that opening the seating arrangement for a more unassigned seating might bring some mixing into the current team divided seating and blend the employees and their ideas.

7 Discussion and Conclusions

This section analyses the results of the study. It also reflects on how the study was conducted and what parts of the study were successful and which were more challenging.

7.1 Summary

This study focused on improving the system quality in the case company by transition from individual part ownership to the shared system ownership. To achieve this goal, this Master's thesis investigated relevant factors affecting the system quality of products that the case company designs and produces. The study started from the business challenge of the electronic systems not meeting the desired quality requirements. This topic seemed quite extensive and challenging and a little vague to start with and focus on quality was a good way to confine the broad topic.

The study was conducted in five steps where first business problem was defined, then the current state analysed and the existing challenges identified related to the system level quality of products. Then the existing knowledge was studied focused on finding best practice to address the identified challenges. Then a proposal was built together with company employees and finally presented for feedback. The study used qualitative research methods and interviewed stakeholders and employees from different positions and teams.

The current state analysis started with drafting the topics and questions and finally holding the interviews with the selected informants. The interviews were open and eye opening. Discussions were profound and different items off topic were also discussed. Major themes started to emerge from the discussion. After the interviews, the weaknesses of current state analysis were identified based on the interviews. Topics were categorized into three themes: Collaboration, Ownership and Tools. These three themes pointed to the directions where to concentrate in the existing knowledge. Material related to leading collaboration, defensiveness in collaboration, silo-effect, FRACAS, Agile product ownership and transparency were studied. The three themes were kept as the basis of building the conceptual framework around the topics and then taken to the next step of building the proposal.

As the outcome of the study, a proposal was built that suggested a new flexible ownership, a more collaborative environment and support tools for the System Owners to use and manage quality issues. In the building of the proposal the conceptual framework and the findings from the current state analysis were merged and brought to the co-creation session. During the meetings some items came up such as how to engage the owners in using the FRACAS tool, merging the proposal to the current change process, handover of project phase to product phase and evaluation costs of poor system quality. These items were discussed and were taken into account in the proposal for those items that were possible. Finally, the proposal was presented to the original business challenge compliers and final comment were discussed and evaluated and fine tuning to the processes were made accordingly. Additionally, the corrective action system was taken into more extensive use especially in one team responsible for PCBA electronics.

The main finding in this study is the work model how the case company could transit from Individual Part Ownership model to a Shared System Ownership model. Subprocesses for the transition are related to three main themes: Collaboration, Ownership and Tools supporting this. A new Shared Ownership work model was suggested and the use of a Lifetime FRACAS tool to record the quality issues.

The study also made recommendations for the case company how to put the proposed model for the shared system ownership into practice, so that the case company can change from the individual product ownership to a shared system ownership work model. The Lifetime FRACAS system was recommended to make the quality items transparent in general description level and support collaboration between teams. This also keeps the confidentiality of the sensitive items and change requests attached and linked under the Corrective Action. I the PCBA team of the case company the FRACAS tool was taken into use in certain products to record the quality issues.

Another recommendation relates to the database of Corrective actions that can be used as a Lessons Learnt database to review in other design changes and new product designs. The database works also as a communication channel between teams and units to create a more collaborative way of working and solving quality items together.

The proposed shared system ownership will bring transparency of quality issues between teams and units. This will result in improved collaboration between teams and

better system quality in the long run. Findings of this study can also be used for building a more collaborative team hierarchy for complex system design. The finding suggest and alternative approach in building an organization to support complex system quality. The transformation will create the basis for an improved system quality design as well a more systematic way for recording and solving quality issues on a system level.

7.2 Next Steps

From the outcome of the study, some ideas for further steps came up. Further research could be focused on the interface design in between the parts of the system. How this could be standardized or how the system could be more modularized.

The study's topic seemed at first quite soft, and the focus tilted a little more in what is the current interface and interaction between the teams, and units and stakeholders, and the steps to improve it. After this is improved the next step would be focusing in the interfaces and interaction in the product.

7.3 Evaluation of the Thesis

This section evaluates the outcome of the thesis and compares it to the original objective. Finally, reflection on the validity and reliability of the thesis is discussed

7.3.1 Outcome vs. Objective

The objective of the thesis was to create a work model to improve system quality. The outcome is a work model that is trying to support system ownership and collaboration between the owners to improve system quality in the long run through design and continuous improvement.

The process is to encourage part owners to come out of their speciality even just a little bit to understand the system and dependencies their part has in their system. The aim of this would open the part owners eyes and give a more system level perspective for the owner.

From the management view point, the work model creates a database that can give a powerful insight into system design and innovative ideas for design changes and new products.

7.3.2 Reliability and Validity

The validity of the study was achieved with the divers selection of internal informants selected in section 2.3. The interviews for Data 1 were planned with a set of topics and questions to guide the interviews. The interviews were recorded and analyzed and used to create a Current State Analysis.

Interviews for Data 2 were co-creation sessions, where found topics in Current State Analysis and Conceptual framework was discussed and ideas related to the items highlighted. Interviewees selected for the co-creation session were Quality Managers and Category Managers. These sessions drove the main points where to focus in when creating the proposal.

Interviews for Data 3 was done in individual feedback sessions where the proposal was discussed and comments about risks and

The Current State Analysis drove the themes that were selected as the basis for the existing knowledge studied. The three main themes: Ownership, Collaboration and Tools were kept as the basis of the study through the whole study; Current state analysis, Conceptual Framework and the Proposal.

The subjectivity of the topic and researcher was discussed and my role, the researcher's, is pointed out to be a part owner. The outcome was aimed to be as objective as possible though it can have an impact on the researcher's, my work model.

7.4 Closing words

The topic turned out to be very interesting to study and the process of the study was enjoyable. The interfaces between people, parts and systems give an interesting perspective to look into deeper. For improved system quality the interaction between indi-

vidual parts needs to be taken into account, but the people designing the parts and the systems need to interact and collaborate effectively first.

References

Gillham, B. (2010), *Case Study Research Methods*, London: Continuum.

Case company (2016). Technology and R&D, Manage product changes. (Internal document) Accessed from: Company intranet. (Accessed: 30th April 2016)

Sheffield, J., Sankaran, S. and Haslett, T. (2012). Systems thinking: Taming complexity in project management, *On the Horizon.* Vol. 20(2), 126-136

Finnie, W. (1997), Strategies, systems, and organizations: An interview with Russell L Ackoff. *Strategy & Leadership*. Vol. 25(2), 22-27.

van Mierlo, M., Leeuwis, C., Smits, R., Klein Woolthuis, R. (2010). Learning towards system innovation: Evaluating a systemic instrument, *Technological Forecasting and Social Change*, Vol. 77(2), 318-334

Kniberg, H. (2012). Agile Product ownership in a nutshell. Accessed from: https://dl.dropboxusercontent.com/u/1018963/Articles/PO-in-a-nutshell.png (Accessed: 20th January 2016)

Ghahrai, A. (2008), Website, Testing excellence: V-model. Accessed from: http://www.testingexcellence.com/v-model-in-software-testing/ (Accessed: 30th April 2016)

Ghanim, Y. (2015), The Adapted V-Model: A Practical Approach to Agile Testing, *International Journal of Software Engineering*, Vol. 8(2), 43 -67

Goh, A. (2015), ROFO principle generates ownership, commitment and team learning – mindset change before implementing total quality management, *Total Quality Management & Business Excellence*, Vol. 26(7-8)

Tamm, J (2015), Cultivating Collaboration: Don't Be So Defensive! TEDxSantaCruz Published on May 26, 2015
Accessed from: https://www.youtube.com/watch?v=vjSTNv4gyMM (Accessed: 16th March 2016)

Ibarra, H. and Hansen, M. (2011), Are You a Collaborative Leader? *Harvard Business Review* Vol. July–August 2011. 69-74

Tett, G. (2015*). The Silo Effect: The Peril of Expertise and the Promise of Breaking Down Barriers,* New York: Simon and Shuster

Smith, R. and Keeter, B. (2010), Up time magazine July 2010
Accessed from:
http://www.nxtbook.com/nxtbooks/reliabilityweb/uptime_20100607/#/46
(Accessed 07th March 2016)

Norman, S., Avolio, B. and Luthans, F. (2010), The impact of positivity and transparency on trust in leaders and their perceived effectiveness, *The Leadership Quarterly*, Vol. 21(3), 350-364

Appendix 1.

Topics and questions for interviews for DATA 1 collection

Is there a quality issue related to your product which you remember and how was it solved?
Did it require collaboration with another team or unit or stakeholder?
Who were the different stakeholders in the case?
How did the collaboration work?
Can you give an example of successful collaboration?
What made the change possible?
Why was it a success?
Is there any obstacles in smoothly implementing a quality change?
Can you give an example of unsuccessful collaboration?
Why did it fail?
Who leads the collaboration in your example?
Is a collaborative leader needed?
Who makes the decision of the change in your example?
Is there a process for this?
Who are involved in this?
Motivation, resistance? Ways to commit?
What makes and issue/improvement/change go forward?
What makes and issue/improvement/change to stall?

Appendix 2.

Example of Field notes of Interviews

Field notes, Interview 5, Data1

Details:	
Interviewer	Eero Putkinen
Interviewee code	Informant 5
Position in company	Project Manager
Date	1.2.2016
Duration	49min
Document	Field notes based on recording
Language	Interview done and recorded in English.

Topic	**Question**	**Field notes**
Quality problem solving and collaboration	Could you give an example of a quality improvement or change that required collaboration between teams?	Categories.. are the owner of the component ,but not the expertise in the component. For example a category don't have resources and the expertise to do mechanical. So that's the collaboration part between two different categories. As the project manager I see the overview and what needs to be done. Then they get the support needed from the mechanical team.
Quality	How to solve quality issues?	From the category a one of the key things there is the priorities. Once the priorities are set then they start asking "hey there is this project…" and they get the ball rolling basically. For the projects that have been running. Component owners are working with many projects and in those many projects they just need to set which is the priority to start with. Each know what is the priority based on business need or safety. Safety is always no 1 then business need.

		It's a little bit different because the projects I'm running are not like firefighting. Because we are implementing new even if we are replacing old products. Basically if it's related to customer feedback to fix those is the product owner's responsibility to do the firefighting. For the new thing we just need to ensure the quality that the feedbacks have been considered.
Product structure	Owner of quality issue	We filter those feedbacks by a team who are defining if its platform or component. It's a rough estimation if its platform or component then it will be received in owner's side. If its component level then they will open change request
Product structure	Platform level case	Usually it is considered unknown So many factors of source of root cause. It will be handed to platform but we don't know which component it is. There are several things from the platform need to check to confirm which could be the potential. There is no flow chart to follow if this is this then this. It's variable and unknown. There is many ways to improve it e.g. feedback data quality. Customer can do what they want with the device even if it is out of configuration and specifications.
Lessons learn and where they are stored Change re-	Example of Component level case?	Compatibilities are a problem. We are updating components in general. Whatever we are creating and it's not backwards compatible. If it's not backwards compatible you might have to update everything. It's difficult for us to keep in track easily if its backward compatible. What we can do as a project we can just send the lessons learnt but The component owner needs to take [into account] what are the next specifications. It just goes to the project folder not necessarily in someone's hand. Once the CR is open. Platform they only follow content of the

quests Change requests		release what CR should be part of the release. If they have sub CRs they open to component level. Not all cases do [create] sub CRs. Because CR is a bit light and spec and title can change dramatically. If you have linked those together and CR change scope and schedule. CR should not be able to move to next milestone. It can end up as a back log but then it might be too heavy. CR is created to be like this special function. And you prioritize what is the most important things. If you make this as big as possible it will end up too heavy to move forward. In one CR there is twelve sub CRs. The main CR might not go forward because of the one sub CR.
Ownership	How to handle priorities?	First thing is who's the owner? If the owner is not available price resource then they will ask different categories if its possible to move somewhere else. The key driver is priority and resource available. Every category has many other projects and I cannot make them say that everything in my project is important. Categories decide themselves what do they think is the important one. Sometimes mindset to see what is important to them then it will work. They have to see what is important. There is many things going on and it's the focus orientation. As a project manager role it's his role to filter and focus what is important and what need to be done. In their priority list. Even thou you keep pushing it depends on the situation. One category can move further ahead is nothing to do with commitment or collaboration. It's whatever they have on their desk which I cannot control.
Priority, Transparency and workload	How to handle priorities?	Based on the new tools you estimate the workload but you always see the day what you think is important. Now with the visibility who the ownership are in different countries now. If you don't have the visibility to support, see, meet work together under one roof it's quite challenging. The feeling of them working and what level busy or not. Only if you are there

		or relay close by you can feel the intensity of the workload. That is the lacking part. Meetings taking their time away.
Transparency	What drives importance of item?	Business need, priority. If you high light its important they will commit. Each category is running many unknown important things none of us know. None of us know what is important on category side they have a list we don't even know. I don't know what is important for you and you don't know what is important for me. Everyone has different expertise and priorities. That the scrum meeting to see the big picture. In the epics we are limited to some categories. Its hundreds of projects every year. I guess there's only three two persons who can prioritize.

Appendix 3.

Agile Product Ownership in a nutshell (Kniberg 2012)