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Identifying Product Defects by Utilizing Component Non-conformity Data

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Preface

For the past eight years I have had the responsibility to provide support in cases when a product has been found to fall short of the initial performance promises. In many cases a small change in usage of the product may result in different results, but major design changes are always about magnitude of the defect to indicate the need of such effort. In big organizations the required data are scattered between organizations with limited or no responsibility to support product improvement, and to me this is a big issue.

Therefore I felt highly motivated to provide my input in a form of this Thesis to someday make decisions based on hard facts instead of insufficient data. The complete learning process behind this study has made me aware of the sides of product improvement and especially reliability engineering I have never even considered. However, this Thesis shows but a snapshot of a bigger and more complex real picture behind the product improvement process, so that to provide the reader with a crisp and clear journey from the beginning to the end proposals.

I would like to acknowledge the talented support provided by superb lecturers of Helsinki Metropolia University of Applied Sciences, especially Dr Thomas Rohweder and Zinaida Grabovskaia who provided me with valuable comments and advice throughout the process, as well as Dr Satu Teerikangas, Head of Master's program in Industrial Management. I wish I would have used your services more systematically. In addition, the study would have been impossible without great support from the case company informants, who are not identified here for confidentiality reasons, and especially the statistical expert group which helped to bring multiple organizations together and enabled this study to be more than just proposals. Additionally the study would not be the same without the support received from my peers in the unpredictable surroundings of EK. Finally the biggest gratitude must be given to my family and friends, especially my girlfriend, for all the understanding required to be able to pull through a short but intensive period of my life. Thank you all for making this Thesis possible.

Esa Ylivainio
Helsinki, 25th of May 2016

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This Thesis focuses on identifying product defects in an industrial product consisting of thousands of individual components. An industrial product with a lifetime of several decades may involve intense maintenance operations and, as a result, there are multiple warranty and post-warranty periods scattered along the product lifetime. Hence, design errors require to be screened from many sources of data in order to be able to systematically act on issues causing impacts to the end user. To be able to act systematically, two types of sources are required to build an improvement business case, first, the quantitative sources to know which cases require attention and, second, the qualitative sources to know how the issue could be fixed. Currently, the case company is lacking the quantitative sources which cause incomplete business cases and possibly some issues being missed.

The objective of this Thesis is to propose improvements for the current screening processes when identifying product defects. The proposal is to include the sources with valuable information of performance failures when components do not meet customer expectations, regardless of the warranty status of a product or a component. The study is conducted as a case study and start by analysing the case company current processes related to non-conformity screening. When issues with the current processes are identified, findings from best practice of reliability follow-up are combined with stakeholder ideas to create proposals for improvements.

The output of this Thesis is the proposal to improve the coverage of quantitative statistical data for identifying product defects collected from non-conformity cases.

The case company can benefit of the Thesis by aligning quantitative data sources to better match the already established qualitative sources of data in order to create solid business cases for the product improvement process. In addition, new data sources may be able to raise awareness of issues which may have previously remained undetected.

Keywords	Product improvement, identifying product defects, product reliability, non-conformity data sources, warranty data, post-warranty data, quality management.

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1 Introduction

In a modern company it is typical to emphasise response times and efficiency of customer support in case customer faces challenges with a product. The data gathered through communication with internal or external customers lead to massive amount of data based on individual cases. If a product or a part of a product has repetitive challenges to fulfil customer expectations, more demanding actions such as re-designing of a weak spot might be required. A business case of a specific phenomenon is a way to justify and prioritize the efforts needed to re-design, test and validate the improved function. And a business case needs facts, not opinions.

To get the needed facts of non-conformity cases requires a systematic follow-up from the supplier, but the relevant data may be fragmented between multiple organizations with different responsibilities, if the data is even correctly collected. The person answering on the customer service phone or e-mail, or the one registering a claim, is rarely responsible for the function of the part in question. Hence the critical data needs to reach the key players who decide at which point actions require to be taken in order to prevent the same non-conformity from taking place in the future. Although IT systems and databases constantly develop further, they do not help unless an idea how to utilize them is considered.

An example case could be found from automobile industry. A new car comes with a warranty, but it does not cover the most typical non-conformity parts, for example, spare parts defined as “consumables”. These parts tend to have a separate shorter warranty after every replacement. The challenge is to collect data at the component level if something fails prematurely during the spare part warranty periods when parts have been installed by, for example, a network company. Or if something fails in post-warranty before a specified replacement interval. Timing belt failure on a car engine, an aircraft engine failure, or a ship engine failure due to one specific component in post warranty but before scheduled replacement are highly inconvenient, and often expensive.

Non-conformity cases are something suppliers want to avoid, but simultaneously maintenance intervals are pushed as far as possible to be able to provide an offer with the lowest lifecycle cost. Major incidents may understandably be noticed by the supplier even if taking place during post-warranty, but most likely there is a high number of smaller and less critical issues of non-conformity resulting in more or less inconvenient situations impacting on customer satisfaction.

This Thesis focuses on utilizing the data sources to systematically screen product non-conformity in order to be able to prevent similar issues in the future.

1.1 Case Company Background

The case company of this Thesis is a global leader in complete lifecycle power solutions for the marine and energy markets. The main products consist of large combustion engines operating on a variation of fuels. The company has operations in over 200 countries and has close to 19,000 employees worldwide. The total net sales of the company is approximately five billion euros. The company is thriving on the brand created over the past 150 years as a responsible business associate, and willing to use its expertise to solve customer's issues. While products have become more diverse, flexible and complex over the last few decades, competitive Operation and Maintenance (O&M) combined with reliability over a long product lifetime have remained the key factors that customers are looking for. These values raise the significance of properly planned maintenance intervals and capability of components to be able to meet the defined maintenance intervals.

1.2 Key Concepts

Research and development of a new product rarely end up in an absolute reliability of the new product. It happens due to numerous limitations including a practical long term testing in different usage and boundary conditions, and simply due to costs of testing multiple scenarios. This is a commercial risk companies take to release new products when they still are new to the market. To release a product with tempting O&M costs, the maintenance intervals of the engines are often prolonged from the previous product. In case intervals are pushed too far for this design to sustain, customer expectations formed by the total cost of ownership calculation, i.e. Life Cycle Cost Analysis (LCCA), and reality do not meet. As a result, product improvement analyses what needs to be done to fix the gap.

To be able to fulfil its task, product improvement requires an efficient follow-up from the field. Individual or random cases are one thing, but the key to making a difference is the early actions to prevent epidemics, i.e. systematic non-conformity of the component failing prematurely. For this end, the organizations responsible for product improvement needs to connect quantitative statistics of the case and qualitative reasons, or symptoms, of a reliability issue to be able to act.

Tracing of these non-conformity patterns of components requires accurate statistical quantitative data. But it might prove challenging to collect these data due to a company size and organizational layout. Fragmented product portfolios, separated organizations, an increasing number of databases and “silo effects” are just a few examples adding to the challenges of collecting usable statistics in order to actually understand the complete magnitude of the issue in question.

1.3 Business Challenge

To guarantee proper function of the products the case company has a process to improve existing products and parts of the product, called Product Improvement Process (PIP). Over the years the author of this Thesis has witnessed several times a component being taken to PIP, but then it is found that design belongs to a supplier and issue gets complicated. When the supplier is contacted, the first question is “Why we have not received claims?” followed by “Do you have statistics of the failures?”. The first question is about vendor claiming and relevant, but not the one considering PIP. The second question then again related to the PIP, as only solid business cases should be in the PIP. For some reasons statistics formed by quantitative screening of a component often are highly positive, compared to expectations formed by qualitative sources such as troubleshooting communication tools. It is maybe natural that massive negative feedback through qualitative sources lead to an issue being taken directly to PIP, but when supplier is involved the case changes. By default, suppliers are not willing to invest on re-design efforts, in case statistics do not support the task.

1.4 Objective and Scope

The experience gathered with PIP indicate a mismatch between quantitative and qualitative sources causing inefficiency in the process. Something needs to be done to be able to act on the repeating failures, even if the design is owned by a supplier. Thus, the objective of this thesis is to propose improvements to gather statistical data feedback of non-conformity regardless of warranty status of a product or a component.

The scope of this Thesis is to understand different organizations responsible for the customer support in case of issues at different points of life cycle, and challenges involved in them from the perspective of the Thesis. This is approached from product improvement point of view, excluding product development and operations development from the scope. In addition, this thesis is limited to internal processes while admitting possible impacts on for example suppliers.

The outcome of this Thesis is final validated proposal for improvements to increase coverage of quantitative statistical data collected from non-conformity incidents.

The Thesis is divided into 7 sections. Section 2 elaborates on methods to reach the mentioned outcome by presenting research approach and design, data collection for the use of the thesis through various methods, as well as validity and reliability plan of this thesis. Section 3 forms Current State Analysis (CSA) of the case company on a top-down approach, starting from product improvement and ending up in the comparison of currently used data sources to the ones potentially viable additional statistical sources related to non-conformity feedback. The CSA end result is a summary of strengths and weaknesses, while focusing on what requires to be improved. Section 4 approaches the best practice of why reliability is significant, how reliability issues such as non-conformity could be followed, and which organization should govern the follow-up of reliability issues. The section ends in Conceptual Framework (CF), on which the main components of relevant best practices are presented. In the Section 5 the CF is merged to CSA results to start drafting the proposals with alternative options. The section continues on refining the draft proposals into proposals with support of key stakeholders. Section 6 is the validation of the proposal, where recommendations are gathered, final proposal is formed, and eventually validated. Section 7 includes discussion and conclusions of the thesis together with the evaluation of the Thesis itself.

2 Method and Material

This section discusses the research processes and data collection for this study. Additionally it provides a plan to avoid biases or other factors impacting on this study in the form of validity and reliability plan.

2.1 Research Approach

To select a proper research approach for this study the target and boundary conditions require being considered. The main question is *how* to statistically identify product defects to ensure the reliability of products through corrective actions, and *why* is it significant to have this availability of statistical data.

Theories presented by Yin (2009) define Case Study (CS) research as the preferred method in situations when the main research questions are “how” and “why”, matching well with the study. Action Research (AR) on the other hand would suit the case as well, as according to Coughlan et al. (2002: 223) AR is well suited for organizational issues which are expected in a study of statistical data collection from multiple sources in a large corporation. However, when AR focuses on research *in* action, CS focuses on research *about* action, and in a case with limited opportunities to perform trial-and-error tests, the CS approach is preferred. If circumstances would support testing of the outcomes, then alternative methods would become tempting.

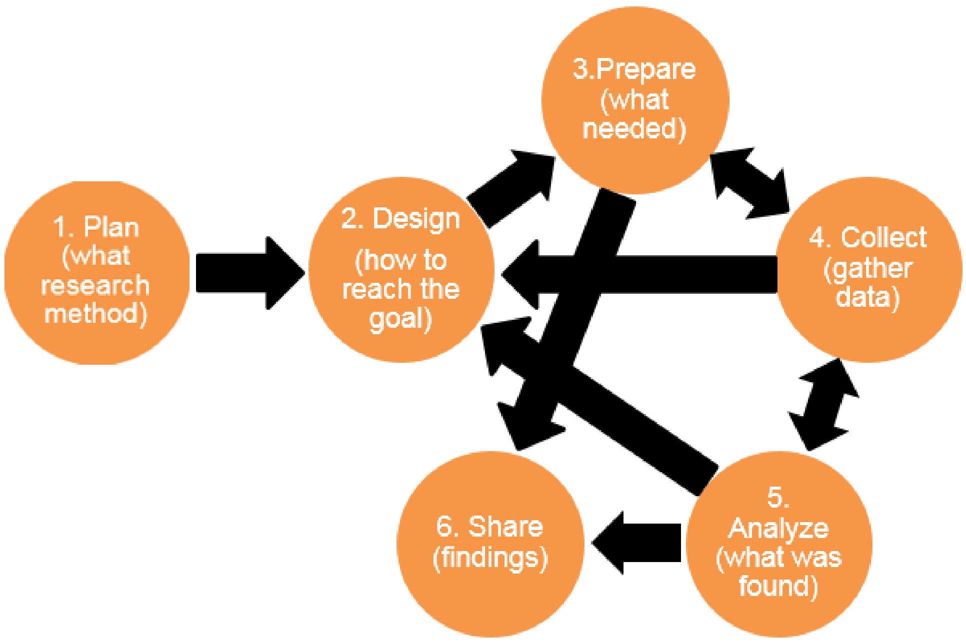


Figure 1. Case study research based on model by Yin (2009).

This study follows a rigorous methodological path of CS guideline defined by Yin (2009), as shown in Figure 1, and started in this study by planning what is be studied, and what research method is appropriate for the cause. The step number two is design of the study to be able to reach the goal, and is presented in the following section 2.2 Research Design, which provides a more detailed explanation for the remaining steps of the study. The step number three is preparation, i.e. what is needed to get the required information, and is provided in Section 2.3 Data Collection and Analysis including iteration in a form of multiple data collection rounds. Together with the data collection rounds the steps from four to six are repeated in this study and form Sections 3, 5 and 6 to eventually have a final outcome.

2.2 Research Design

The design of this study is formed into separate steps, as presented in Figure 2. The figure provides each step with the goal, data source, and expected outcome.

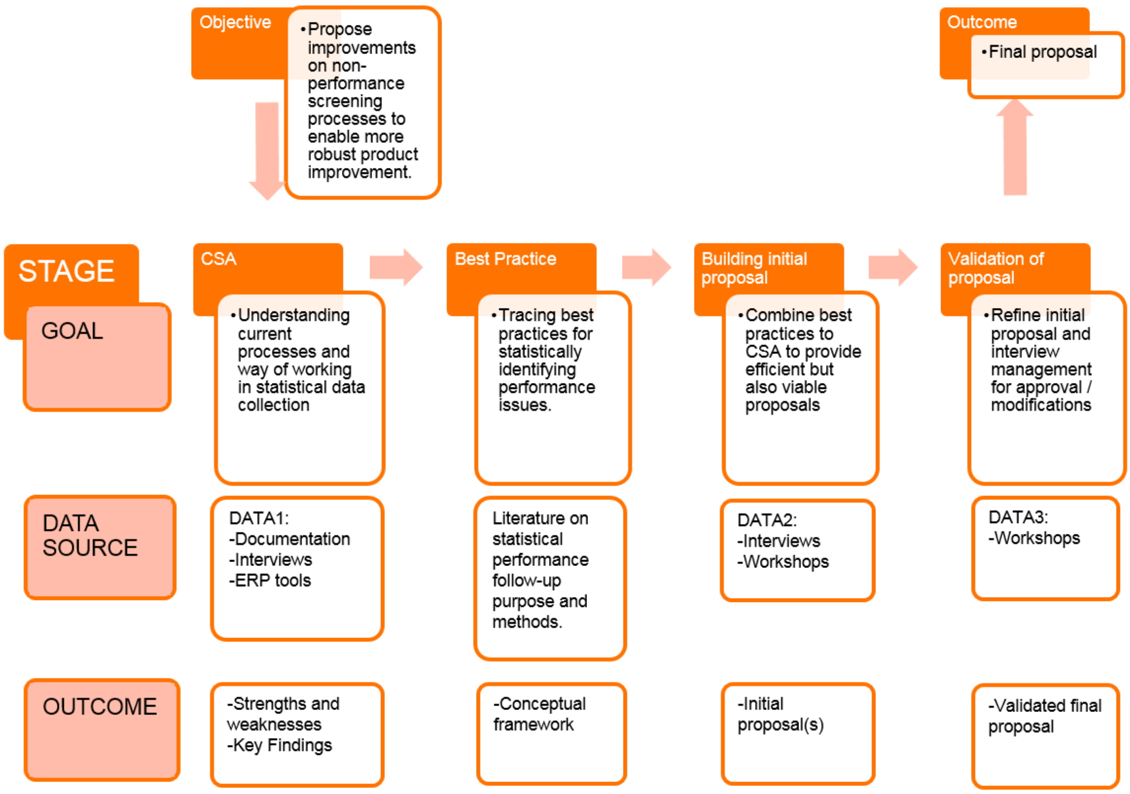


Figure 2. Research design of this Thesis.

As seen from Figure 2, the research process starts in Section 3 by clarifying how the case company is currently operating related to the non-conformity screening, which forms the Current State Analysis (CSA). This includes Data 1 collection and ends up in understanding of strengths and weaknesses of the current processes. At the end of CSA, impacts of the most serious weaknesses are discussed to know what needs to be improved. In the next step, best practice regarding the focused weaknesses is searched from the relevant existing knowledge to provide ideas for the Building of Initial Proposal. To build the initial proposal, Data 2 is gathered and key persons are involved to draft and refine the actual proposals. At the last stage, the proposal is provided to the management for approval, in a form of a Data 3 collection round, to discuss and validate the proposal. The validated final proposal is a result of the Thesis project, but to reach this point a lot of data needs to be collected and analysed.

2.3 Data Collection and Analysis

Data collection for this study is created based on such qualitative data collection methods as interviews, documentation and observations, stated to be typical for the case study by Dubé and Paré (2003). In practice these mean three main sources of data collection: (a) the company internal documents or intranet definitions to understand processes and guidelines for way of working; (b) interviews and a workshop with the key stakeholders to verify internal document validity and to gather non-documented information or ideas to utilize; and (c) tools to access the company ERP-system data to both confirm gathered information and evaluate data availability. All these data make the primary data collected by the researcher. Some exceptions take place in a form of data extracted by others and provided in a form of, for example, Excel documents, but secondary data with possible reliability issues are kept to a minimum.

The study includes total of three data collection rounds, described in more detail below.

Data 1 defines the starting point of the study and forms the Current State Analysis (CSA). In this first round of data collection, all three data sources are used as shown in Table 1.

Table 1. Data 1 collection for CSA.

	Description	Page/total pages	Doc. Number
DOCUMENTS	1. Product Improvement Process definition	-	Intranet info
	2. Non-conformity directive	8 / 40	DBAB622574
	3. Issue Identification general presentation	2-3 / 6	DBAD875292
	4. Issue Identification intro to service units	7-8 / 14	DBAD474621
	5. Project and product warranty definitions	-	Intranet info
	6. Bright Sky training presentation	67-78 / 99	DBAC015023
	7. Customer Assistance Procedures	17 / 25	DBAA118674
	8. QlikView definition	-	Intranet info
	9. Spare part claim definition	-	Intranet info
	10. Product manuals	-	Confidential
	11. Business & Support Function News	-	Intranet info
	12. OS - Operational Procedures	4 / 7	DBAD703615
	13. Presentation of spare part discounts	3 / 5	No document number
INTERVIEWS	**Position**	**Date + Duration**	**Documentation**
	1. Global Logistics Services, GM	4.2.2016, 20min	Skype interview, audio & video recorded.
	2. Customer Assistance, Non-conformity data analysis & reporting expert	10.2.2016, 30 min	Skype interview, audio & video recorded.
	3. Global Logistics Services, Claim manager	10.2.2016, 1h10min	Skype interview, audio & video recorded.
	4. Customer Assistance, Non-conformity data analysis & reporting expert	11.2.2016, 20 min	Skype interview, audio & video recorded.
	5. Quality Management, GM	18.2.2016, 30 min	Skype interview, audio & video recorded.
	6. Business Control, GM	31.3.2016, 25 min	Skype interview, audio & video recorded.
	7. Product Management, Business Controller	31.3.2016, 27 min	Skype interview, audio & video recorded.
	8. Pricing Manager	31.3.2016, 34 min	Skype interview, audio & video recorded.
TOOLS	**Tool**	**Description**	
	1.SAP Logon 730	The case company ERP system access portal, utilized to confirm data throughout the process.	
	2. QlikView with Issue Identification tool	A tool combining quantitative data in SAP to multiple qualitative data sources. Used to trace reliability issues in field.	
	3. QlikView with Non-conformity Analysis tool	A tool used to trace non-conformity costs and FOC deliveries based on SAP data.	

As seen in Table 1, the case company CSA starts by approaching the company documentation to gather qualitative information regarding internal processes, definitions and responsibilities. The interviews are conducted in parallel to confirm instructions, the way of working, and to find correct key individuals to contact for further details. Just as the documentation, the interviews may be divided into specific organization functions such as spare part logistics (Global Logistics Services), product warranty department (Customer Assistance) and quality department (Quality Management), while Pricing and Business Control provide additional data.

In addition, the interviews could be divided into management level on interviews 1, 5, 6 (up to GM level) focusing on question “Who can provide detailed information about this case in your organization?”, in case the company documentation is found lacking a solid touchpoint able to answer the questions raised during the process. The remaining interviews 2, 3, 4, 7 and 8 are conducted with experts of specific details vital for this Thesis and focus on questions “How do we currently operate, why, and what is the end result of this?” Videos of interviews and workshops performed over Skype are confidential material including the transcripts of the interviews. To secure validity of this study a screenshot of the recordings gathered is found as Appendix 1 with data collection rounds separated.

In addition, few tools are utilized to confirm both qualitative and quantitative data gathered in the ERP system to check what data actually exists. Unfortunately, the extracted data is classified and only relevant key points, and some pictures are shown in this thesis.

Due to the amount of data collected for CSA, the data is not analysed in a separate section within CSA, but instead the data sources are presented when utilized in the process.

Data 2 collection follows the logical path from the point where the company documentation ends, and some new needs appear to be considered. Data 2 consists of interviews, a workshop and s document received as a result of the interviews.

Table 2. Data 2 collection for building of proposal.

	Position	Date + Duration	Documentation
INTERVIEWS	1. Management System, Manager	5.4.2016, 50min	Skype interview, audio & video recorded.
	2. Parts Coordination Management, Manager	6.4.2016, 26 min	Skype interview, audio & video recorded.
	3. Global Logistics Services, Claim Process Development Manager	11.4.2016, 22 min	Skype interview, audio & video recorded.
	4. Quality Management, Senior Manager	21.4.2016, 50 min	Skype interview, audio & video recorded.
WOR KSHO	**Participants**	**Date + Duration**	**Documentation**
	1. Product Sales Area Manager + Product Sales Senior Sales Engineer	18.4.2016, 40 min	Skype workshop, audio & video recorded.
DOCU- MENTS	**Description**	**Page/total pages**	**Doc. Number**
	1. Excel document containing all spare part claims from year 2015. Extracted from SAP.	Excel document	Extracted data, no number

As with Data 1, the interviews arranged for Data 2 focus directly on key individuals relevant for building the initial proposal, i.e. experts from specific organizations are interviewed with a the main questions being derived from Sections 3 and 4 as “Is the existing data reliable?”, “How could we make it reliable?” and eventually “How could we implement this source of data in the existing data collection tools?”. Interview number 2 is linked to workshop 1 within Sales organization to build a proposal for Sales department, while interviews 1 and 3, and document 1 focus on separate proposal for Global Logistics Services. Interview 4 conducted with Quality Management aims to confirm the proposal ideas from the organization responsible for quality issues, and to answer any funding needs required for implementation of the proposals.

The last data collection is round 3, presented in Table 3. This includes feedback session for the initial proposal with the management in a form of workshops.

Table 3. Data 3 collection for validation of proposal.

	Participants	Date + Duration	Documentation
WORKSHOPS	1. Global Logistics Services Claim Manager + Customer Assistance Non-conformity data analysis & reporting expert	15.4.2016, 60 min	Skype workshop, audio & video recorded.
	2. Sales GM + Parts coordination man. + Product Sales Man. + Quality Senior Man.	2.5.2016, 30 min	Field notes.
TOOLS	**Tool**	**Description**	
	1. QlikView with Non-conformity Analysis tool	A tool used to trace non-conformity costs based on SAP data.	

The final data collection aims to validate the proposals as an end result of the process. Due to two separate proposals, there were two workshops conducted; one aiming to test the proposal in a workshop with key individuals from Global Logistics Services and Customer Assistance, and the other aiming to validate the proposal for Sales department together with Sales and Quality department managers. The tools utilized in the process are part of comparison between the existing data sources and the proposed new sources, with the aim to evaluate the results.

2.4 Validity and Reliability Plan

To secure quality in academic research, validity and reliability of this study require attention and a plan.

Validity according to Quinton and Smallbone (2006) refers to internal validity and external validity. Internal validity measures the outcome of the research, i.e. is the original question in line with the findings, while external validity assesses the capability of the results being applied to other contexts or situations, and to what extent could they be for example scaled up.

To ensure internal validity, this study aims to stay on the set objective until an outcome has been reached. To reach this, the study follow the predetermined steps of the Research Design, aided by the “Gate model” utilized in Metropolia University of Applied Sciences which includes mandatory presentation of each step visible in the Research Design before moving to the next one. In addition, Yin (2009) proposes three methods to increase internal validity; using multiple sources of evidence, creating chains of evidence, and let interviewees review the draft of the research. The study includes triangulation of data to guarantee data validity (and to avoid misinterpretation), and in many cases interviewees are requested to practically show the tools or cases they are referring to while video is recorded. Additionally a chain of evidence is used and elucidated. This serves double purpose as not all interviewees are well aware of the product improvement process and presenting case visually helps to understand the circumstance.

To ensure external validity is more challenging in a study with qualitative approach to collect quantitative data, but according to Quinton and Smallbone (2006) some writers do not consider external validity relevant. However, the study aims to follow a logic that may be implemented into cases with similarity to some extent.

Reliability of a study is determined by repeatability checking if the same outcome were reached it the study was conducted at another time, by another person, or by another method (Quinton and Smallbone 2006). In the context of this study, since the business world is constantly changing into one direction or another, practical outcomes may differ. Practical solution to ensure reliability in this study is to use multiple sources of data and cross-check the information gathered. Confidential data sources present a challenge for reliability in this study that could not be overruled. Therefore, to improve reliability this thesis aims to use only documents with document numbers provided by the case company document server when document is uploaded. Exceptions to this are simpler definitions extracted from the company intranet as there is no document number.

Finally, this Thesis aims to avoid any biased views or opinions, but it requires to be noted that the author of the thesis has been employed by the case company for more than a decade and has been responsible of securing functioning of certain component types for about a decade.

3 Current State Analysis of Identifying Reliability Issues

This section covers the current state analysis of the case company. The target is to provide full scope of how component non-conformity is statistically followed in the company during the lifecycle of a product. This is performed to be able to evaluate which channels of statistical data sources are working properly and which possibly need further attention.

3.1 Overview of CSA

Due to the amount of information the findings of Data collection 1 is not presented in a separate section. Instead the process within the company is approached top-down and data sources are informed during the process where input has been utilized. The CSA starts by defining the actions aimed to be performed related to field reliability issues, and continues to focus on identifying of these issues. Once the current identifying is clarified, the section continues to clarify sufficiency of this action by comparing timelines of the identifying coverage to locate possible weaknesses.

In this section significance of the interviews increase while narrowing down on *why* something is not part of the identification process, and for the sake of clarity this Thesis is rapidly focusing to the quantitative data sources.

3.2 Acting on Identified Non-conformity Issues

The target of this Thesis is to eventually improve statistical data supply by proposals for the benefit of the Product Improvement Process (PIP). The best way to approach is to find out what the PIP and PIP cases stand for, and the definition is found in the company intranet PIP pages.

> *A PIP case always derive from a (realized or likely) product non-conformity occurring on the field (during pre-warranty, warranty or post-warranty). Basic criteria that leads to a PIP case is that problem contains fundamental impact on overall product reliability, where the root cause and solution is often unknown, and field modification is needed.* (Data 1, Document 1)

As stated in the definition, non-conformities are not bound to a specific warranty status. The term non-conformity is maybe common, but an accurate definition is found in the case company non-conformity directive document.

A non-conformity is a deviation from a requirement in e.g. a contract, specification, standard or process, or from an expectation. A non-conformity occurs when supplier fails to meet the defined scope, agreed performance targets, commitments or the expectations of the customer or other interested parties. (Data 1, Document 2)

From these statements it may be understood that non-conformities are followed by one way or another in direct warranty cases, but additionally in case the customer expectations are not met. In case a “fundamental impact on overall product reliability” is found a PIP case initiation is the end result. The company intranet PIP pages provide further definition on case evaluation.

For each PIP case, agreed facts (technical / technological, financial etc.) need to be collected systematically to assess the possible risk level for the company. All this is summarized as a well analysed "business case" based on which company Management can decide whether it is feasible to assign further actions for solving the problem towards the Customer. (Data 1, Document 1)

These statements outline the purpose of the PIP together with the rough idea of the process flow, but the information of “agreed facts” needed to be collected systematically is especially significant for this study. Systematic collection of for example financial data typically would mean analysed statistical data of warranty costs. The PIP itself or the outcomes are not the target of this study, but the step to decide which issues are taken into PIP, called Issue Identification stage, is relevant and visible in Figure 3.

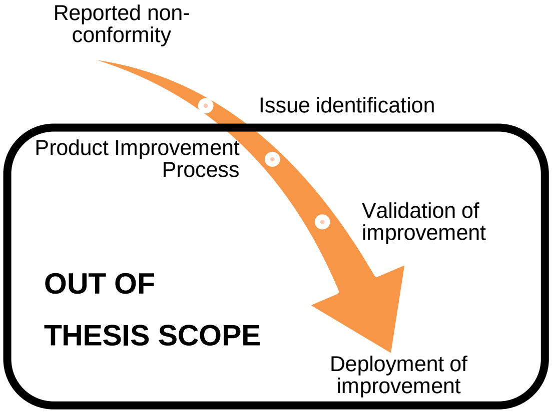


Figure 3. Simplified process flow based on Issue Identification General Presentation (Data 1, Document 3).

The main purpose of Issue Identification is to link reported non-conformities and PIP, i.e. perform problem screening from the field.

Issue identification is a systematic process to explore new issues based on data screening and information screening/sharing. (Data 1, Document 3)

When Issue Identification itself is divided into steps, the end result is three main actions, shown in Figure 4.

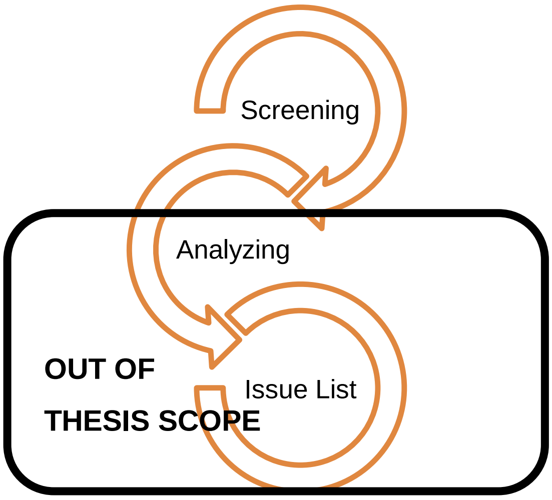


Figure 4. Issue Identification steps based on Issue Identification intro to service units (Data 1, Document 4).

To perform the screening step there is a tool called Issue Identification tool released in 2016 to collect best possible data of a specific material number through various sources. The creator of the tool was interviewed to understand the background as well as utilized data sources.

> *There has been an Issue Resolution project launched by Quality Department with a sub-project called Issue Identification. The purpose of this sub-project has been to find issues faster and provide information of issues to Technical Service.* (Data 1, Interview 4)

As mentioned, the sources may be divided into quantitative sources, which indicate the magnitude of the issue, and qualitative sources which aim to help to understand the reason behind reported non-conformities. This is illustrated in Figure 5.

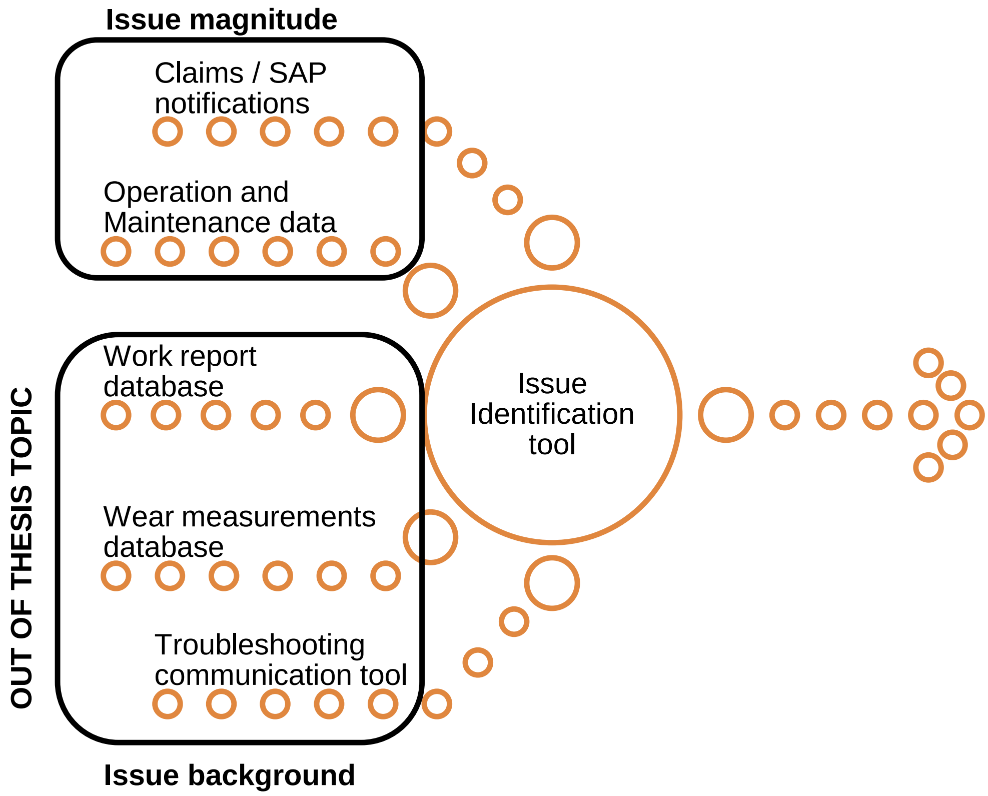


Figure 5. Simplified Issue Identification tool function. (Data 1, Document 4)

The sources behind issue background are separated for a reason: the qualitative sources are not built to provide the number of non-performing components. In addition, communication towards customers is not performed with real material numbers, but instead by general spare part numbers indicating a specific part of a product. In Issue Identification tool this spare part number is back-traced through SAP to give a “sophisticated guess” which material could be in question. (Data 1, Interview 4)

The sources able to indicate magnitude of an issue are divided into two. Operation and Maintenance data is collected from the customers with a maintenance agreement, but implementing this data into the tool has not been performed yet (Data 1, Interview 4). If found functional, it might provide high amount of data related to products or components being replaced or maintained, but only from customers with maintenance agreement. As this source of data is already under work, this study does not focus on it any further. The second source, Claims / SAP Notifications refers to warranty claim data collected into SAP, and continues in the next section.

3.3 Identifying Non-conformity Issues during Warranty Period

A field reliability issue should be noticeable one way or another, and as found in the previous section the case company is following claims / SAP notifications to make action evaluation based on numbers. Claims meant in the Issue Identification consist of two types, as explained by the tool creator.

> *At the moment we use only commissioning (claim) data and warranty (claim) data.* (Data 1, Interview 4)

Commissioning data and warranty data refer to two different warranty types. Commissioning data is officially *Customer Delivery Project Non-conformity*, which covers the customer delivery project non-conformity detected mainly during the installation and commissioning phase (Data 1, Document 5). This could be considered pre-warranty period as product is not yet in use. Warranty data then again refers to *Warranty Non-conformity claims* created by a customer related to a specific delivery project occurred during the warranty period (Data 1, Document 5), i.e. when product has been taken into use. A timeline of the two claim types is visible in Figure 6.

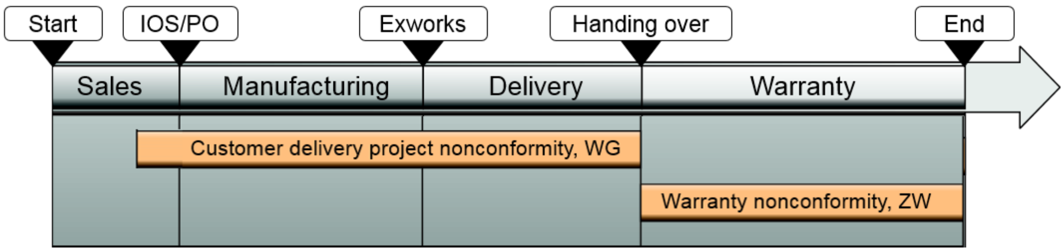


Figure 6. Simplified view of warranty periods over time. (Data 1, Document 6)

The main source of information is *Warranty Non-conformity* period, as product is in use and may face non-conformity issues. Period covering warranty claims includes three sub-types. By default a product has *Contractual Warranty* period of 12 months from handover and/or 18 months from product delivery, whichever occurs first. In addition, if there are any repeating issues with a specific component, then an additional *Contractual Warranty* may be provided for unspecified period of time. The third alternative is *Additional Warranty* as especially agreed extension of warranty to cover specific parts of the delivery. (Data 1, Document 7)

What this practically means is that by default warranty claims are only gathered during the first year of product use, but it may be extended in a form of continuing limited warranties to undefined period of time until specific issues have been fixed. What is significant is the arrow on Figure 6 extending further after warranty has ended, and this is a post-warranty period called *Lifecycle Services* (LCS). Product warranty claims with a default of one year coverage falls short of the product lifetime of several decades. The study continues to trace background of LCS not being implemented in the tool. Summary of the current findings are presented in Table 4.

Table 4. Summary of the current findings.

Statistical data source listed for Issue Identification tool		What actually is utilized
Claims / SAP notifications data	➡	Only Project and Product warranty claims, i.e. by default one year of product use covered.
Operation and Maintenance data	➡	Not implemented yet. Limited to customers with O&M agreement.

The Issue Identification tool creator was interviewed further, and the tool was found to run in a program called QlikView and extracts data from company main ERP system SAP. What the program does, is gather 4 years of data based on cost (or quantity) of a specific material being sent to a specific product type Free of Charge (FOC). This data is compared to the total FOC deliveries for that product type. All this is shown in a graphical form at monthly basis and a trend is calculated based on values over time. (Data 1, Interview 4)

To simplify: The tool indicates how big part is specific material from all materials sent to specific product type at monthly basis.

The program QlikView is stated in the company intranet as “Dashboard style interface lets business units, functions and organizations analyze all their data quickly and efficiently. This tool can be used for deeper analysis, reporting, forecasting for any type of information (Sales, Orders, Inventory, Production, Account Receivables, Account Payables, Estimates, Trends etc.).” (Data 1, Document 8).

Access to QlikView with Issue Identification tool add-on was applied, and function of Issue Identification tool related to statistical part of the tool was cross checked with the findings by using a relatively new material number with known defect performance.
How Issue Identification presents the historical trends is shown in Figure 7 below.

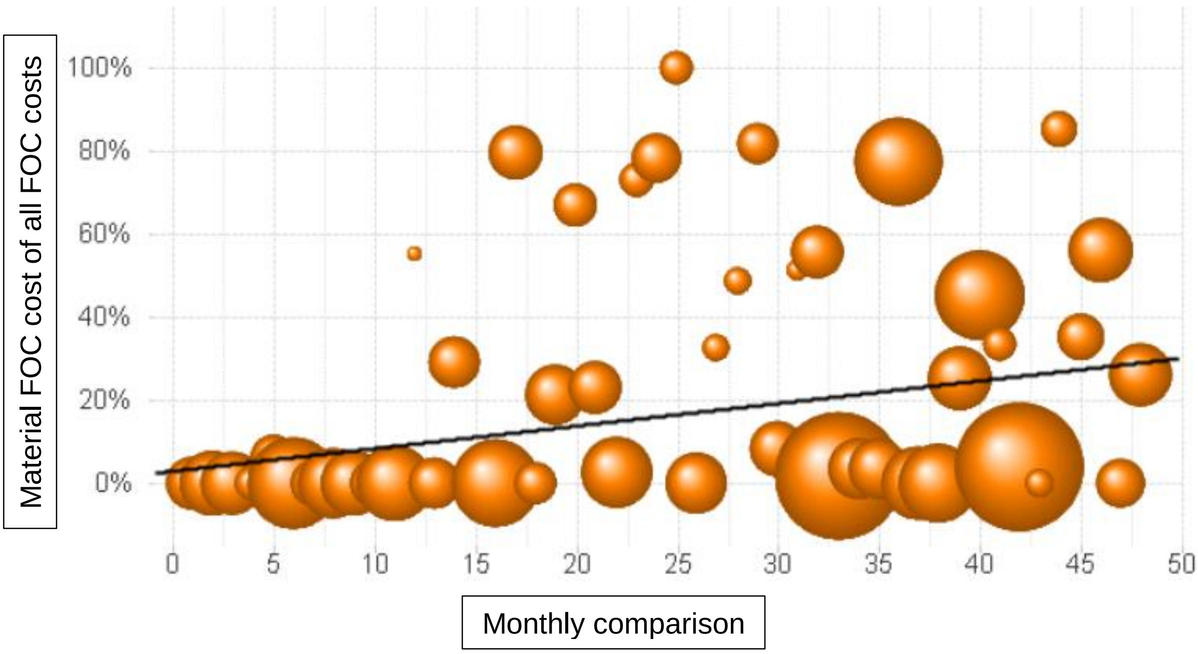


Figure 7. Issue Identification tool example of one material number. (Data 1, Tool 1)

The function or analysis part of the Issue Identification is not part of this thesis, but the relevance of FOC costs / number of sent parts to the function of the tool is important.

Access to another QlikView add-on called *Non-conformity analyzer* was also provided, enabling access to SAP claim data. FOC data extraction for the two utilized data sources (Project and Product warranty claim data) were checked, shown in Table 5.

Table 5. Example cases of tracing material number warranty non-conformity statistics from QlikView using Non-conformity analyzer. (Data 1, Tool 2)

Source type	Example of FOC data from QlikView	Data included
WG - Project non-conformities	**Material Sent** Material | Material Description | Notification Qty | Material Qty | | 3,827 | 0032C025801 | SLIDE RING GASKET WITH O-RING D167 | 6 | 1,984 PAAR001532 | STUD | 2 | 1,661	Material number, description, notification Qty and material Qty visible (+ additional confidential data).
ZW - Warranty claim	**Material Sent** Material | Material Description | Notification Qty | Material Qty | | 12,572 | PAAR075118 | O-RING 89.5*3 | 7 | 936 021.501.003.205 | O-RING 32,92X3,53 | 45 | 909	Material number, description, notification Qty and material Qty visible (+ additional confidential data).

In the two examples FOC data is connected to the claims, resulting in a good amount of data being recorded and available for Issue Identification tool to extract.

When FOC costs are considered it is easier to approach the missing post-warranty data, i.e. the LCS period. The LCS period following the warranty period is heavily fragmented into maintenance operations of different magnitude due to the nature of the products. Just as a car, a product has maintenance intervals where specific components are being replaced or checked. And just as with cars, these intervals are based on educated estimations as long as accurate data is not available. The concept of maintenance intervals requiring a consumable component replacement is projected on Figure 8 below.

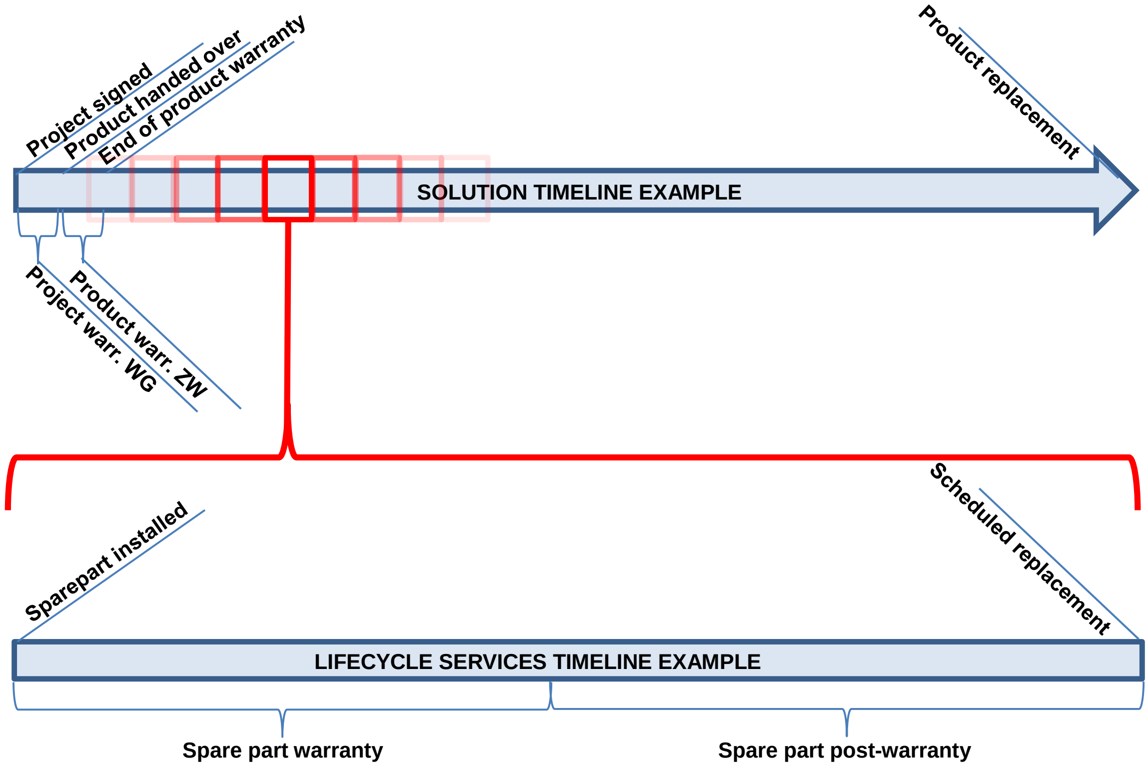


Figure 8. Lifecycle Services timeline example projected on solution timeline example.

Not all components have scheduled replacement intervals as replacement need may be based on wear limits, or for example performance measurement. Yet the significance of high number of critical parts to be replaced at a given interval has a role on both product reliability and the case company revenue. The LCS is further approached in the next section.

3.4 Identifying Field Reliability Issues during Life Cycle Services (LCS) Period

As presented in the example Figure 8, the LCS period is divided into Spare part Warranty and Spare part post-warranty until the part is replaced once again and the cycle restarts. This repeats as long as OEM components are used for maintenance and maintenance schedule is followed.

First of all, the coverage of spare part warranty has been defined as 6 months of use or 12 months from delivery, whichever comes first (Data 1, Interview 3. Confirmed from Data 1, Document 9). This period of six months may collect maximum of 4 380 hours of operation.

A period of spare part operating in post-warranty is defined by replacement intervals which deviate significantly between products and usage intensity, as well as some other boundary conditions. The best source of information is product manuals, but to put all this data together would require another thesis. For the sake of simplicity, major maintenance intervals, including significant part replacements, of three products in production are shown in Table 6, based on manuals of each product.

Table 6. Major maintenance intervals of three products. (Data 1, Document 10)

	Product 1 (Small)	**Product 2 (Medium)**	**Product 3 (Large)**
Major maintenance interval	8 000 – 20 000 hours of use	12 000 – 24 000 hours of use	12 000 – 24 000 hours of use

An average value when three products are combined is 17 000 hours between major maintenance operations. This is a heavy generalization and could not be taken as accurate figure, but it provides the idea of spare part warranty rarely covering the whole usage period. The end result is expected proper function under post-warranty period.

To approach these two periods as a source of statistical data both require separate subsections.

3.4.1 Spare Part Claims as a Source of Data

As data from spare part claims were found not to be utilized in the Issue Identification tool, the data requires to be studied. The definition of spare part claim is found on company intranet.

> *A spare part claim (XS) is a claim made by a Customer related to a specific spare part order occurred during the applicable warranty period in accordance with the applicable contractual terms*. (Data 1, Document 9)

The problem of spare part claims collected during the warranty period is originating from separating cause codes behind a claim.

> *Two of the biggest reason codes are "wrong part" or "wrong quantity picked" causing a quarter of all claims, which is an indication that there is room for improvement in our way of working.* (Data 1, Document 11)

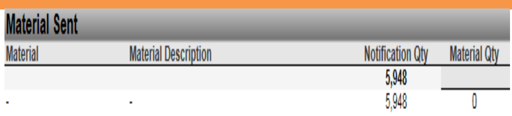
This finding also came up in Data 1 interviews 1, 3 and 5. Practically what separates warranty period of a new product and spare part warranty is, that with a new product it is easy to know what to deliver as bill of material of the product is accurate. In comparison, a spare part being delivered to a 20 year old product might not be the correct one due to many reasons. One might be products of a previous competitor entering the LCS period directly through acquisition, and in such cases suppliers tend to change, and there is a high risk of SAP master data not being correct. This is irrelevant for the Thesis, but provide understanding of the possible cases.

According to interviews, the cause code separation improved in late 2014 (Data 1, Interview3), but this actually is not the only issue. In addition, FOC is not always used as the way it is used with other warranty types. The organization responsible of spare part claim settling has various ways of working on claims. Instead of shipping a new component FOC to customer, the customer may be requested to purchase a new part, and the price of a failed component is reimbursed by a credit note (Data 1, Interview 3, confirmed from Data 1, Document 12). This allows confirming that the part has been received back and possibly placed back on stock if unused (wrong delivery etc.).

The two ways of working complicates data gathering. In addition, "XS notification and FOC are not linked in the SAP, hence it could not be confirmed that FOC is related to certain XS notification." (Data 1, Interview 3)

To confirm the finding, FOC delivery data was checked from Non-conformity analyser the same way performed earlier to Warranty claims and Project claims, shown in Table 7.

Table 7. Example cases of tracing material number spare part claim statistics from QlikView using Non-conformity analyzer. (Data 1, Tool 2)

<table>
<tr><th>Source type</th><th>Example of FOC data from QlikView</th><th>Conclusion</th></tr>
<tr><td>XS - Spare part claim</td><td>
<table>
<tr><th colspan="4">Material Sent</th></tr>
<tr><th>Material</th><th>Material Description</th><th>Notification Qty</th><th>Material Qty</th></tr>
<tr><td></td><td></td><td>5,948</td><td></td></tr>
<tr><td>-</td><td>-</td><td>5,948</td><td>0</td></tr>
</table></td><td>Only notification Qty. as usable data due to missing link between XS notification and FOC data.</td></tr>
</table>

As visible in the Table 7, there is no FOC data behind spare part claims. Thus FOC data is unavailable for Issue Identification tool.

Spare part warranty was found to cover limited period of time, but before spare part is scheduled to replacement there might be post-warranty period as well.

3.4.2 Spare Part Post-warranty as a Source of Data

The question of how to follow post-warranty performance overall is challenging. Typically when replacement intervals in the manual are too long, a compensation is requested. According to Quality Management (Data 1, Interview 5) and Issue Identification tool creator (Data 1, Interview 2 and 4) discounts given in such cases have not been considered as any source of performance statistics.

A company internal presentation (Data 1, Document 13) on discount percentage and impact from 2013 to 2015 was received for the study, and it indicates discounts increasing over time making the topic even more relevant. The organization behind the presentation was approached to gather knowledge behind the data used, and especially if it can go from the general level of the presentation to indicate specific types of discounts at component level.

> *Order consists rarely of one material number, but instead it is a bigger package of items. Discounts are not separated for each material, but for the complete order*. (Data 1, Interview 6)
>
> *Discount is not marked at material number level, and there are many material numbers at one order and one discount percentage is marked for all.* (Data 1, Interview 7)

It is apparent that one order consists of one discount, and thus it is impossible to trace deviations at component levels from the existing discount data.

An alternative was proposed to get component specific data by comparing actual material sales price versus list price in SAP (Data 1, Interview 7). A test with 13 material numbers was performed based on SAP data, with discount data visible in Table 8.

Table 8. Actual received price vs. list price

Mat. No.	Mat. 1	Mat. 2	Mat. 3	Mat. 4	Mat. 5	Mat. 6	Mat. 7	Mat. 8	Mat. 9	Mat. 10	Mat. 11	Mat. 12	Mat. 13
Discount 2014	0%	+3%	0%	+3%	-5%	-1%	-6%	-8%	-4%	-3%	-6%	-5%	-26%
Discount 2015	-6%	+10%	-3%	-11%	-4%	-5%	+10%	-9%	-11%	0%	-7%	0%	-35%

The problem with this data is that total discount may consist of many different reasons. As show, some materials have even positive discounts if, for example, import costs are included in the sales price or delivery is done with high priority, but otherwise transfer costs should not be included (Data 1, Interview 8). The data shown in Table 8 is unreliable and significant deviations between years is indicating inconsistency. However, material number 13 with known defect is visible in the list which could be seen as discounts being given due to technical non-conformity.

To summarize; this method may show something when issue has reach critical stage, but as a source of screening for Issue Identification it is unreliable as separation of discount reasons in question cannot be performed.

> *The problem is also that at one day you get one result and the next day the result might be different, not to mention if done by another person. To make this accurate is difficult.* (Data 1, Interview 7).

> *I have to say that the price point tool cannot go to the level needed. I would wish that sales would have the information of what is the discount reason at detailed level and there would be a reason why big discounts are being given*. (Data 1, Interview 8)

When the question of discounts being given due to technical reasons is provided to the Business Control GM, the answer is “I personally have heard of specific components unable to reach the planned replacement interval and discounts have been given” and later states “You have an interesting Thesis topic!” (Data 1, Interview 6)

As a conclusion the company is providing annually higher discounts, and at least some of them are based on technical difficulties to reach maintenance intervals, but the data is not existing to follow this at material number level.

Next the main findings are presented to form a base to build the Thesis on.

3.5 Key Findings of the Current State Analysis

The current state analysis of identifying field reliability issues was conducted by analyzing internal documentation and interviewing key stakeholders. The Issue Identification tool and Non-conformity analyzer tool were used to confirm findings. Figure 9 presents the strengths and weaknesses of the findings first in the general level, and then on the more detailed level regarding issue magnitude.

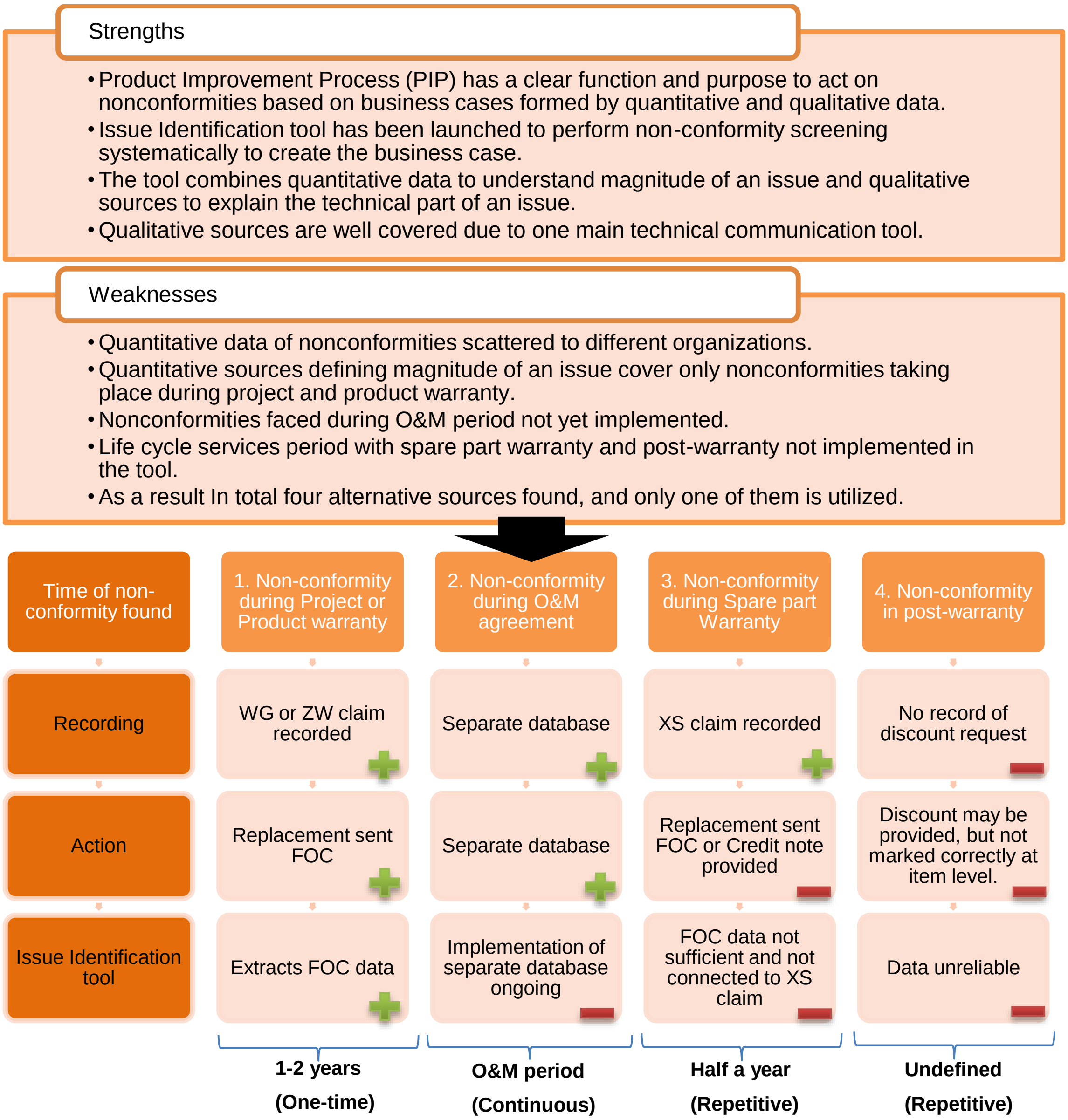


Figure 9. Strengths and weaknesses of identifying magnitude of field non-conformity issues summarized.

Currently the Issue Identification tool is able to follow only the project and product warranty period. Coverage of this source of data is restricted by default to the first year of product being used. In addition, O&M agreements are currently being implemented into the Issue Identification tool. By company documentation non-conformity is when the customer expectations (formed by manual) are not met and as a result these non-conformities should be followed to know when to perform corrective actions. However, the current process of identifying issues is not extending beyond the very beginning of the product use, practically missing statistical data from decades of product use. This is a gap between words and reality, and the target of this Thesis is to provide proposals to close the gap.

The period missed by Issue Identification tool is Life cycle Support (LCS) period, which is the period when product is being maintained at scheduled intervals. The parts installed on the product during maintenance have limited warranty period of only six months of use, resulting remaining of the replacement interval belonging to the post-warranty period.

The target of this thesis is to propose implementation of complete LCS period to extend statistical data to cover the complete lifetime of products, which means two separate proposals need to be built.

The two sources of data able to make a difference are not in a form of easy implementation to the existing Issue Identification tool. Spare part claim FOC data is both insufficient due to credit notes also being used, and non-existing from Issue Identification perspective due to missing SAP link between a FOC delivery and a corresponding XS claim. In addition, the spare part claims consist of high number of non-quality related issues, and utilizing of any data require filtering based on cause codes. These issues are summarized in Table 9.

Table 9. Summary of the issues found to utilize spare part claims data.

First proposal target: Utilizing Spare part Warranty as a statistical source

- **Problem 1**: High number of claims not related to part function.
- **Problem 2**: Not only FOC deliveries used.
- **Problem 3**: Spare part claims and corrective action not linked.

The discounts given due to technical non-conformity during post-warranty have an issue of marking one total discount for a complete order instead of marking discount reasons for each item on the order. Thus discounts or discount reasons at component level are inaccurate. In addition, if discounts based non-conformities are provided they are not separated from all other discounts when sales are entered in SAP.

Table 10. Summary of the issues found to utilize post-warranty discount data.

Second proposal target: Utilizing Post-Warranty failures as a statistical source

- **Problem 1**: Discounts not marked at item level in an order.
- **Problem 2**: All discounts could not be considered to originate from non-performance.

Topics chosen for the next section have been selected to provide further understanding of the best practices related to the two proposal needed to be made.

4 Best Practice on Identifying Field Reliability Issues

This section focuses on best practices regarding identifying reliability issues. First it provides an outline for the theories bound on key findings of the CSA, and then starts to approach these theories top-down.

4.1 Introduction

Findings presented in the CSA indicate data sources being unfit for Issue Identification tool. The main purpose of Issue Identification tool is to enable PIP to fix the gap between the customer expectations and experiences. Changing or modifying existing processes in a corporation usually lead to a project, and projects need funding. To get any practical results the expected questions are *why*, by *who* and *how*? All of these need to be answered in this section to provide reasoning, responsibilities, and ways of collecting the data.

The following sections refer to ISO 9001 certificate, which is not publicly available free of charge. The case company ISO 9001:2008 documents are used in these cases, but it requires to be noted that there is a new version released in 2015.

In addition, before diving into the deep end with reliability it requires to be defined what reliability actually means. According to Hahn et al. (1999: 133) “reliability = performance over lifetime”, and in rare cases lifetime is equal to warranty period. Furthermore reliability is not only non-performance data, but “The probability that an item can perform its intended function for a specified interval under stated conditions.” (Barringer and Weber 1995: 3). After all, without the non-performance data the reliability data cannot exist.

4.2 Reliability Governance Requirements

To start the process of defining the governing function responsible for sufficient follow-up of reliability issues the International Organization for Standardization (ISO) is a proper choice.

> *ISO 9001 helps organizations demonstrate to customers that they can offer products and services of consistently good quality.* (Lazarte 2015)

The certificate received by over million companies' state reliability issues to belong to Quality Management (ISO web pages). This is supported by Meeker and Escobar (1999) by defining reliability as a key element to quality improvement.

Furthermore when requirements for the ISO 9001:2008 certificate are studied the QM organization of the company should focus to enable continual improvement, analysis of data, corrective action and preventive action. The process of continual improvement utilized by ISO 9001 is maybe the most common iterative process known: Plan-Do-Study-Act (PDSA) cycle, presented in Figure 10 below.

Figure 10. Plan-Do-Study-Act (PDSA) cycle. (Langley et al. 1994)

Just as the PDSA cycle may be seen in this thesis, it needs be utilized in Quality Management department functions to seek improvements in reliability data sources. Although the ISO standard provides arguments for continual improvement, the following section provides more throughout reasoning what makes reliability so significant.

4.3 Reasons to Act on Reliability Issues.

One of the many reasons to aim to prevent reliability issues was already pointed out by ISO; customers tend to prefer already the idea of high quality products. According to Nelson et al. (2005) reliability is the most influential determinant to the customer satisfaction (in IT systems). Some authors go even further and describe product not being the generic thing itself, but a complex cluster of value satisfactions (Levitt 1980). Performing reliably at the required level increases the customer satisfaction and, according to Heskett et al. (2008), highly satisfied customers are loyal to the provider and hence provide monetary benefits.

Reliability might be a benefit or a burden, and by corrective actions it may be improved, but originally it is based on the choices and compromises made by designers, and this is where the threat towards reliability originates. An ever increasing pace of product releases due to technological advancement, and the customer demand, are making products more complex while pushing product performance capabilities to new levels. The illusion of a highly reliable product is even harder to reach with a fresh product. One method of assuring customers of the reliability is warranty, as through warranty manufacturer bears at least some of the risks involved with the product for a preset period of time. By offering warranty to a product, the manufacturer adopts a financial risk from customers, believing the benefits of offering a certain type of warranty being greater than burdens within. The manufacturer additionally plays a critical role on confirming satisfactory product reliability increasing its own motives, but operating environment, usage mode, and usage intensity is often up to the customer. (Blischke et al. 2011)

All products are not the same, and it leads to different classifications of products. Blischke et al. (2011) use one classification type leading to three product categories; consumer non-durables and durables such as food and toasters, industrial and commercial products such as trucks and batteries, and specialized products such as aircrafts. Lifecycles of products in different classifications most likely deviate, as some of them are simpler and shorter than others. The lifecycle needs to be considered when a product, or warranty period coverage, is designed. According to an article by Asiedu and Gu (1998) the product lifecycle may be divided into four phases: design development, production, use, and disposal. All of these are creating costs at multiple levels within their own phase known as cost breakdown structure, but the *use* refers to operation and maintenance (O&M) period which is most difficult to predict (Wilson 1986). According to Gupta (1983), U.S. Department of Defence traced over 75% of life cycle costs coming from O&M. In addition, Wilson (1986) studied U.S government records indicating O&M costs exceeding initial acquisition price by tenfold.

Related to lifecycle cost calculations it must be considered that a single designer is focusing on costs she can control, while a company developing the product in a lifecycle cost analysis might have wider interests (Asiedu and Gu 1998). A study by Creese and Moore (1990) focus on the challenge of lifecycle cost calculations at design stage, and at the final detailed design stage the accuracy should be within -5 to +15 percent. To reach this accuracy demands a lot of info to be known, such as “product design details including dimensions and finishes, the specific process operation and process parameters, the requirements for product support and product reliability, and even the product disposal requirements” (Creese and Moore 1990: 26).

In practice lifecycle cost analysis is not an easy area of operation for a product designer to optimize, as a component manufacturing cost increase of 10% might have insignificant impact on manufacturing cost of a product. Meanwhile the magnitude changes in case the very same component has to be replaced for example ten times over the lifetime of a product. In the other hand there might be an option of lower manufacturing costs, but it might result in 20 replacements instead of ten. Costs of manufacturing (and sales price to customers) may be calculated, but replacement intervals and costs bound on replacing the component are in the end estimations, based on best available information.

Maintenance schedule and replacement interval of a consumable component in a product may be approached from different point of views, depending on wanted reliability. An article by Laurens and Molen (2010) elaborate on this topic through four high priority processes to deliver value, and the first of them is significant in the context of the thesis. Total maintenance reliability aims to prevent poor reliability and safety issues by proactive maintenance through preventive and condition-based maintenance for critical equipment. Some customers require reliability to reach 99% and aim to prevent unplanned shutdowns by all means necessary, when some customers are happy with 90% and are willing to perform maintenance reactively rather than proactively. From maintenance cost point of view these two might be completely different, resulting in comparisons between maintenance cost versus unplanned downtime impacts.

> *Reliability relates to a perception of system dependability.* (Nelson et al. 2005: 218)

Blischke et al. (2011: 7) states downtime, in case of a business enterprise, to have an effect on “production of services and goods, which, in turn, affects both the goodwill of clients as well as the bottom line of the balance sheet of the seller”.

All products and components deteriorate over time and/or usage (Blischke et al. 2011) resulting in a reliability reduction without proper maintenance. One of the key ideas behind risk of non-performance may be approached through The Hazard Curve function, presented in Figure 11, which provides the probability of failure *h(t)* in a graph over time *t.* Decreasing hazard rate in the early stage represents infant mortalities due to for example manufacturing errors, and failure probability decreases over time while the product or component ages. This may be reduced by running-in of the product prior shipping to the customer to eliminate the highest failure probability. Increasing hazard rate represents wear-out stage where failures occur at higher probability over time. (Hahn et al. 1999)

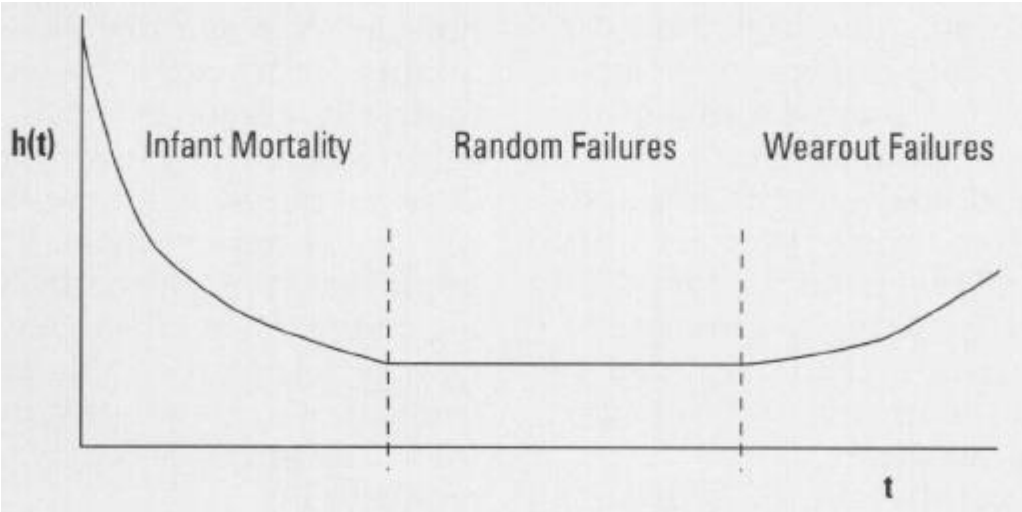


Figure 11. Bathtub Hazard Curve Function (Meeker and Escobar 1999)

There are significant amount of studies at which point of the curve warranty period should end, and especially if product or component should be fixed instead of delivering a new replacement, but this study is not focusing on optimal warranty optimizations. Instead, what is interesting in the theory of non-performance risk modelling is that there are ways to check if replacement schedule has been designed properly to take place before wear out failures reach a defined threshold point. One of the most popular models to estimate product failures over lifetime is the Weibull distribution due to the accuracy of the model (Meeker and Escobar, 1999), but to perform these calculations there needs to be at least some data.

> *Use life testing and/or field data and life distribution analysis to determine how your product behaves over its expected lifetime.* (Wilkins 2002)

Now the question is about field data, but obviously there are possibilities in simulations once data is gathered.

4.4 Gathering of Product Reliability Data

The terms such as Mean Time to Failure (MTTF) and Mean Time between Failures (MTBF) might provide information of reliability, but as everything else related to reliability they offer little unless made at component level. Blischke et al. (2011) define traceability at component level critical to expect any corrective actions. The target of all data eventually is to bring information, and what information is needed leads to the three main issues related to data, presented in Table 11.

Table 11. Key questions to gather information through data. (Blischke et al. 2011)

Key questions to gather information through data
•What kinds of data are collected? •What should be collected? •What needs to be done to collect data properly?

The first question is related to the current status of what data does the company have and could it be utilized as it is, while the second question represents theory, presented in Figure 12.

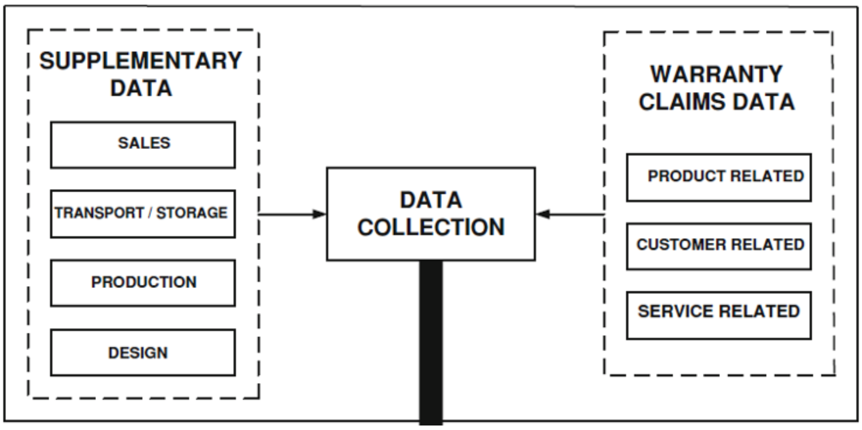


Figure 12. Data collection separated into two groups. (Blischke et al. 2011)

Warranty claims data is obtained by after sales support during the processing of claims and can be divided in to three segments. The first one is *product related* data considering factors such as technical non-performance of a component, mode of non-performance, age and usage at non-performance. The second segment is the *customer related* data focusing on for example operating mode, environment and usage intensity. The third source is *service related* covering issues such as cost of repair, quality of repair or service, and rectification actions such as refunds. But the warranty data alone is not sufficient to define reliability as it misses all functional components or the ones not under warranty. Supplementary data then again is all other sources to fulfill the data to cover the complete life cycle of the product. These could be internal or external organizations that generate data such as spare part sales, services, service contracts, follow-up surveys etc. (Blischke et al. 2011)

Practicality of the warranty claim data becoming relatively easily as valuable statistical data should not be underrated. Utilizing this source of data for example provides cost-effective feedback loop required by ISO 9001:2008. However, this completely misses the post-warranty period, as it is not required by the standard and does not maybe inflict such direct costs as warranty claims.

> *Depending on the product and the manufacturer, these (warranty) costs typically vary from 1 to 10% of the sale price of the item, and may have serious implications with regard to the manufacturer's reputation and the profitability of the business.* (Blischke et al. 2011: preface)

The supplementary data requires efforts to be taken to organize a proper flow of correct type of data. An example is shown in Figure 13.

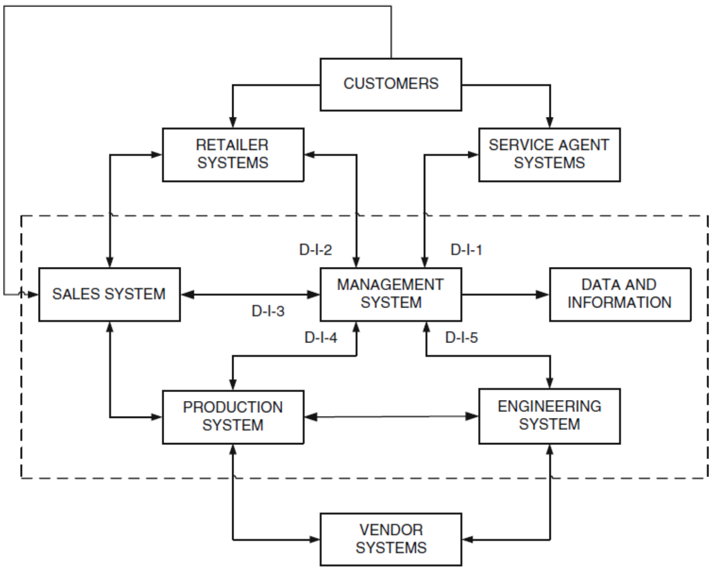


Figure 13. Supplementary data collection systems example. (Blischke et al. 2011)

According to Blischke et al. (2011) the units may have different data collection systems, but the data should be centralized to efficiently support decision making. In addition, provided data of the sources must be translatable into information for decision making.

The key message from gathering data for the benefit of reliability improvement is the requirement of both warranty claim data, provided through centralized data handling, and supplementary data, which may come from both internal and external sources.

The findings above provide a good base for data gathering, but there are more issues than the big questions mentioned, as shown in Table 12.

Table 12. Summary of data related issues based on Blischke et al. (2011)

Summary of data related issues
• Data not obtained on post-warranty failures. • Data incomplete or missing (lack of data). • Data reported incorrectly. • Data censored. • Data only from failed items, not from un-failed items. • Delays in reporting. • Deviations on delivery causing pooling. • Data handling in big corporations (amount of data, fractured data).

When the correct type of data is collected from the correct sources, it may be analysed.

4.5 Analysing of Product Reliability Data

Analysis of data is not directly in the scope of this thesis, but it cannot be avoided when data utilised in analysis is concerned.

Before analysis is performed there are several steps required to be taken to confirm reliability of the data, shown in Table 13. First the source of the data requires to be verified. When source is confirmed the variables data should include and units of measurements are to be confirmed. In addition, possible data (or source) missing require confirmation. At the early stage of analysis the results are to be followed. (Blischke et al. 2011)

Table 13. Summary of typical tasks for analysis reliability based on Blischke et al. (2011).

Analysis reliability confirmation
• Verifying source of the data • Verifying data to include variables specified • Verifying units of measurement • Checking for missing data • Correcting or deleting obviously incorrect results • Identifying unusual results

The key target and level for analyzing depends on the objective and available data, but there are certain factors required to be considered related to reporting of the analysis, presented in Table 14.

Table 14. Common targets for analyzing based on Blischke et al. (2011).

Targets for analysing
• Description of the key features of the data • Summarized information content • Graphical representation of data • Preparation for detailed statistical analysis

Eventually analysis might result into actions. This might be improvements on components, instructions, material handling etc., or result might be that data is insufficient, which practically should start the PDSA cycle again, but this time to improve the data collection instead. As the saying goes, “No pain, no gain”. (Fonda 1980s) Based on this, the conceptual framework for the Thesis is formed.

4.6 Conceptual Framework of Collecting Non-conformity Data

As found in the preceding sub-sections there is significant emphasis to give proper attention to guarantee reliability feedback loop. This section summarizes the arguments vital for this study in a form of a Conceptual Framework (CF), presented in Figure 14. Target of the conceptual framework is to provide the ideas which are used to create the proposal.

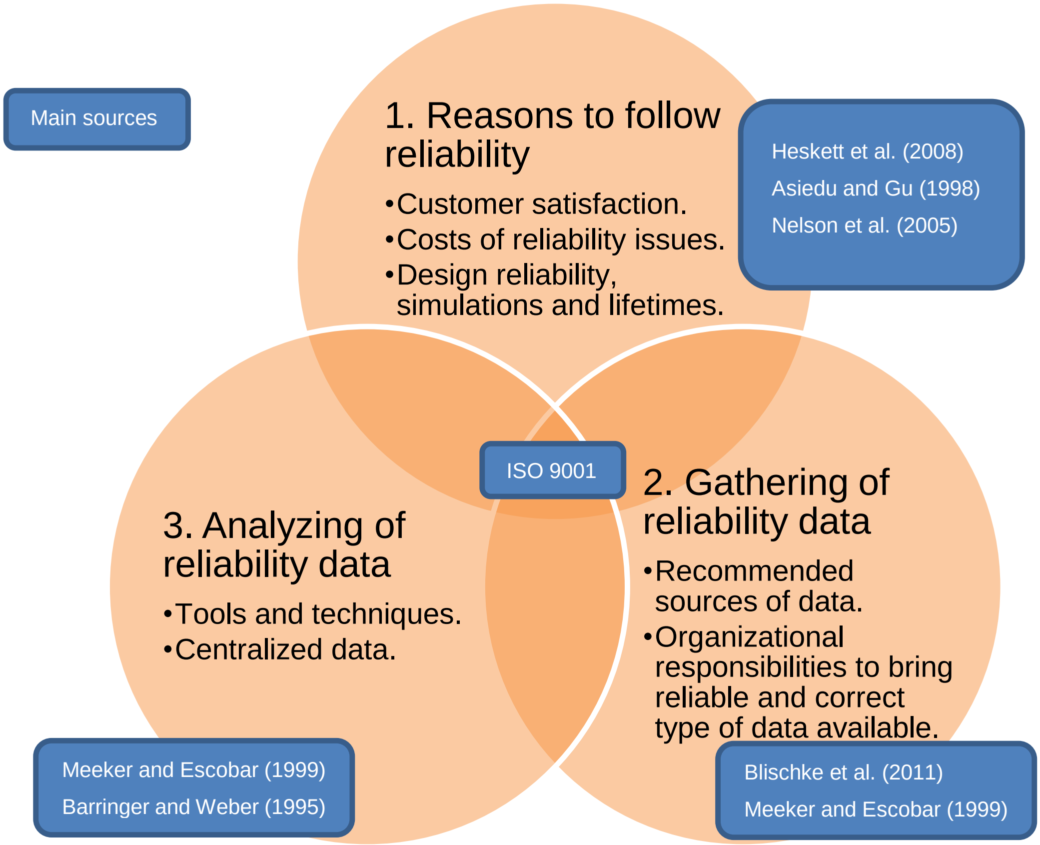


Figure 14. Conceptual framework of this study.

The CF is formed by three main topics to create a logic between the questions why, who, and how.

The first out of the four sections could be considered as *reasoning* of what makes follow-up of reliability so important. While ISO 9001 might lack specifics to further define tasks required in this particular case it still identifies Quality Management as the accountable function behind continual improvement (ISO 9001:2008). Further grounding for investing on reliability performance follow-up is based on the customer satisfaction and continuous challenges reliability is facing due to new designs being released at increasing speed.

The second section of the CF focuses on data collection itself, and based on a book by Blischke et al. (2011) warranty claim data is insufficient without supplementary sources such as spare part sales, services sales, contract management etc. In addition, the data requires to be collected at component level and with sufficient details to serve the purpose. The data collection is critical as non-existing or incorrect data might not be later created, and the analysis tools depend on data.

The third section enters the data analyzing stage and presents ideas how to confirm data sources, variables included, units of measurement etc. together with targets for analyzing (Blischke et al. 2011).

5 Building a Proposal to Collect LCS Non-conformity Data

This section aims to merge key CSA findings with the best practices found in the previous section and to build proposal drafts based on results. As shown in the Figure 15, first boundary conditions for proposals are outlined based on best practice and CSA results. At next step proposal options are drafted based on practical options to be reviewed with key stakeholders to decide which, if any, is found suitable for the task. The outcome of this section is refined proposals for validation.

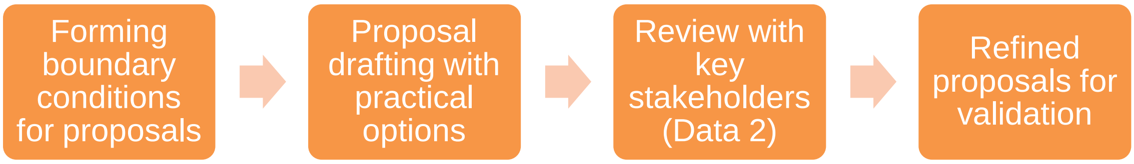


Figure 15. Process to build proposals.

The Data 2 collected for this Section is presented while reviewing alternative options for proposal, as done with Section 3 to form CSA.

5.1 Forming Boundary Conditions by Connecting Current State with Conceptual Framework

Before drafting proposal options, a layout requires to be set. When best practice and CSA findings are compared at the general level they might be divided into three steps, visible in Table 15.

Table 15. Best practice compared to Current Status.

	Governing responsibility	Gathering of data	Analysing of data
Best practice	Reliability and non-performance are quality issues and responsibility of Quality Management.	Warranty and post warranty data required. Data in a format enabling analysis.	Analysis through centralized data collection. Analysis results to be evaluated.
Current state	Quality Management has introduced the Issue Identification program to follow non-performance cases.	Spare part warranty data not utilized. Post-warranty data not utilized. Data not sufficient for analysis.	Data analysis monthly by CA through centralized data handling enabled by Issue Identification tool.
Conclusion	Best practice in line with current state.	Best practice not in line with current state	Best practice in line with current state

What is found functional in the Table 15, are governing responsibility and analysing of data. The best practice defined governing responsibility of continual improvement as Quality Management responsibility (ISO 9001). As found in the CSA, the Issue Identification program is a part of the QM Issue Resolution project, and thus in line with the recommendation. A verbal commitment from Quality Management was requested to possibly modify the Issue Identification tool function, and an approval with request to propose improvements was received. This not only opens opportunities to expand Issue Identification tool, but additionally enable data analysis to be reported through existing channels. To create new tools alone could be considered challenging, but to dedicate resources to analyse the data periodically is maybe even a bigger obstacle, although out of the scope of the Thesis. Regardless of the sources utilized, the analysis of data is recommended to be performed centralized (Blischke et al. 2011). For this, the Issue Identification tool would be optimal, or at least the best known solution. There are further analysis requirements, but these as well are out of the scope of the Thesis, and responsibility of the reporting function of the Issue Identification process.

The problem found in the Table 15, is the gathering of data. As it was found in the CSA, non-conformity cases during spare part warranty and post-warranty are not part of the screening process. The main problems for excluding the sources from the screening process were already found during CSA, and are presented in Figure 16.

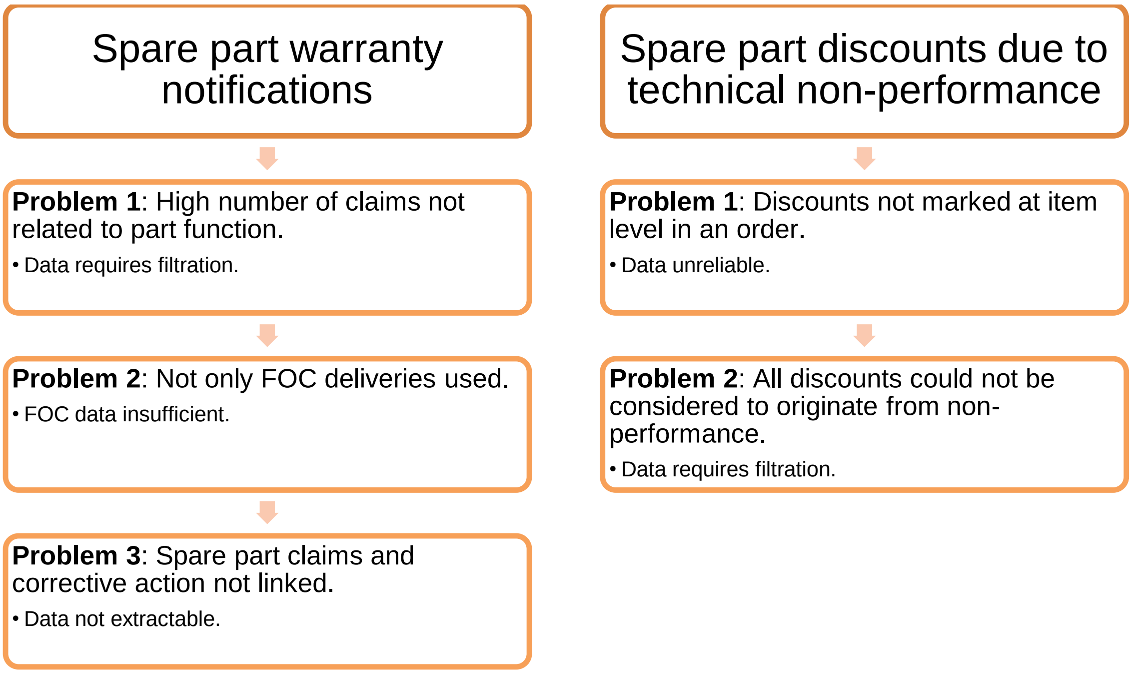


Figure 16. Issues found in CSA for the two sources.

According to Blischke et al. (2011), some of the most typical issues regarding data gathering were data not obtained on post-warranty failures, data incomplete or missing, and data handling in big corporations due to data existing across organizations. These fit well the cases found in the CSA; data is incomplete on both cases, data responsibility is in organizations with no functions in PIP on both cases, and one of them is the missing post-warranty period data.

The best practice listed sources of data as two different groups; warranty data and supplementary data. When the two missing sources from the CSA key findings are divided into these groups, the spare part claims naturally belong to warranty data, while discounts could be considered as supplementary data. However, if discounts due to technical non-conformity before scheduled replacement create loss of revenue, or at least gross margin, the difference between the two is not that clear. Thus, this Thesis continues to focus on the two issues as equals, as both have monetary incentives to reduce non-conformity through PIP. To close in on the data collection from the two sources, two separate proposals are built in separate sections.

5.2 Proposal Building for Spare Part Claims as a Source of Data

The reasons behind problems to utilize Spare part claim data found in CSA was as follows:

> *The spare part claim FOC data is both insufficient due to credit notes also being used, and non-existing from Issue Identification perspective due to missing SAP link between a FOC delivery and a corresponding XS claim. In addition, the spare part claims consist of high number of non-quality related issues, and utilizing of any data require filtering based on cause codes.* (Section 3.5)

One obvious option is to create a link between FOC delivery and the actual claim, practically making the FOC deliveries similar to Product and Project Warranty cases. However, it was noted that FOC deliveries are insufficient as it is due to credit notes additionally being used, so also credit notes would require to be linked. This is *Proposal 1, Option #1*, found in Figure 17.

An alternative option could be to search the information being recorded in SAP when a spare part claim is entered. Practically this would mean following of feedback instead of action, which deviates from current statistical follow-up of Issue Identification tool. This is *Proposal 1, Option #2*, found in Figure 17.

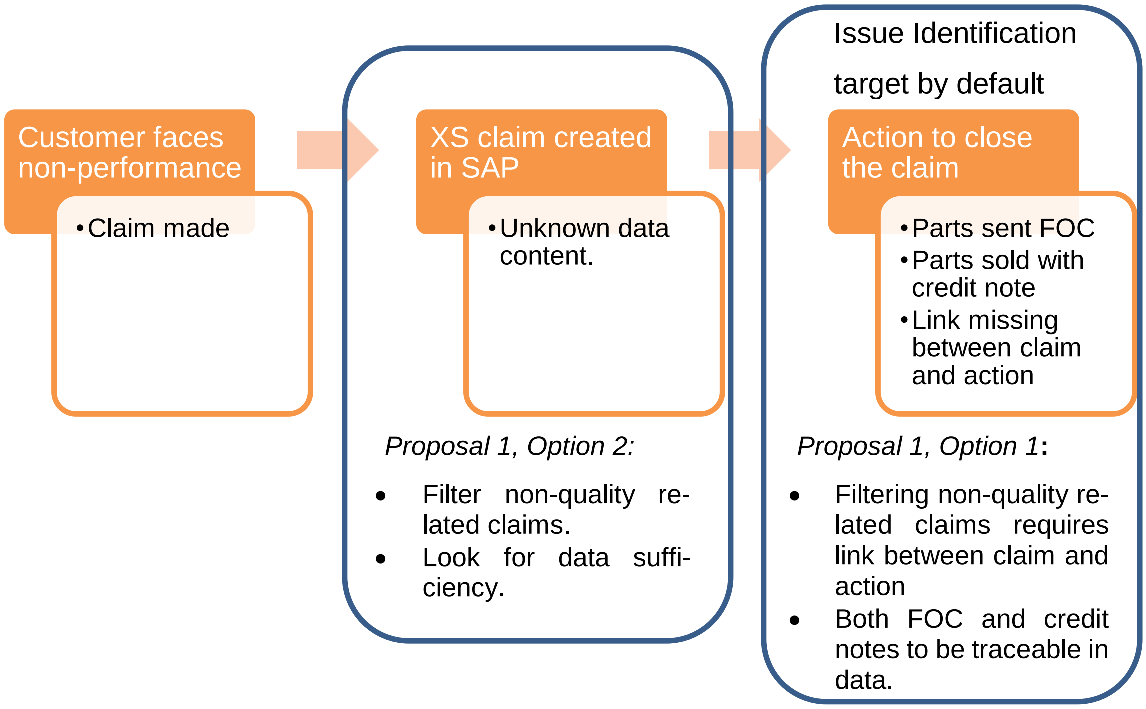


Figure 17. Proposal options for spare part warranty claims.

Regardless of the options, the data requires to be filtered down at cause code level to consist only quality related claims. For this, the case company Quality Department was contacted to find individuals with possible further information. As a result an interview with Management Systems manager was arranged, which revealed quality issues covering approximately 25% of all claims (Data 2, Interview 1). To gather reliable quality related data, the excessive data (75%) requires to be filtered. To study the raw data for filtering options, an excel document (Data 2, Document 1) of spare part claims entered in 2015 was received from the interviewee.

At the next step an interview with spare part claim manager was arranged to verify data on the excel document, and to further study the found two options and to screen for any other alternatives.

Proposal 1, Option #1.

In the interview it became apparent, that the idea of creating a link between spare part claim and FOC or credit note is already in implementation due to other purposes.

> *There is a new entry field in the sales documents implemented in mid of February 2016 for other purposes where notification number may be added, so that action could be traced back to XS notification regardless if FOC or Credit Note. Originally the intention was to use this only for FOC deliveries, but use is intended to spread to include credit notes as well. Training for this is still ongoing.* (Data 2, Interview 2)

The option #1 could be implemented in near future when training has been done, and way of working has been changed to create the link between a claim recording and a corrective action. Due to link not existing in the past, there is no option to check history data. Proposal is presented in Figure 18.

Proposal 1, Option #2.

The excel document (Data 2, Document 1) received as a result of an earlier interview was found to actually consist more data than spare part claim documentation should have by default.

> *Some of the data in excel must have been added separately, probably extracted from SAP.* (Data 2, Interview 2)

The data added was cost of components claimed, extracted separately from SAP and entered in the document. If this could be done for an excel sheet consisting remarkable number of claims, it probably could be done in Issue Identification tool as well. This alternative has a benefit of creating history trends of parts being claimed in the past, and as a result of the interview the proposal 1, option #2 was selected as superior. For validation purposes a workshop was scheduled to confirm the option from Issue Identification tool creator, and to further check the filtering options of the data. (Data 2, Interview 2)

The changes as a result of Data 2 collection may be seen in red in Figure 18.

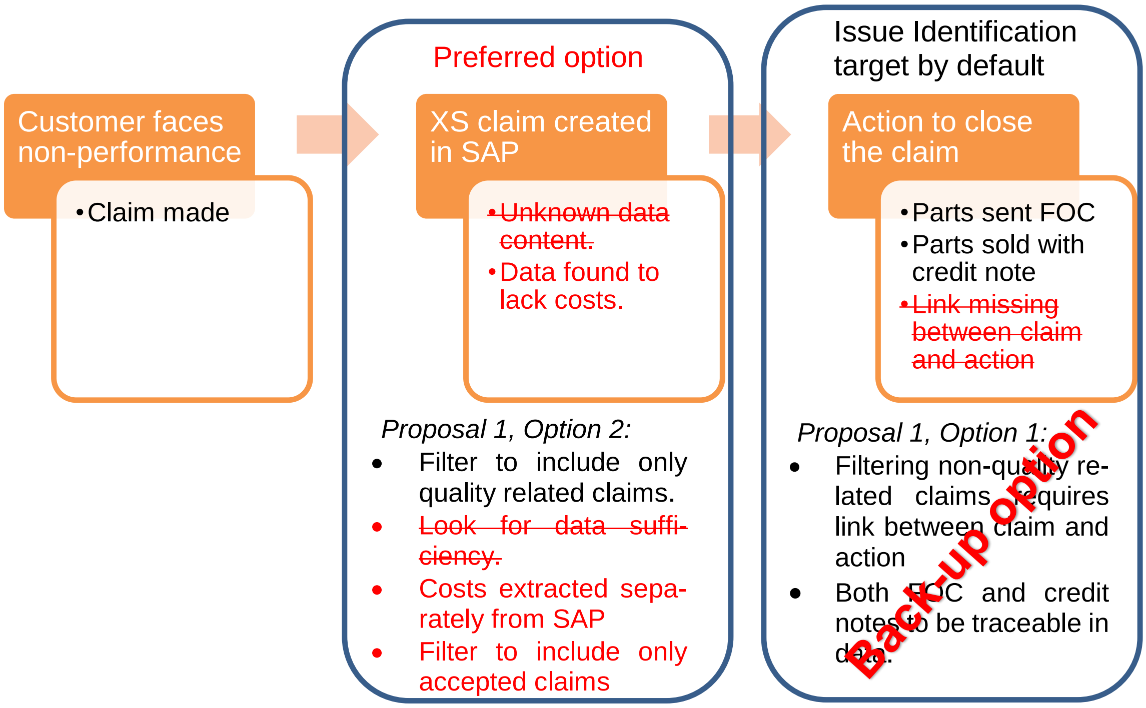


Figure 18. Proposal for spare part warranty claims.

Proposal for spare part claims as a source of qualitative data starts by changing the approach of data extraction from *Action* to *Recording* stage. The proposed data extraction ends with all other relevant data except costs, and hence data of costs requires to be extracted separately based on material number and quantity claimed to create cost similar to FOC. In addition, the data needs to be filtrated to consist only claims with technical background, and claims which have been approved.

Any further actions with the resulting data is out of the scope of this thesis and up to the Issue Identification tool creator/operator for the best fit seen. Validation and finalization of the proposal is performed in a separate workshop.

In the next section another proposal for spare part post-warranty is being created.

5.3 Proposal Building for Spare Part Post-warranty Discounts as a Source of Data

One optional proposal to trace non-conformity based on discounts provided was already tested in CSA section 3.4.2 by simply comparing sales prices versus list prices over a given period of time, but this resulted in unreliable results due to many pricing and delivery factors impacting the end result. Hence it could not be considered as an option for proposal.

To create new ideas the difference of spare part post-warranty discount and actual claim require to be noted, as the problem with discounts is that the existing data is not detailed at the level needed.

> *The post-warranty discounts have an issue of marking one total discount for a complete order instead of marking discount reasons for each item on the order, thus discounts or discount reasons at component level are inaccurate. In addition, if discounts based non-conformities are provided they are not separated from all other discounts when sales are entered in SAP.* (Section 3.5)

Without data ever existing the Issue Identification tool is unable to provide any statistics. Due to this finding the proposals are bound on feeding data into SAP in one stage or another. Draft options for these are presented in Figure 19.

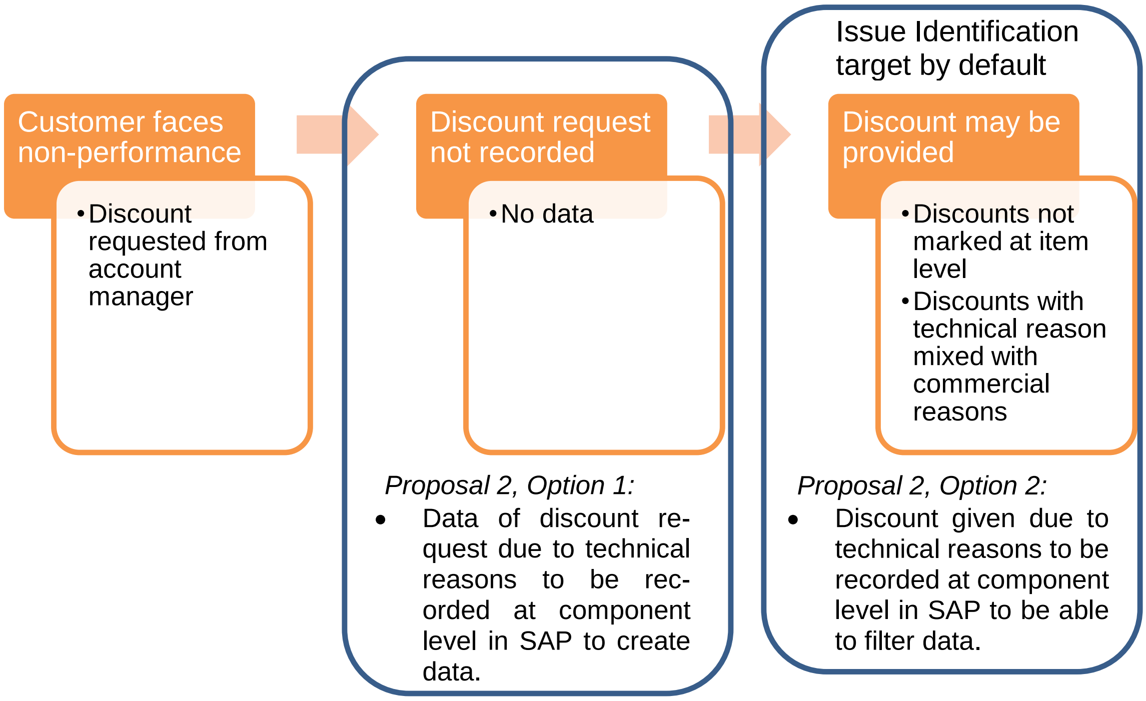


Figure 19. Proposal options for spare part non-conformity in post-warranty.

To approach the challenge of discounts given due to technical non-conformity in post-warranty an interview with Parts Coordination Management Manager was arranged. During the interview the SAP transaction where sales are visible was viewed, and it became apparent that discounts may be separated at item level as proposed in *Option #2* by using a specific discount code type. Further finding of the interview was responsibility of these discounts (pro-rata) to belong to organization called Product Sales. (Data 2, Interview 3)

A workshop was arranged with Product Sales organization to gather further understanding of the current pro-rata cases and proposal options. In the workshop it was found that pro-rata cases are handled case by case after specific discount percentage has been reached, and in such cases there might be something written about the discount. By free-text filtering some data could be extracted, but it was considered highly unreliable. In addition, the purpose is to trace not only high percentage pro-rata discounts but all discounts with technical background. The proposal options were checked in the workshop and discount requests were found to be contacted to account managers through multiple ways, making the Proposal 2, Option 1 impractical for implementation. The end result of the workshop was recommendation to contact Sales management to include detailed marking of discounts with technical background in the new upcoming instructions (Data 2, Workshop 1).

After the findings from Data 2 collection the proposal is rather straight forward. Proposal in this case is described by what is needed, as management may use other sources with more experience in sales processes to refine the idea. In addition, it needs to be noted that the aim of this thesis is to improve quantitative data sources to be able to provide input and eventually prevent repetitive issues of technical non-conformities and not to change pricing policy itself. Thus pro-rata calculations are not considered in the proposal.

Quantitative screening process for PIP purposes is done at material number level by Issue Identification tool, hence products with non-conformity during post-warranty require to be marked separately in case discounts are given to prevent the customer dissatisfaction. The screening tool (Issue Identification tool) would extract data from SAP based on specific cause code limited to only pro-rata cases.

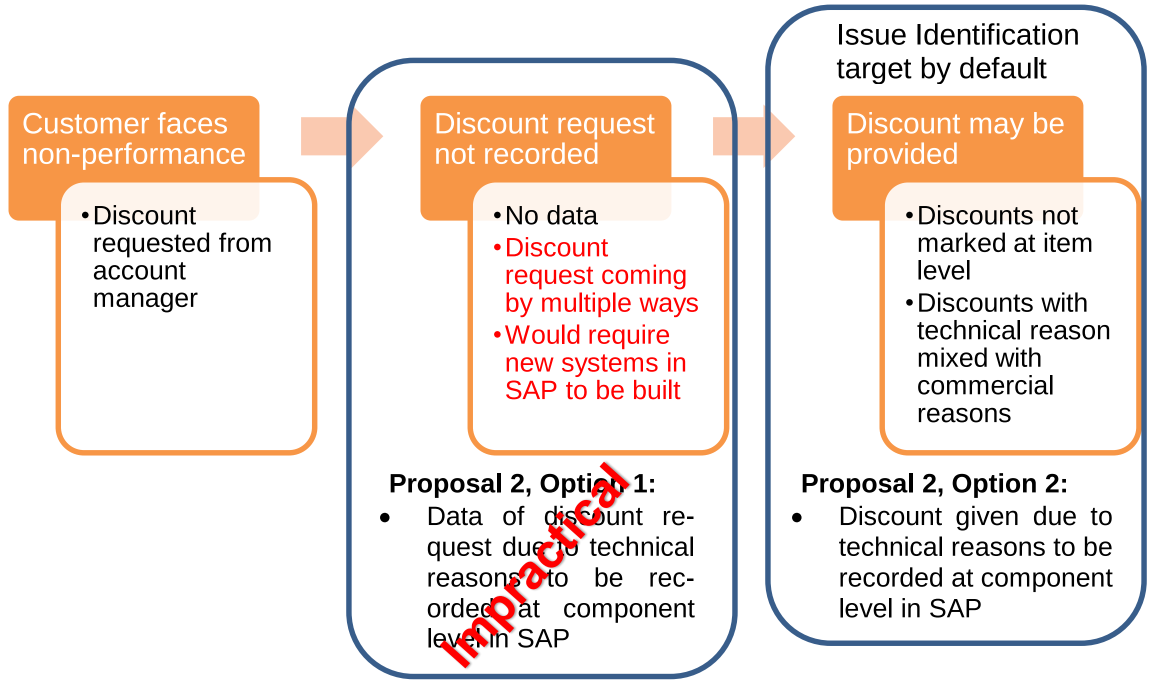


Figure 20. Proposal for spare part non-conformity in post-warranty.

Reason for the proposal to be so general is that it is detailed enough to provide what is needed while giving a lot of flexibility.

5.4 Summary on Building of Proposals for LCS Non-conformity Data

To form the proposals the process involved several steps, presented in Figure 21.

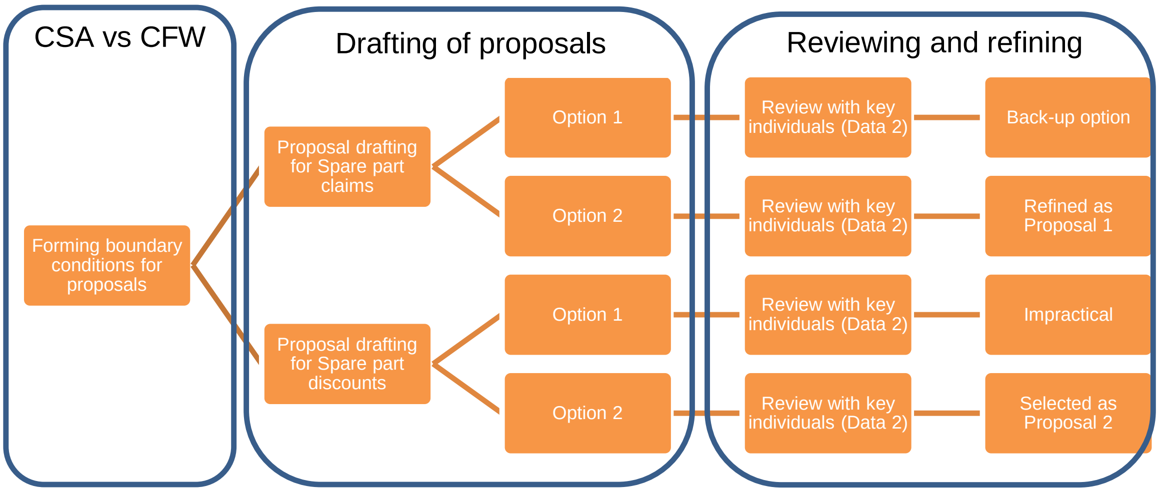


Figure 21. Building of the two proposals.

Two separate proposals were made for two separate cases with big differences on implementation. First the cases were quickly compared to the best practice regarding the Issue Identification tool to decide if there is any sense to even consider an alternative tool. Decision was made to aim to utilize Issue Identification tool, if only possible.

The first proposal regarding spare part claims started with three problems listed in Section 3.5. The easiest way to solve the challenges was formed by changing Issue Identification tool data extraction to focus on the actual spare part warranty claim in SAP instead of focusing on actions taken related to a claim. The claim data in SAP was found not to include costs, but as material number is existing in the claim data the costs can be extracted. Once all needed data is gathered, it is filtered to consider only technical claims and only to claims which have been approved.

The second proposal regarding non-conformity during post-warranty period is both simpler and more complex. There is no data in SAP currently to perform filtering of the data reliably, and thus the proposal was drafted to separate technical discounts from commercial discounts, and to do it at item level in an order.

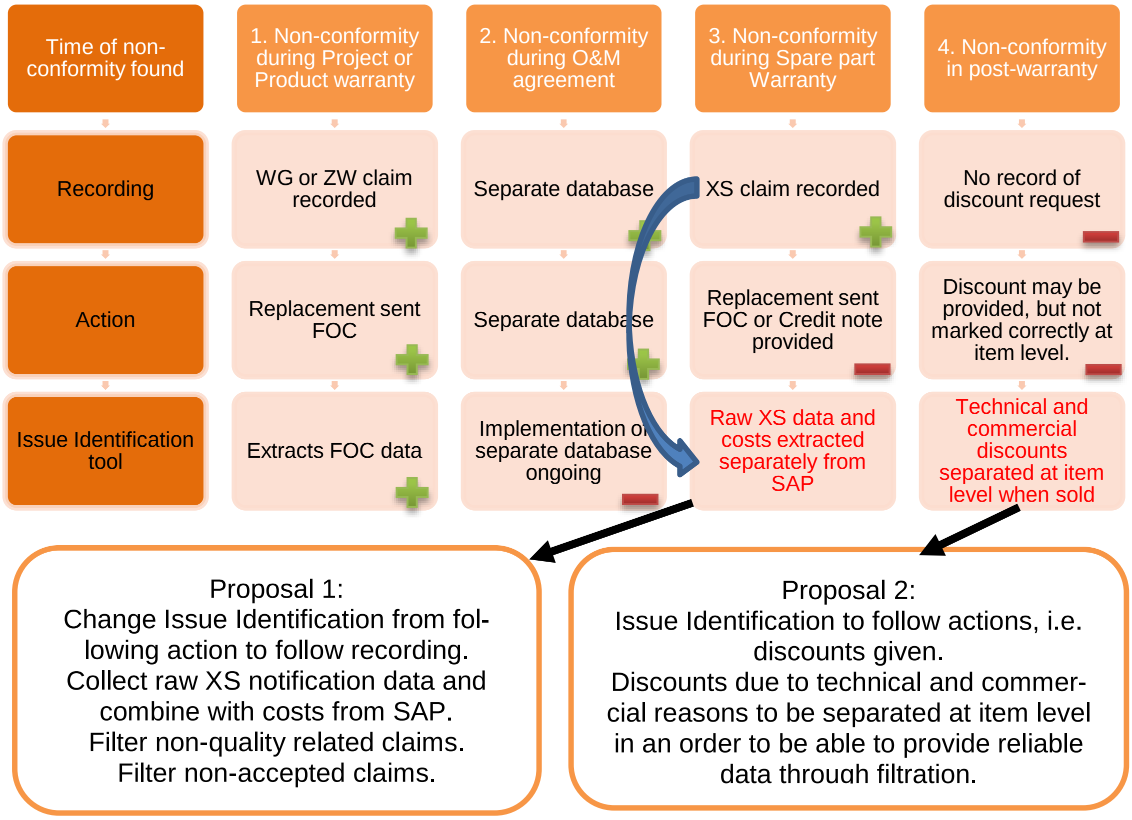


Figure 22. Two proposals summarized.

The two proposals were refined during the process with the support of experts of both cases, and validation in the next section is performed with management of the relevant organizations.

6 Validation of the Proposal to Collect LCS Non-conformity Data

This section discusses the validation stage of the proposals given in the previous section and, as shown in Figure 23, adds findings of Data 3 to formulate the final proposals. In addition, the Section includes evaluation of results for both proposals at the level enabled by the collected data, and presents the action plan for the proposals.

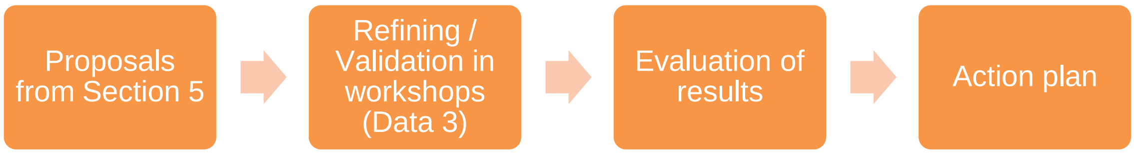


Figure 23. Process utilized in this section.

The evaluation of results is performed separately for the two proposals in this section, as comparisons are a part of Data 3 collection.

6.1 Validation Stage for Final Proposal on Spare Part Claims as a Source of Data

To validate the proposal for spare part claims, a workshop was organized with the Logistics Services claim manager responsible of spare part claims, and Issue Identification tool creator. The three main challenges stated in the proposal were checked, and a proper filter was found to include only “material quality claims” to focus on the claims with technical reasons with a specific defect type as well as filtering to include only accepted claims. The only issue remaining unsolved was to extract costs to enable similar follow-up of costs as currently performed in the Issue Identification tool. However, according to the tool creator this may be easily performed when material numbers are available. As a result of the workshop, an implementation project was launched. (Data 3, Workshop 1)

> *Project can be started immediately. Estimated to be implemented in mid May 2016. Spare part claims will be part of a monthly report through Issue Identification project.* (Data 3, Workshop 1)

A minor change proposal was given by the Issue Identification tool creator regarding the monthly reporting. It aimed to prepare two pages where one would include all product types and another would include only currently produced products. This is understandable as the current production requires to have higher priority, but the older products require attention as well. However, the reporting responsibility is part of analysis activities of the Issue Identification program and thus not in the scope of this thesis. As a result of the process, the final proposal is considered validated and presented in Figure 24.

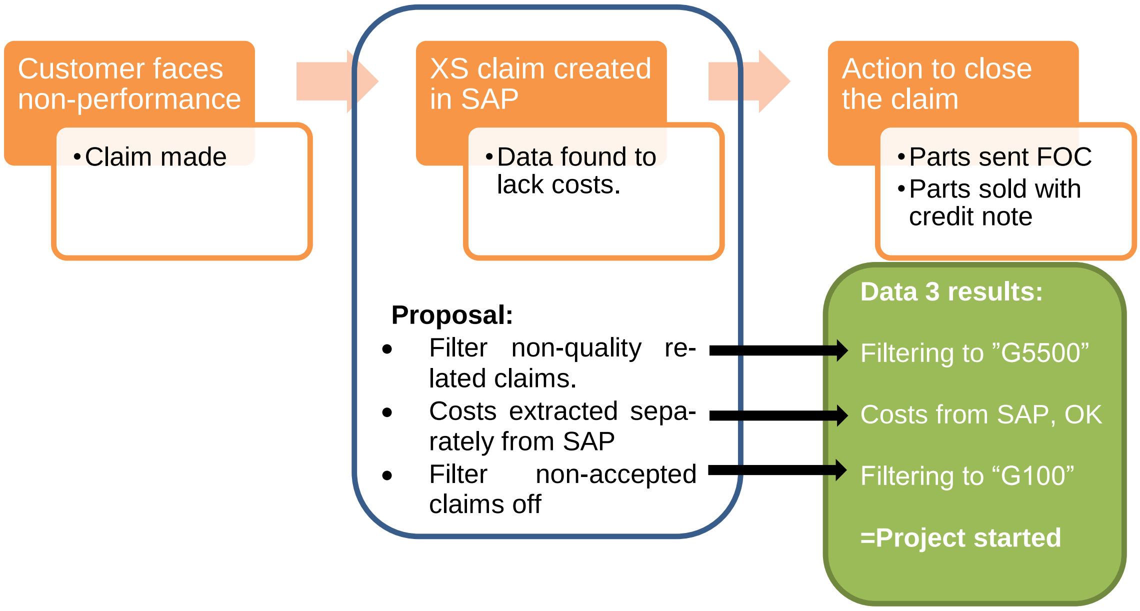


Figure 24. The final proposal to implement Spare part warranty claims in Issue Identification tool.

Preliminary funding approval for the implementation has been granted by the case company Quality Management organization, and is handled between Quality Management and Customer Assistance organizations if needed.

6.2 Evaluation of Results from Proposal on Spare Part Claims

In the validation sessions, comparison was additionally done between the current data sources and the proposed new source. For this, Project and Product Warranty claim FOC statistic (the data currently followed in Issue Identification tool) were extracted through Non-conformity Analyzer(Data 1, Tool 3) to consist complete year 2015. It was compared to the values provided by the Excel document (Data 2, Document 1) consisting spare part claims from year 2015 while using the filters proposed (only material quality related claims, and only approved claims). Based on this comparison, the statistical amount of claimed material quantity being followed increased by mere 5% over this period. Statistical number of claims being followed increased by 12%, but this is not a target to be followed in Issue Identification tool. Major impact was found on costs of claims being followed, where value increased by 32%.

To summarize, the amount of individual claimed components followed through the new source does not increase significantly, but the components followed are of a high commercial value. It may be speculated, that during project and product warranty period an issue with one component may lead to replacement of all similar components in the product. For example, leakage of a single sealing ring in a new product might lead to replacement of hundreds of similar rings. In case the same sealing ring would leak under spare part warranty, the customer may find commercial compensation of a single ring financially insignificant compared to the efforts needed. Hence the findings could have been expected.

6.3 Validation Stage for Proposal on Spare Part Post-warranty Discounts as a Source of Data

The proposal was checked in the workshop together with Quality Management responsible for the Issue Resolution program and Sales department management and specialists responsible for the way of working during the sales process.

In the workshop, it was found that there are 48 different codes for discounts, but none of them is purely for technical cases. One of the 48 different codes was the one already found suitable in Data 2 collection to separate discounts for each item in an order. However, while the code could be seen to include both commercial and technical discount reasons they could not be separated by filters reliably. The non-existing technical code was practically the final confirmation that the company SAP sales transaction needs to be modified to enable proper filters. The proposal was modified together with Sales accordingly to copy the function of the already used code in SAP and create a new code dedicated to only technical cases, or alternatively modify one of the existing codes for the same purpose. (Data 3, Workshop 2)

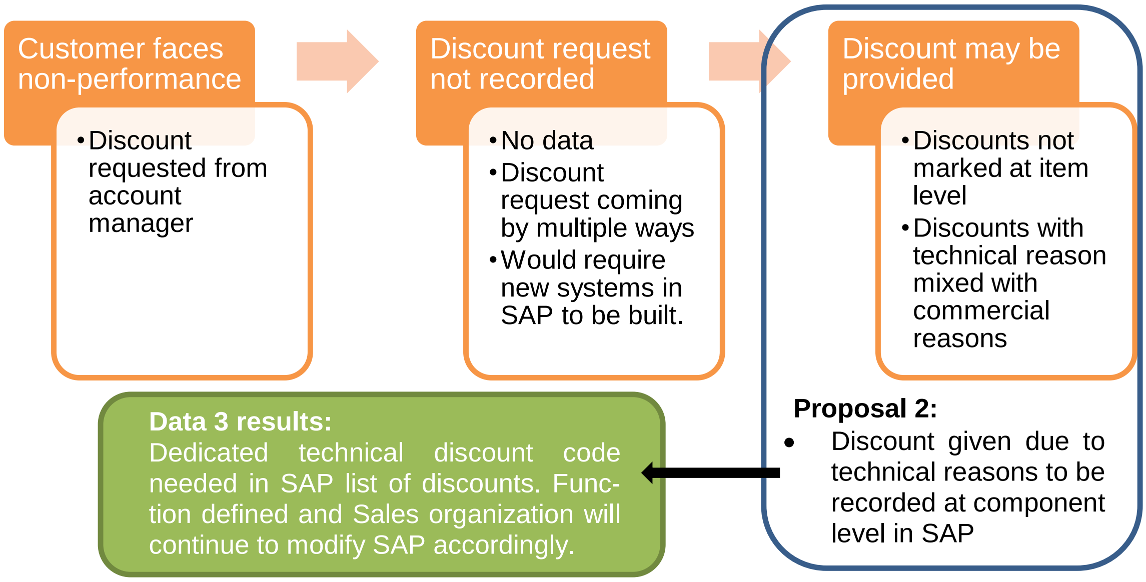


Figure 25. The final proposal to separate technical and commercial discounts in SAP during sales process.

The proposal was validated and implementing the new code has become a task to the case company Sales department. With the new code, filtration of data is not a challenge, but how to analyze the data in the Issue Identification tool is the next question. However, since analyzing of the data is not in the scope of this Thesis, this challenge is for the next researcher to resolve.

6.4 Evaluation of Results from Proposal on Spare Part Post-warranty Discounts

Due to the filtration issue with the existing data, it is impossible to accurately calculate the impact of the new source. To have an estimation of possible impacts, the same procedure was performed as with the previous proposal evaluation.

Project and Product Warranty claim FOC statistic (the data currently followed in Issue Identification tool) were extracted through Non-conformity Analyzer (Data 1, Tool 3) to consist complete year 2015. It was compared to the values included in the discount presentation (Data 1, Document 13) for year 2015. As discounts are presented only as lost revenue, only financial impact may be estimated. In case none of the discounts are considered to have technical reasons, the impact is naturally 0%. In case all of the discounts are considered to have technical reasons, the impact is 460% increase of monetary value followed currently by Issue Identification tool. Neither of these values could be considered realistic, but they present the scale. All other factors, such as number of components concerned or amount of orders including technical discount reasons are completely unknown due to the issues already mentioned.

One additional benefit of this source could be found with the Bathtub Hazard curve, presented in Section 4.3 on the Figure 11. If a component replacement schedule has been pushed too far, wear-out failures will start to take place. In case a customer demands discounts due to this phenomena, it should be recorded by this source and corrective actions to components, or component lifetimes, may be taken. As found in the CSA, none of the warranty periods is able to serve this purpose effectively.

6.5 Final Proposals and Action Plan

The final proposals are result of the validation stages, and the action plan is continuum from the final proposals, as visible in Figure 26.

The proposed action plan for spare part claims requires no further details, as it is already being implemented. But action plan for post-warranty non-conformity has only started by stating what is needed to have the data in a detailed level, thus enabling further actions. Once discounts in post-warranty are separated between technical and commercial reasons, the data becomes available; but if not done at item level on an order, the data is not be reliable. Hence instructions are required from Sales department to serve the purpose and eventually be able to tell which components have challenges to reach the defined replacement interval. To reach this point, Customer Assistance experts behind the Issue Identification tool need to be contacted when the data is reliable and made available.

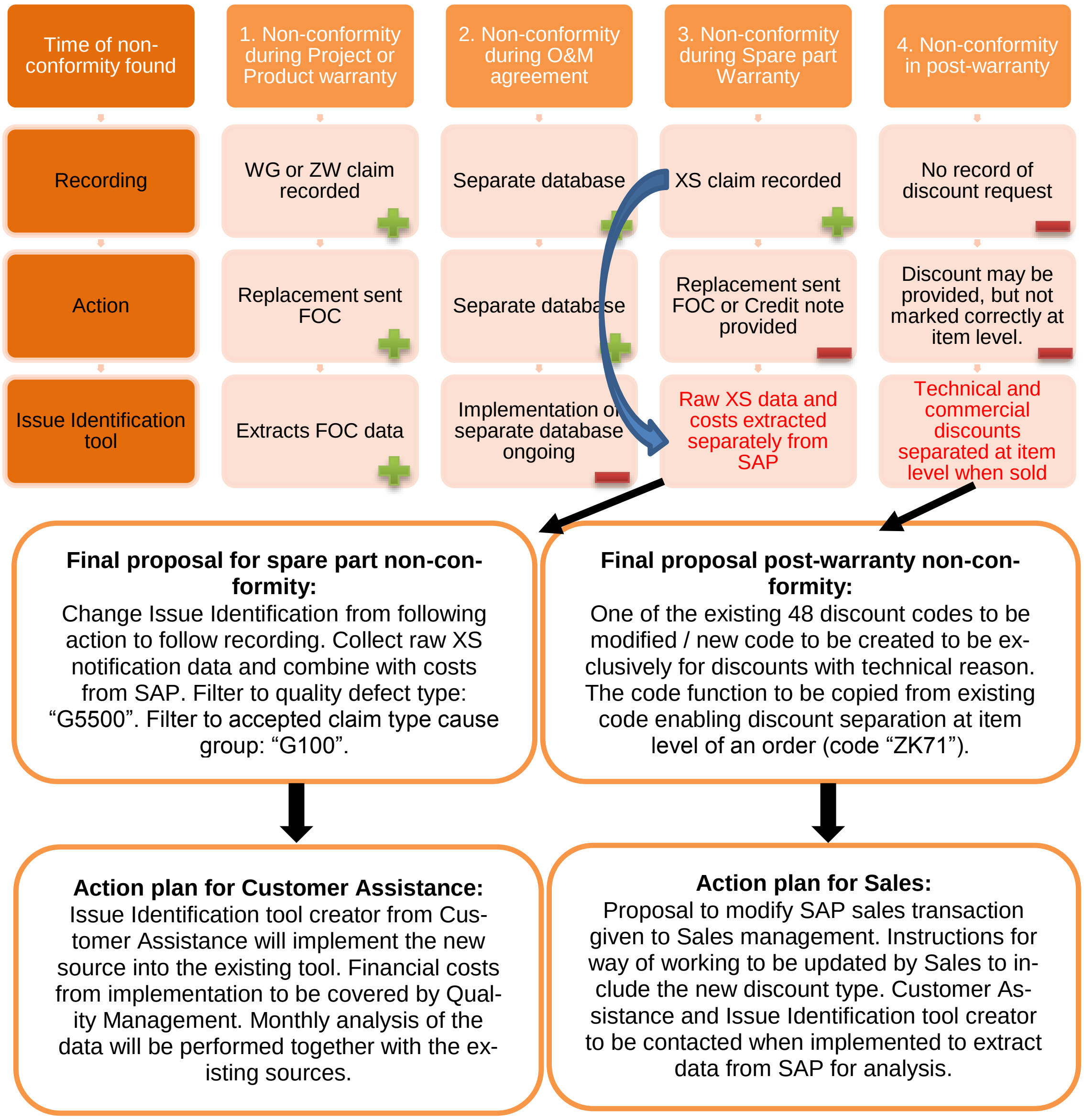


Figure 26. Final proposal and action plan.

This concludes the validation of the two proposals, and the next section summarizes the Thesis.

7 Discussion and Conclusions

This section summarizes the results of the Thesis and reviews the actions taken throughout the research process by comparing them to the plan made in the beginning.

7.1 Summary

This Thesis focused on exploring the statistical screening of product non-conformity issues. The case company is producing energy solutions based on large combustion engines consisting of thousands of individual components and a lifetime of several decades, including extensive maintenance operations at the predetermined intervals. The company aims to secure quality and reliability of the products by a process to improve existing designs of individual components or subassemblies in case non-conformity happens in the field. The process requires data of what actually fails to meet the customer expectation and be able to act, but over the years there has been a lack of statistical quantitative data to provide a reliable figures on failed components. Due to the tools utilized in the case company, this means issues are seen in real life through troubleshooting but not in statistics, efficiently having an impact on decisions required to improve product performance. The impact is emphasized in case design IP rights are owned by a supplier, as facts are needed to make a change.

The research approach selected for this study is a case study, as it suits the purpose with questions “why” and “how” and the rapid schedule of the Thesis. The case study approach started by dividing the Thesis into small steps to get from the beginning to the end including several data rounds. The first step was to focus on CSA within the case company in order to understand which data sources are currently utilized, and how these sources are spread over the product lifetime, eventually coming to a question why some sources were not utilized. The key findings of CSA indicated that a centralized tool called Issue Identification is being implemented to trace non-conformity, but the tool is not extracting the data during the lifecycle services period of a product, i.e. period after product warranty period, which in this case is several decades. The possible sources to improve the current situation were identified by utilizing the spare part warranty claims and discounts given to spare parts in case of technical non-conformity. Taken together, these sources were found to create a logical continuum to include LCS period into the Issue Identification tool, and thus eventually collect more data to make decisions on.

The next step was to focus on the best practice consisting of three main topics including smaller sub-topics within them: reasons to follow up the product reliability, the actual gathering of reliability data and typical mistakes, and finally, analysis of the data. These topics formed the conceptual framework of the study, while some additional topics provided further grounding.

The third step was to draft the proposals to improve the current state, which started by comparing CSA and CF at a general level. This indicated proper attention from Quality Management towards the significance of product improvement in the form of Issue Resolution project, and especially the Issue Identification tool were found to form a solid ground to build proposals on. Few proposal options were drafted and later refined together with key stakeholders to come up with practical, efficient, and reliable proposals. As a result, two proposals were formed, one able to bring spare part warranty claim data into the existing Issue Identification tool, and the other to enable discounts given due to technical non-conformity as the data source in the future for the same tool.

The fourth step was to validate the two proposals which was performed separately for each by arranging workshops with management of the organizations in question. Logistics Services management decided on the spare part warranty claim data and once all filters and data extraction were defined, the proposal went to implementation. The implementation is being performed to provide the new data source along with the existing sources in the existing Issue Identification tool. Another proposal was for post-warranty non-conformity data collected by following the given discounts. This proposal came to a conclusion of data being too generic to be filtered reliably, so that the only possible solution was to propose a new discount code for Sales in SAP and changes in the way of working. Practically, the proposal outlined the discounts given due to technical reasons to be separated from other discounts when the discount is being marked in SAP sales transaction, and discounts require to be marked at item level in an order. By these changes the Issue Identification tool may extract and filter the data, but before this point there is no reason to make further plans to implement the data in the Issue Identification tool.

As a conclusion, there is at least some benefit coming from the study for the case organization. As the quote by Barringer and Weber (1995: 20) say, “Some facts are better than no facts.” This quote suits the PIP situation incredibly well. The new proposed sources with impacts on data are shown in Figure 27 below.

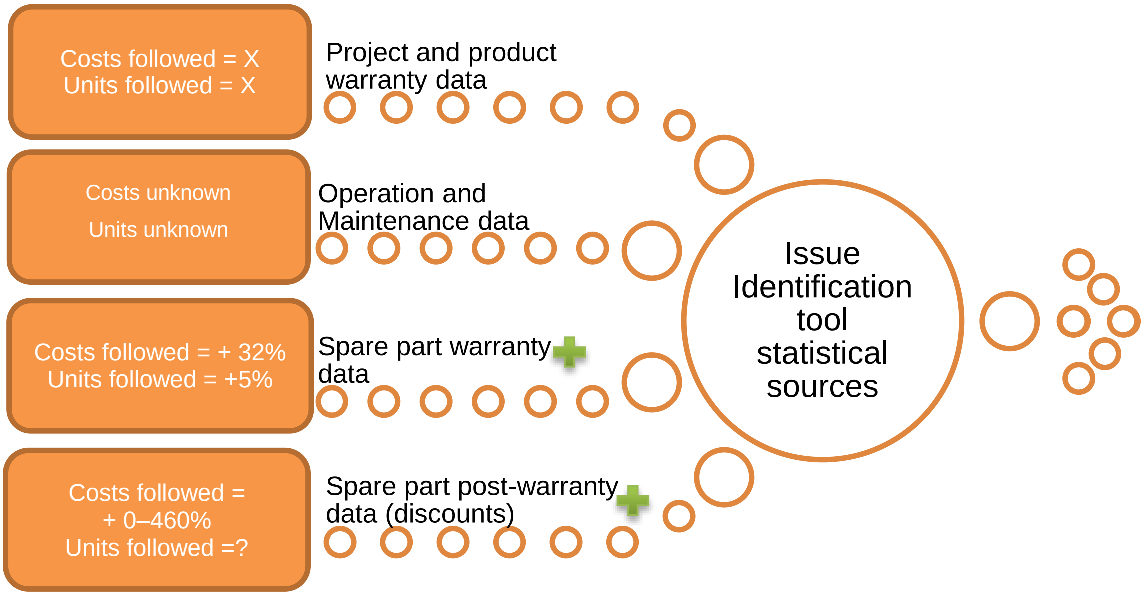


Figure 27. The two proposals and impact of Issue Identification tool.

Figure 27 compares the two new sources to a Project and Product warranty data from year 2015, as it was found to be the single functional source for Issue Identification tool. The first proposal for Spare part warranty data was tested to increase followed costs by 32% and followed units by 5%. The second proposal for Spare part post-warranty data to be followed through discounts has huge potential, but depending on rates between commercial and technical discounts the impact on costs might be 0% or 460% while number of units involved remains unknown.

What is more important than percentages of data received through these new sources of statistical data is that spare part claims will not be neglected by PIP and if customer purchases OEM spare parts any possible failures will be in the statistics when decisions are being made. In case spare part post-warranty discounts become available, the complete lifetime is covered, which would be significant according to best practices. In addition, it would enable closer examination if replacement intervals for the “consumable” components have been defined correctly.

7.2 Managerial Implications

This Thesis has evaluated the case company screening activity essential for PIP function. Inspection of the current screening process indicated a significant loss of the quantitative statistical data feedback coverage during a complete lifetime of a product. The evaluation of the company screening process is presented in Figure 28 below.

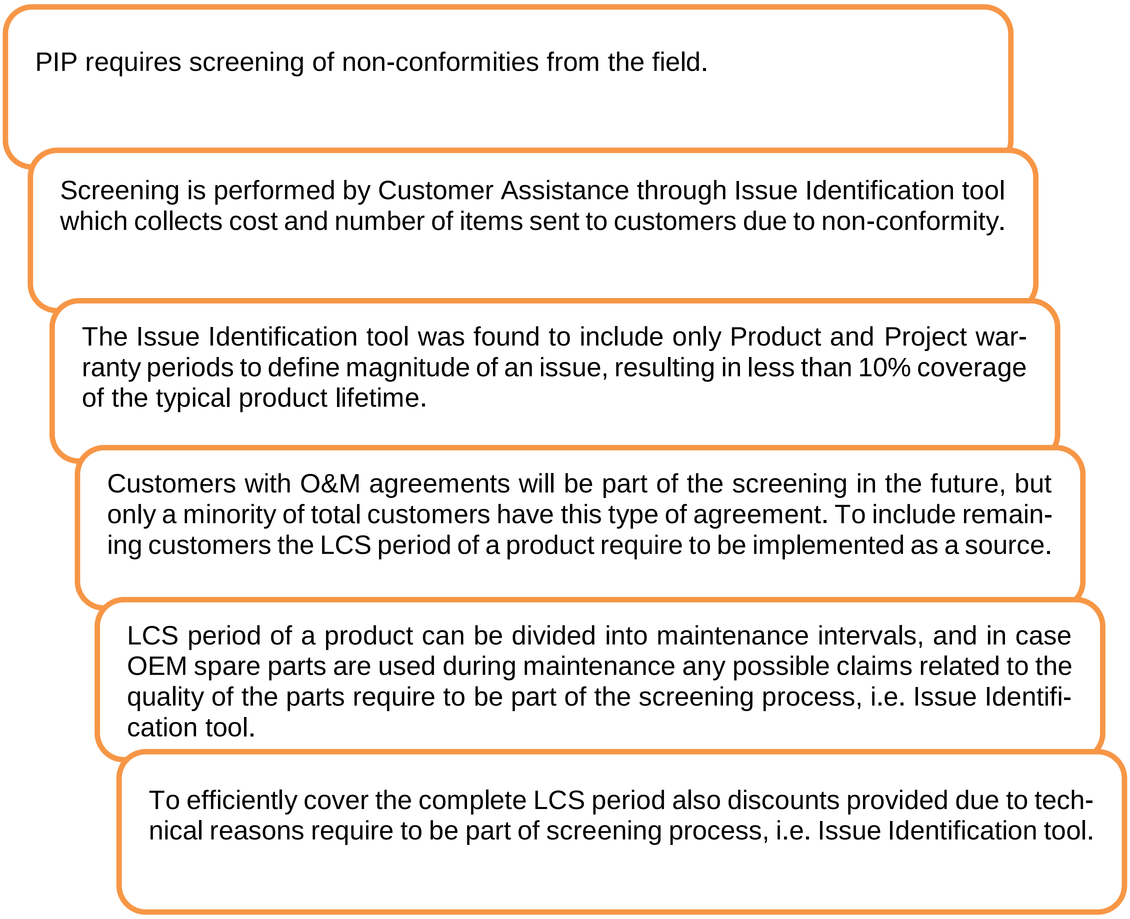


Figure 28. Case company screening process evaluation for management.

To be able to improve the existing screening coverage, two proposals were developed in this Thesis together with key stakeholders from:

- Customer Assistance responsible for Issue Identification tool reporting
- Global Logistics Services responsible for Spare part non-conformities
- Sales responsible for discounts
- Quality Management responsible for Issue Resolution (PIP)

The first proposal suggests to implement Spare part claims as a source for Issue Identification tool. This proposal was finalized in co-operation with GLS, CA and QM organizations in the Thesis, and is already being implemented through existing systems and hence requiring no further actions. Based on analysis of the data from 2015, this increases screening of costs by 32%, and screening of items by 5%.

The second proposal relates to implementing the Spare part post-warranty data as a source. This proposal was refined together with Sales and QM organizations to be able to collect only technical issues from discounts provided to the customers. The proposal includes changes in SAP sales transaction used when orders are placed in the system, requiring actions from Sales department. The most challenging task is to change Sales department way of working globally to separate commercial and technical discount reasons at an item level of an order. The required actions are presented in Figure 29 below.

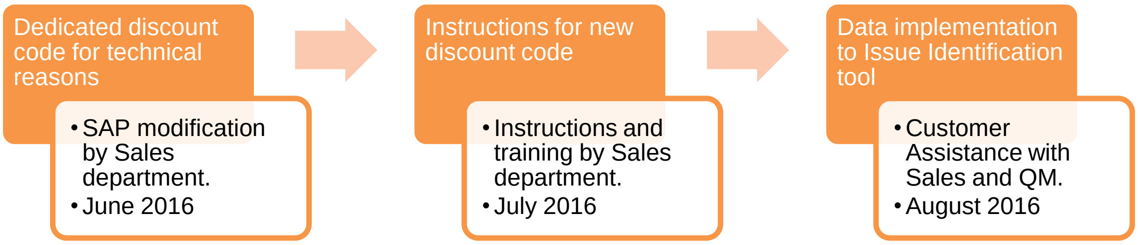


Figure 29. Main action points required to utilize discounts in screening process.

The improved screening coverage will benefit Technical Service to build business cases for PIP, and thus Technical Service, including author of this Thesis, provides support to implement the sources mentioned.

7.3 Evaluation of the Thesis

The relevance of this Thesis could be reflected in all the effort that has been made to have a process to improve products once a problem is found. For some reason PIP has been known by each individual participating in this Thesis, but a few has ever considered what it takes to actually build a business case for PIP. Even less have considered their valuable input for the benefit of others. During eight years of participating in PIP meetings, this has remained as the most significant single issue in the process overall, but most of the efforts to improve the situation have been guided towards qualitative sources, while the Issue Identification tool is the first real effort done to improve quantitative sources by adding O&M data into the data stream. Hence this Thesis has received a warm welcome from the individuals participating in the PIP, but to be able to deliver practical proposals there were a lot of challenges.

Motivation is not an issue, as this Thesis was done due to personal experience of repetitive product non-conformity issues not being shown in the statistics. Instead schedule is the limiting factor. The complete study would be nice and maybe more fruitful if action research could be used over and over again and add one source at a time and learn by doing (research). In this case it would have been impossible to do in a few months, especially if company size and organizational fragmentation related to the data sources are taken into consideration. In case the discount data in SAP would have included enough details, this Thesis could have ended in results probably nobody was expecting.

In the beginning of the study it was difficult to reach critical stake holders over organizational borders, and it took a lot of preparation to start the interviewing process. Even when the key individuals were reached it often turned out that people are travelling a lot, but luckily Skype interviews helped to overcome some of these issues. Conducting interviews through Skype was additionally one of the benefits of data gathering, as especially videos helped to confirm some highly critical issues especially related to the discount follow-up proposal. In addition having the Issue Identification tool creator providing full support and having an access to the tool itself were beneficial to come to the point where the Thesis is at the moment.

One particularly tricky issue was how to explain the proposal building of two practically separate issues in a way that it would make sense, and the section was re-written multiple times, probably sometimes with a step back. In many points of the Thesis excluding of the discount follow-up was considered, especially when proposal of spare part claims follow-up went to implementation which was beyond the original plan. However, this would have missed the significance of including LCS period as a whole, and thus it was decided to include the discount follow-up proposal in the Thesis, no matter how general the proposal would become. Probably, the Thesis would have been much more professional without it, but in the end this Thesis was aiming to fix a real Achilles heel in product improvement.

7.3.1 Outcome vs Objective

To reach the outcome, the study first traced the currently utilized statistical data sources and studied the limitations of these sources, as well as options to increase the coverage and trace possible alternative sources. Once these options had been mapped, the best practice of data non-conformity sources were elaborated to come up with a plan to prepare proposals in collaboration with key stakeholders. The proposals later were refined to the form of final, validated proposals. Outcome of the Thesis is thus two proposals to increase the coverage of statistical data sources. One of the proposals is already in implementation, while another is a proposal for the Sales organization to consider. If these are reflected on the objective of the Thesis, the result can be considered to be achieved. Both final proposals aim to increase the statistical data coverage related to the non-conformity in the field, which was the original problem.

7.3.2 Validity and Reliability

Reliability and validity of this study were planned and defined in Section 2.4, and this section aims to reflect on that plan.

First the internal validity was ensured by comparing the outcome with the original business challenge. The Thesis aimed to look for unutilized statistical sources of nonperformance data and search for ways to utilize them to benefit both the company and customers through enhanced PIP. Some of the questions changed during the process, as in the middle of the thesis the Issue Identification tool was released replacing the old one that barely even considered the screening activities. This clarified the process description within the case company significantly and changed approach from “where is the missing data?” to include more ambitious approach of “how could the data be utilized?” Due to this change much of the Thesis was completely re-written to implement the new tool, but it became apparent that the interviews and documents utilized supported the more ambitious approach well, as organizations behind the possible data did not change. Internal validity could maybe be improved, but the Thesis has focused on one goal throughout the process with support from the Research Design in Section 2.2.

The triangulation of data throughout the process in this Thesis is probably sufficient, although maybe not as visible as it could be, and the outcome including one direct implementation and one validated proposal indicate that data has been correct. One limitation of the data sources found was the company ERP system SAP as there are limitations of what type of information employee of a specific organization can extract while an individual from another organization may get different data. This was found several times during the process, and the problem is that the lack of data might not be that apparent without data comparison. These cases were noted during the triangulation of data but not presented in the Thesis to stay on the topic, and practically it would require another Thesis to explain why and what has been filtrated. Other tools focusing on extracting raw SAP data do not have the same user limitations which was beneficial for the study.

External validity of this Thesis had lower priority than internal reliability, but as Quinton and Smallbone (2006) stated some writers do not consider external validity relevant. The approach selected may be scaled up to include more sources if needed, but if context changes there might be little to benefit from this Thesis. Centralized data collection may be generally recommended to provide a broad view through multiple data sources, but for example, post-warranty non-conformity data in many occasions may be irrelevant if products differ from the case behind this Study. Additionally finding the best practices of utilizing data sources in post-warranty period was found challenging, and practically forced the study to rely mostly on warranty data sources. While challenging in the conceptual framework, in practice this had little impact on the Thesis as post-warranty in this particular case creates loss of revenue in a form of discounts, which could be correlated to the warranty costs.

Finally, the reliability of this study is determined by its repeatability. If the study would be performed by another method the end results probably would remain the same eventually, but if it was done by another person the PIP itself and the data required to build a business case probably would require further studies. In this Thesis, these were briefly mentioned in the beginning of CSA to find the real issues behind the challenge of building a business case. If the study would be done at another time, the result might additionally be different, and as it was seen during the process, the release of Issue Identification tool made the outcome possible. If the study would have been done half a year earlier, the end result would most likely have been completely different and focused more on centralized data collection than scanning for candidates for the existing tool. As especially the beginning of the study relied on the company internal documents, there was an emphasis on reliability in other sources, and thus interviews, including one of the workshops, were handled over skype and recorded with both audio and video to follow the interview with minimum interpretation error options. As the recordings of the interviews and field notes are not shared, there is a screen cap of the Skype recording manager in the Appendix. Additionally, the Thesis presented some of the key findings in a form of screen caps from the tools utilized, but many more were censored due to confidentiality reasons. Related to the interviewees, it is challenging to gather multiple sources with the required expertize, and hence the same sources were used several times for different specific questions for further details. At the same time, it made it possible to get more precise insights from the involved stakeholders and increase reliability through this dedicated involvement.

7.4 Closing Words

The problem with product improvement is that it often is taken as granted. If something seems to fail more often than expected, for sure it will be improved. However, the effort and risks involved in the process require to know at what scale the defect takes place. In case statistics are unknown, decision making becomes slower and more inaccurate than it needs to be. In the current global markets companies need the figures, or the other option is to hope competitors have them neither. This Thesis presented some practical challenges and ways to handle them, to get the figures in the case company. By doing this, the company is able to spot issues previously unseen and evaluate situation from helicopter perspective across organizations. Eventually, ignorance is not always a bliss in the business world.

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Appendix 1. Interviews and workshops recorded over Skype.

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Completed	15:57 10.2.2016	371 MB	01:11:05	
Completed	10:22 11.2.2016	369 MB	08:00:00	Data 1
Completed	10:52 18.2.2016	154 MB	00:31:55	
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Completed	12:54 6.4.2016	83 MB	00:26:20	Data 2
Completed	16:12 11.4.2016	191 MB	00:22:20	
Completed	9:03 15.4.2016	502 MB	01:00:40	
Completed	12:57 18.4.2016	178 MB	00:40:56	Data 3
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