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Quality Control Process Development

Active Quality Control Process for Bladefence Oy

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The goal of this thesis was to create, implement and verify the best possible quality control process for the client company. The study focused on creating the most resource efficient quality control approach for a medium to small client company, with secondary focus areas concentrated on scalability, effective quality feedback loop, and on-site auditing.

The thesis was conducted using Action research methodology, and a separate project for creating the process was run in the client company. The project team consisted of five to six individuals that were mainly from the operational management level. The main method used for the process creation and validation was the Six Sigma method, supported by theory from a range of theoretical sources and industry best practice.

The development part of the thesis includes the initial process creation, the process implementation and three separate cycles where the process was first used, and then improved in an empiric trial-and-error phase. The development part was based on a series of semi-structured interviews with the internal stakeholders relevant to the focus areas of the study.
After conducting the research cycles and interviews, the final assessment was done by comparing the metrics and data gathered and assessing the results of the research project. The results were measured by the number of non-conformities found; time spent in the quality control tasks, time spent correcting non-conformities and resources spent on auditing. The assessment was based on data, subjective experiences of stakeholders, and feedback collected during the research cycles.

By implementing the quality control process, the team was able to tackle an actual non-conformity, improve overall reporting quality, and create a functioning feedback cycle between the operations management and field technicians. The quality control process and other recommendations were adopted as a permanent part of the client company operations.

Keywords	Process development, quality, Six Sigma, auditing

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Opinäytetyön tavoitteena oli luoda ja implementoida uusi laadunhallinta prosessi asiakasyritykseen. Prosessin toiminta varmennetaan, sekä optimoidaan parhaaksi mahdolliseksi projektin aikana. Pääasiallinen fokus on ollut mahdollisimman resurssitehokas laadunhallinta metodi pienen tai keskisuuren yrityksen tarpeisiin. Toissijaisina fokusalueina on prosessin skaalautuvuus, tehokas palautteenanto ja työmaa-auditointi. Tuloksia mitattiin löytyneiden poikkeamien määrällä, laadunhallintaan käytetyn ajan määrällä, poikkeamisen korjaamiseen käytetyn ajan määrällä, sekä auditointiin käytettyjen resurssien määrällä.

Tutkimusmetodina käytettiin toimintatutkimusta. Tutkimus suoritettiin samanaikaisesti asiakasyrityksessä tehdyn kehitysprojektin kanssa. Projektiin osallistui kuusi henkilöä, jotka kuuluivat operatiiviseen johtoon. Tämä ryhmä oli isolta osin samaa, joille prosessin omistajuus projektin jälkeen jäi. Pääasiallinen työkalu prosessin luomisessa ja kehittämisessä oli Six Sigma metodi, jota tuettiin useilla erillisillä teorialähteillä. Täydet metodi ja teoriakuvaukset löytyy luvuista kahdesta viiteen.

Opinnäytetyö kuvaa ensin prosessin luomista, sitten implementointia, ja lopuksi prosessin parantamista empiirisesti yritä-ja-erehdy metodin kautta kolmen tutkimussyklin ajan. Näiden kuvausten jälkeen seuraa sisäisien sidosryhmien kanssa tehtyjä puolistrukturoituja haastatteluja liittyen tutkimuksen fokusalueisiin. Nämä kuvaukset löytyvät luvuista kuudesta yhdeksään.

Tutkimussyklien ja haastattelujen jälkeen tehtiin loppupäätelmät vertaamalla kerättyä dataa sekä arvioimalla projektin vaikutuksia. Päätelmät perustuvat dataan, eri sidosryhmien subjektiivisiin kokemuksiin, sekä muuhun tutkimuspäiväkirjaan kerättyyn tietoon.

Implementoimalla tämän prosessin, projektiryhmä onnistui tunnistamaan yhden poikkeaman, parantamaan raportoinnin tasoa yleisesti, sekä muodostamaan kahdensuuntaisen palaute dialogin operatiivisen johdon, ja suorittavan portaan väliin.

Avainsanat	Prosessin kehittäminen, Laatu, Six Sigma, Auditointi

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1 Introduction

1.1 Case Company

Bladefence Oy, is a Finnish company that operates in the renewable energy sector, more specifically in wind power sector. Company is a typical service company that offers maintenance services for wind turbine blades. Company was founded in 2010 as a subsidiary company for Janneniska Oy. Janneniska Oy offers hydraulic operated truck mounted boom lifts, for lifting personnel to work in heights otherwise not reachable by other means. These lifts are officially called mobile elevated work platforms, or by the hyphen MEWP.

Idea for the business came from a customer need. Many companies were hiring Janneniska's MEWPs to wind parks for access purposes. MEWPs in question can reach a working height of 104 meters within 15 minutes of arriving to the site making the machines an excellent access method for blade maintenance. Owners soon found out that selling just the access method is difficult as wind park owners wanted to buy the maintenance as a package, and therefore a group of technicians was hired from Isle of Wight in United Kingdom to bring in the expertise needed to repair and maintain the blades.

Currently the company operates in Europe, Canada and United States, and employs about 70 people during the blade repair season that spans from May until November annually in the Northern hemisphere. The group turnover is little over 12 million euros, and only 5 percent of that turnover comes from Finland.

Company's current activities:

- Inspection of blades (Physical or Ground based camera)
- Turbine lightning protection system check with resistance measurement.
- Repair of defects on blades rates in categories one through five.
- Retrofitting the blades with leading edge protection products, or heating systems.

These services are delivered by sending a team of technicians to a wind park to perform the agreed scope of work. Team usually consists of two or three technicians that live in the nearby hotel for the duration of a project. Work is done by stopping the turbine. This is done by technician of sufficient skill or with a help of turbine technician provided by the wind park owner. After turbine is stopped the team uses the chosen access method to access the blade and perform required works. Bladefence uses three access methods currently and the works can be done from ropes, suspended platforms or MEWP's. Each of the access method requires special training from the technicians, in addition all technicians need to have specific training for working in wind parks provided by global wind organization. Technicians must also be proficient in composite works as the construct of the blade is mostly glassfibre.

1.2 Business Challenge

Business challenge that thesis navigates is quite common for middle-sized company facing fast, almost violent international expansion. Bladefence as a company has been constructed on top of a core team of individuals that have high initiative and deep technical understanding of the services provided. Operational structure, as a result, relies greatly on the teams being independent in resolving issues on-site and reporting any changes to project managers without delays. (Managing Director, 2020)

In current structure project managers handle the timing of the projects, and documentation involved as a back-office people. Operational teams include 2-3 people. These teams perform the required works as agreed with the customer. Guideline for these works is a work instruction, either one is provided by the customer or Bladefence's in-house instructions are used. These instructions give detailed information about the technical specification, to which the repair must be done. Also, the materials used are either regulated by customers approved materials list or decided by Bladefence operations. (Managing Director, 2020)

It is one of the trademark features in blade repairs that the scope of work changes on site when technicians actually get hands on with the defects. These changes, that usually end to adding hours to the scope are then communicated to the customer by project management. Operational teams generate report forms from their work, usually one report per a single defect repaired. This means that a single project can generate anywhere between 10 and 1000 reports. Reports include all information relevant to the repair like wind farm information, turbine numbers, blade numbers, unique ID for defect, humidity and temperature, pictures to illustrate different phases of repair, and pictures to ensure used materials are not outdated. (Managing Director, 2020)

Bladefence has in past emphasized proactive quality measures by offering more internal training to technicians than its peers in the industry, this has kept the overall amount of warranty cases very low, as figure 1 in chapter 2.5 illustrates. However, the technicians are seasonal workers that work as contractors, and their contracts are usually for a single season only. This leads to a situation where, as the number of technicians grow, so does their turnover, and this brings undesired variance to repair work quality. (Managing Director, 2020)

Challenge is to ensure that the work done on-site corresponds to the work instructions given to the team. Currently the control is non-existent due to large amounts of reports and other data created. Research aims to create a quality control process that would allow the current business model to function but would also create an additional layer of security eliminating warranty cases in repair work. This should be achieved with minimal impact on back-office resources that are already limited. (Managing Director, 2020)

1.3 Scope of work

Scope of work for thesis is to test multiple variations of possible processes during season 2020, to learn what type of process would give the desired end result. Processes are modeled using Six Sigma tools. After this is done action research methodology is used to test these processes during the blade maintenance season of 2020.

Each action research cycle is aimed to last about 2 weeks, and after that a feedback is collected from both operational management, and the technicians. Like in action research usually, this information is then brought to research project group for analysis and further development of processes for future cycles.

This will continue until the best practices and components for the process have been mapped. Based on these findings the project will create the process models that are the objective of the research.

1.4 Objective

Objective of the result is to produce list of process layouts to be presented to the board of directors in Bladefence. It is clear that this process will ultimately be a part of the operational setup, but different versions are needed to address the resource strain of the new process.

Bladefence as any company works by balancing precious resources against business needs, and while perfect process would be ideal, it might be too resource heavy for the company in this crucial phase of expanding. That leads us to develop a solution that will scale up with the company itself.

Desired end result is three process options with different operational parameters that would be presented to the board. In essence this would mean a light, medium and heavy version of the process in terms of resource drain. For company management team this would give, the possibility to adjust the use of resources according to requirements and would significantly raise the possibility of immediate implementation of the process.

1.5 Research timetable and execution

Research will be executed during year 2020. Research project will be planned and required theoretical base reviewed during time period spanning from March to May, first thesis seminar will be kept during this period.

Second time period from June to August includes the actual research cycles, and related feedback sessions. During this time the aim is to map the best practices, create and test the process layouts, and produce most of the research data. Third time period from September to November will include finalizing the analysis, as well as this thesis paper, and presentation to Bladefence's board of directors.

1.6 Data collection methods

Bladefence is a pure network organization, where employees are usually physically located far away from each other. This makes observing the actual operational work on-site nearly impossible, since the way the work is done would change the minute an observer would arrive on-site. Therefore, the observation is limited to reactions of the technicians after process is implemented, and further observation in a controlled setting.

In Action Research: Principles and Practice, McNiff offers a following set of questions that could be used to determine the data collection methods:

- What do I want to find out?
- Where am I going to find it?
- Who can tell me?
- What should I look for? How will I recognize when I see it?
- What will it tell me, when I find it?

(McNiff 2013, 106.)

It is obvious that I want to find out the effects of different process layouts to day-to-day operational work of Bladefence. This information would be best collected from the technicians executing the work, but their 10-hour days are already filled with reporting, and labor-intensive work, so extracting the information directly from them would not be successful. This means that the technician perspective will have to be included in other ways.

Next best source for information is the direct managers of the technicians, and the auditing manager providing feedback from the work to the technicians. These participants will be a part of the formed project group, and their field notes will also include any data from data point of the tested processes in research cycles. These participants should also look for any reactions and/or changes in behavior of technicians in day-to-day interactions, and specially in their reporting practices. This information should give us an indication of the overall effect of the new process as well as particular notions about technician’s response to being monitored and receiving feedback on their work.

With these restrictions in mind, the following data gathering methods will be used:

- Research diary
    - Main researcher
- Field notes

    - Operations Manager
    - Project Manager
    - Quality Manager
- Reports
    - Repair reports
    - Daily progress reporting
- Interviews
    - Semi-Structured group Interviews
    - One-to-One

Findings are mostly stored in main researcher's diary, where daily discussions and other findings are logged. This will be supported with field notes gathered from immediate operational team. Reports, and daily progress reports from the technicians will provide supplemental information. In order to enable technicians to participate in the process according to action research principles, a group interview with semi-structured structure will be held to share observations of the implemented cycles, and ensure internal learning takes place during research.

1.7 Research questions

Research question in both the driving force, and the focusing factor on any research. Jane Agee mentions in her article of qualitative research questions, that one of the attributes of good research question is to bring focus to the matter being researched. She also mentions that many times the first attempts generate questions that are overly broad in nature and lack reference to a specific context. (Agee, 2009.)

With this in mind I created one main research question, that brings the focus on two things. One is the task that the process needs to complete, other is the use of resources it creates. These are the main up- and downsides of implementing a process like this, and therefore the main subjects that should be measured during the research. There is also room to add one, or two research questions should the need arise during the research cycles. Research questions are:

- What is the layout of the operational process that Bladefence should follow to successfully control the quality, without overtaxing resources?

- Which corrective actions have required effectiveness, in relation to resources used when non-conformities are discovered?

- Will on-site auditing bring additional benefits to any observed factors in this research?

1.8 Measurement of the research outcome

Research outcome, and in relation the success of research is measured in two ways. First, is a simple success or failure measurement that revolves around the question “Did we successfully produce a new process?”. This is not included in research questions as it is obvious that this will be accomplished.

Second way is to measure different effects of the new processes. In action research, the final form of the new processes is not determined yet, and many of the effects involved are subjective in nature. Because of this we must look into the process theory to see, which common denominators will likely be present for us to measure. In their book Damil & Damil write that process in essence is any workflow that changes inputs to outputs, and that in general the workflow can be executed as desired, so in conformity, or executed wrongly or as non-conformity. (Damil & Damil 2014, 18, in Brady & Monk & Wagner 2001.)

We also know that the process will be created with Six Sigma DMADV tool, and when implement the efficiency will be measured with Statistical Quality Control (SQC) tools. From this we can deduce that sampling will be an important part of the processes.

Therefore, following information is measured:

1. Non-conformity frequency in samples

2. Working hours in relation to amount of samples

3. Working hours used to correct non-conformities

4. Working hours used for on-site audits

Expectation is that most of the benefits will be subjective in nature and fall under the umbrella of qualitative information. It is of course important to collect quantitative information about hours and non-conformity amounts as these have direct cost-effect in Bladefence organization. However, expectation is that many of the perceived advantages in the research are subjective and, in the end, compared against direct cost-elements.

1.9 Expected benefits of successful research

Having a working active quality control process will affect the overall operations of Bladefence in multiple ways. Most obvious benefit is that the quality will be actively followed. This will over time reduce warranty cases, that is in short, the desired outcome for the company's perspective.

However, there are multiple secondary benefits that will follow. Remote teams will realize that their work is being monitored, and this will reduce the number of non-conformities against work instructions in general. Another secondary benefit is that implementing this process will have an effect on reporting procedure, as more information will be needed to monitor the repair process in great detail. Also, operational process for complex repairs might need an upgrade due to risk management emphasis on larger, more difficult repairs.

There are also benefits regarding external stakeholders of the company. Process like this will leave a document trail, that can be used in different qualification procedures for future customers. Quality increase should also have positive impact on current customers, as lower amount of warranty work will ultimately mean that the turbines will spend more time in production.

2 Current state analysis

2.1 Seasonal nature of wind power maintenance

Operation model in Bladefence currently is a typical for turbine maintenance industry and it is seasonal in nature. Working in wind power parks requires different methods for working at heights like platform or rope work. Both of these types are difficult, or impossible to do during high winds. In addition, the blade repair work is mainly lamination work, that requires high ambient temperatures for the resins to cure properly.

Due to these reasons the work done in wind power parks is highly seasonal with most of the maintenance work taking place in the four months that have the lowest average wind and highest ambient temperature. These months in Northern hemisphere are June, July, August and September. Rest of the year is considered as “high wind” -months and only critical maintenance is performed during that time.

2.2 Scalability of staffing

Due to seasonal nature of the work described under previous heading, Bladefence scales the number of staff radically between on-, and offseason. Currently about 20 % of the staff, is under traditional employment contract, and 80 % of the staff are contractors whose services are contracted for the duration of the season.

Contracts are usually between 6-9 months in length, and they are re-negotiated in the beginning of each year. Currently most of the contractors are returning for the following season, but the turnover rate is still a lot higher than with full time employees, currently sitting at 20 %. High scalability is mandatory for a company like Bladefence since during the off-season there is little to no revenue, and therefore employing permanent staff for operations is not possible.

From a quality perspective the contractor turnover is a significant driver for quality assurance in general. Contractors have varying levels of expertise in repairs, and they are internally graded to three different categories accordingly.

2.3 Current operational model

Current operational model is typical for this type of business but differs greatly from traditional service business models. When customer places an order, the information is passed from sales to project management. Project management then contacts the customer to agree on the timetable of service delivery, and a list of pre-project information that is needed to clear the technicians for work. This includes a host of documentation for health and safety, and risk assessment purposes, as well as contact information and site-specific information.

After this the technicians will travel from their respected home countries to retrieve a van with materials from either Helsinki, or Toronto depending on the continent. Next step is to mobilize to customer site. Technicians also carry their own personal protective equipment with them after the season has started, and therefore only one person from the team is required to retrieve the van. After reaching customer site, the technicians will work autonomously on-site liaising with customer technicians and producing reports for project management on their progress. Accommodation is generally a nearby hotel, or in some cases a cabin or some other larger option.

Teams work remotely on multiple sites, and often in different countries, and even different time zones than the project management. This emphasizes the need for self-starting employees and makes day-to-day management of service quality a challenge.

2.4 Current quality control measures in place

Currently the quality control measures in Bladefence are highly focused on pro-active approach, with the goal of mitigating the possibility of an error during repair process. This means that during the recruiting phase, the technicians are set into three categories according to their previous repair experience.

Second notable effort towards quality control is the in-house training the technicians receive before the season starts. All recruited technicians will gather in either Helsinki or Toronto, where a mandatory yearly refreshment training for industry related working on heights, first aid and operating in wind power sites is given. After aforementioned is completed, technicians receive a week long training that includes using all the different reporting systems, making repairs according Bladefence work instructions and hands-on training in lamination, where senior team leads observe and correct every technician individually.

After dispatching the technicians to sites to work, the project manager maintains daily communication using Microsoft teams, and phone. Repair reports are generated from semi-automated mobile application that automatically populates the pictures to right places in the report, with required handwritten descriptions. However, there is no system in place to check the content produced, and no audits are done to actually monitor the compliance of the technicians work on the sites.

2.5 Current quality in numbers

Bladefence has a history of doing more than bare minimum regards quality. However, the way things are setup operationally is highly focused on proactive measures described earlier. These methods have been very effective when business has been revolving around relatively small number of technicians. Quality is easier to maintain, when the team is small by an efficient recruitment process paired with internal training. In 2018 the amount of worked hours, and as consequence, number of technicians increased. After this you can see clear upward trend in warranty work in the following chart.

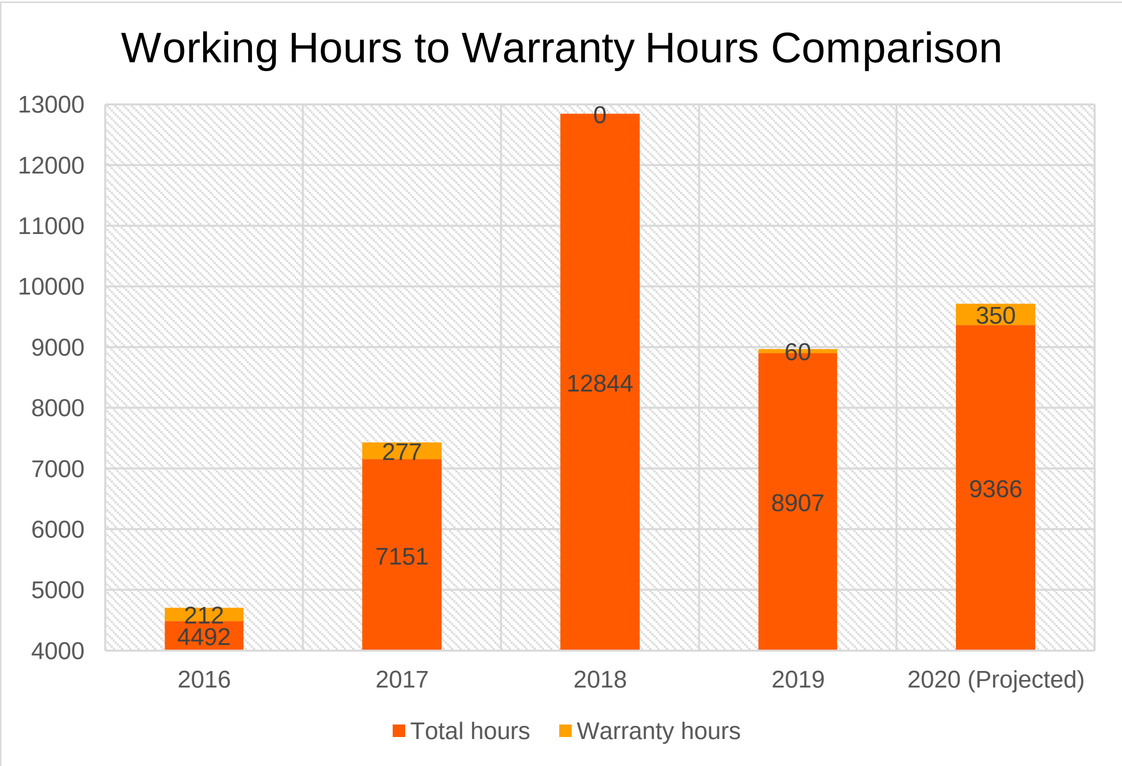

Figure 1. Working hours to Warranty hours comparison chart

Another emerging pattern that is supported by the diagram is the two-year warranty period. This means that any warranties due to poor workmanship, are usually visible two years after the work itself has been done. In the chart, the low hourly amount in 2016 has resulted to zero warranty hours in 2018, and the record number of hours in 2018 will result as the highest recorded amount warranty hours in 2020.

Additional note is that although the record hours in 2020 are just 3,6 % of the total amount of hours worked, the impact is not visible only in warranty working hours. In order for

Bladefence to execute a warranty repair, there are multiple secondary processes that also consume resources. These include ordering materials, staff rotation planning, mobilizing to site, and possible site-related training to technicians. All this has a large negative impact to operations that are usually running at capacity during season.

3 Service quality theory

3.1 Perception of quality and SERVQUAL model

In her book Mihaela L Kelemen presents eight different perceptions of what is perceived as quality. Bladefence sometimes uses the value-based approach when customizing services to a certain customer need. This means that the attributes of the service can be adjusted towards lower quality if a lower price point is required. That being said the default perception in Bladefence is so biased towards user-based approach that it would be a waste of time to discuss the others. According to Kelemen in this approach quality is typically defined as meeting and exceeding customer expectations, this approach is highly prevalent in the group of companies Bladefence is a part of. Kelemen also mentions that while multiple quality guru’s highlight the importance of this aspect, there is only small number of instructions about how to translate customer wants to a product or service specifications. (Kelemen 2002, 18-26.)

Traditionally when quality, or quality processes are discussed, the first thing that people think about is a manufacturing line in a factory, where a product is being manufactured. It is true that quality measurement dates back to the early days of industrialization, when most of the quality work was focused on manufacturing quality. However, measuring the success, or on other hand pointing out the flaws in manufacturing process is simple because quality of the process, and customer quality perception are highly correlated.

In service quality it is not as simple. This is due to the fact that customer experience and therefore their quality perception are affected by multiple variables in the service performed. These differences in perception are best illustrated by a SERQUAL model (Figure 2) that has been created in 1985, to illustrate and highlight five gaps between customers’ perceived expectation, and the company’s management’s expectation in relation of the actual service provided: (UK Essays, 2018.)

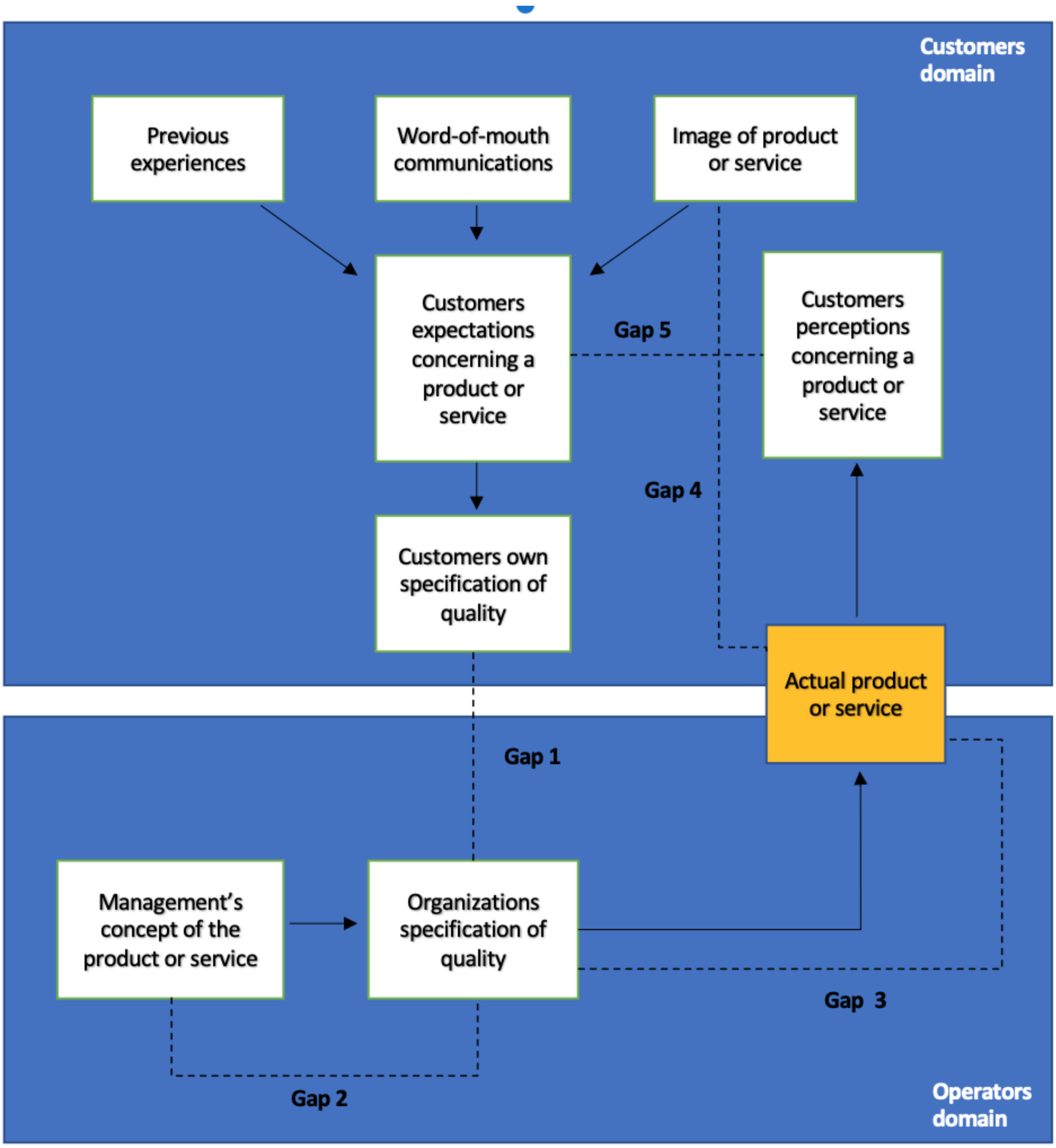

Figure 2. Adapted SERVQUAL model (Kelemen 2002, 62.)

3.2 SERVQUAL metrics evolution

Originally the SERVQUAL model was developed to measure 10 aspects of service quality: reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding and tangibles. This original set of aspects was considered complex, and it was generally agreed that it was statistically unreliable. Therefore in 1990 the model was refined to five more general aspects:

1. Reliability – Ability to perform the promised service accurately and dependably.

2. Assurance – Knowledge and courtesy of employees and their ability to convey trust and confidence.

3. Tangibles – Physical facilities, equipment, and the appearance of personnel.

4. Empathy – Caring and individualized attention to customers

5. Responsiveness – Willingness to help, and to provide prompt service

(Rodriques & Hussain & Aktharsha & Nair 2013, 2.)

According to Audrey Gilmore, SERVQUAL system is based on measuring differences between customer expectations and service outcomes. These differences are measured over five different “performance gaps” illustrated in figure 2. To measure satisfaction, the model uses the difference between customer’s expectations and perceptions of service. (Gilmore 2013, 42.)

Noteworthy difference between Kilmore’s interpretation of the gaps, compared to Kelemen is that the fifth gap in Kelemen’s model suggests that the actual service will create customer perception of the service, which then can be different from customers expectation concerning service. In Kilmore’s book this is described as “overall difference between management perception of customers expectation and customers expected service” (Gilmore 2013, 42-) Latter would suggest that management perceptions of customer expectation more directly affect service delivery and in conjunction the capability to match customer expectations. It seems that other author highlights the importance of customer perception, and other the service provider’s capability to grasp the wants and needs of the customer. (Gilmore 2013, 42; Kelemen 2002, 62-63)

3.3 SERVQUAL criticism

SERVQUAL is the most used framework when describing the concept of service quality. This is probably due to the fact that it is easily generalized and adapted to multiple different scenarios. Due to its general nature, SERVQUAL approach has received a lot of criticism about its viability.

Kelemen points in her book, that the whole sub-gap model is questionable, as for reasons she lists following. First is that customer expectations vary between different customers and therefore predicting them accurately or completely is impossible. Also, managements perception of what the customer wants is biased by different views and opinions, and therefore not a solid basis for establishing quality specifications. Second point is that converting these specifications to work standards reduces the possibility to tailor the service to fit the customer, as standards need to be clear and concise. Third issue found by Kelemen is that even in the case that management succeeds in establishing working standards, then the employees interpret those standards in a way they were not meant to. (Kelemen 2002, 63.)

Gilmore has included criticism from multiple different researches to create a list of issues raised about SERVQUAL. List includes the fact that there is no proof in any research that performance vs. expectation gaps is relevant to customer. Criticism also mentions that SERVQUAL is too heavily process oriented, and that the five dimensions are not universal in nature and have too high intercorrelation. There is a mention that there is no need to measure expectations, and that five gaps are not enough capture all the variability within SERVQUAL. Part of the critique is also the reoccurring statement that between different service encounters the customer assessments in different categories and scales withing SERVQUAL might vary. (Gilmore 2003, 43.)

While both authors have different approach in providing the criticism on SERVQUAL, there is a clear common denominator. Whether it is the delivery, or specification, or any other aspect of service quality, the perception between what is deemed good and bad varies greatly between different persons. This suggests that each service delivery, or encounter is different, because the variables change. Therefore, any prediction or measurement based on this model, are not entirely accurate.

3.4 SERQUAL Application

In the context of this thesis, the SERQUAL model is used to illustrate the gap we are addressing and connect it to the service quality concept in general.

Our future process aims to bridge the third gap in figure 2, or make sure that there is as little variance as possible in it. Bladefence uses considerable resources to standardize and document the first two gaps. Third gap is also documented, but the information is not verified, and the need for added quality control is evident.

As the goal of the research is to develop an internal quality control process there is no direct customer involvement. This means that most of the critique SERVQUAL faces does not apply to this project, since we are focusing on one gap only. However, verifying that the service is delivered as intended by the company, will have direct secondary effect to the customers perception of the service.

4 Process theory

4.1 What is a process.

Process is a description of activities required to reach a certain outcome. Processes are used to standardize the way of working within a company. Key point is to produce uniform results every time a process is executed. Processes have multiple parts that are described in similar fashion between different sources, these parts are required in the process description to produce measurable results. Berman describes these in her book as follows:

a. Input. It can be tangible product, or a part of the product, or on the other hand intangible like a customer request or need. Whatever the input for the process is it is needed for the project to run and produce targeted results. Most processes have multiple inputs from different stakeholders.

b. Trigger. It can be any event that is a signal for the process to start. Triggers can be based on time, or an ending of another process, or almost any condition that is specific for the process itself.

c. Customer. Customer is anyone who has a use for the output of the process. This stakeholder can be either internal or external for the company.

d. Output. Output is the end result of the process. This can be anything from actual product, to report or a quote. Key is that by delivering the output next steps in the process chain can happen. Output must always be measurable, even in the cases where it is intangible.

(Paraphrased according to Berman 2014, Chapter 1.)

4.2 Process creation

Process creation starts by mapping the different stakeholders for the process. This requires that the creator of the process, views the process from the outside in. Looking at a process from that perspective, gives out the idea of external pieces needed to form a project. In other words, it defines the inputs needed for this particular process. If these inputs are available, great, but if not, they need to be created. After that we can figure out how to convert those pieces into a desired output. (Berman, 2014, Chapter 7)

4.2.1 Process mapping

In he's book "The basics of process mapping" Robert Damelio describes in detail the different levels of project mapping. He describes three level of diagram frameworks as follows:

a. Relationship map. This is a visual representation of the different part of an organization and its internal and external supplier-customer relationships. It is a high-level map with a general overview of the dependencies between different entities.

b. Cross-functional process map. This map describes organizations workflow that consist of interrelated activities. It is also called a swim lane diagram since it has horizontal brackets for different functions. Relationship map shows different entities in organization and cross-functional process map shows the activities that take place inside those entities.

c. Flowchart. Flowchart includes the most detailed view of a single output created during the work. It can also categorize the activities to value-creating and non-value creating activities.

(Paraphrased according Damelio 2011, Chapter 1.)

There has been a consensus in business process notation since the early 2000's. It originally started in early 90's with diagrams introduced by Geary Rummler and Alan Brache, and their notations are generally called Rummler-Brache notation. Later in 2004 the Business Process Management Initiative (BPMI) brought business modelling vendors together and created Business Process Model and Notation (BPMN). This was very close to unified modeling language (UML) created earlier by Object Management Group (OMG). In 2005 these organization merged and are now working to ensure that both diagram variations work together. (Harmon 2019, Chapter 9)

4.2.2 SIPOC map

One of the most common and widely used relationship maps is a SIPOC map. Name comes from hyphen of Supplier-Input-Process-Output-Customer. In the book innovators toolkit, SIPOC is described high-level map that helps the transition of a developed process into an actual delivery. Mapping starts from identifying the outputs of a process, and then by defining customers for every output. After this the key inputs are deduced based on the process need, and finally the suppliers for these inputs are designated. (Silvestein Samuel & De Carlo 2012, Technique 51)

Critique towards the SIPOC model is that it is inadequate in defining the scope and all different stakeholders, especially for a service process. There are different models to describe and narrow the scope of work more accurately. (Long, 2010)

5 Auditing theory

5.1 Auditing fundamentals

Auditing is the procedure of checking individual work, or books of accounts against documented system. Origins of auditing is in the financial side of business, and the best know external audit type is the book audit for companies before releasing yearly results. Nowadays auditing is common in most supply chains, and also internally in companies that hold quality certificates. Auditing usually consist of four separate steps. First is the definition of the auditor. Second is the auditing plan like when, where and what should be audited. Third step is to compiling information from audit, usually this means filling a report. Fourth step is the actual presentation of the results for the audit. (The Economic Times, 2021)

Modern auditing has a multifaced approach, as almost anything can and is audited. Basu mentions at least cost audit, management audit, performance audit, social audit and human resource audit in his book (Basu 2009, Chapter 12.1). To this list you could add at least environmental audit that is becoming increasingly common in different supply chains. All of the audit types have different requirements, advantages and disadvantages. In this thesis we focus on internal quality auditing, as it is the only relevant type of audit for project and the client.

5.2 Auditing history

As many other words also word “audit” has its roots in Latin. Word is derived from word “audire” which translates roughly to “to hear”. Origins of Audit are very old as this might suggest, but in its current form it has been practiced only after second world war. Double entry system for financial records was invented in Venice in 1449, and the author of this system was the first person to describe the duties and responsibilities of an auditor. During industrial revolution the modern company structure with board of directors was born, the board of directors then needed to report accurate financial numbers to shareholders increasing the need for auditing work. By the early 1990’s the auditing was done by professional accountants and the verification of financial statements became the main objective for audits, since the accuracy of financial reports became the focus point. In 1913 the companies act was released that made audit of company accounts compulsory, this was later updated in 1956, with new companies act that contained elaborate descriptions of auditor qualifications as well as powers and duties. (Basu 2009, Chapter 1.3)

5.3 Internal auditing

In Basu’s book internal audit is described as follows: “Internal audit means the independent appraisal of activity within an organization for the review of accounting, financial and other business practices. It consists of a continuous and critical review of financial and operating activities by a staff of auditors functioning as a part of the management and reporting to management and not to the shareholders” (Basu 2009, Chapter 4.4).

This means that it is a review of internal procedures conducted by internal staff reporting directly to management. In essence, the company is validating its own actions by performing periodical checks on itself. In his book Denis Provonost mentions an important distinction to this, as internal audit is a verification activity it is always important to know what the reference is the procedures is are validated against. Provonost also mentions that internal should focus on verifying activities against process documentation, objectives and specifications or external standards. (Provonost 2000, 15-16)

5.4 Internal quality auditing

As any quality audit, internal quality audit aims verify different aspects of the organization affecting quality. Traditional way to address this is addressed in books by both Provonost and Russell. It is described in three levels where the highest level is the system audit. It means auditing the management system as a whole, taking into account how to organization is managed from top to bottom. Second level focuses on the processes that are audited specifically against their respective criteria, this might change between different projects or deliveries. Third and the most specific level is focused on the product or service delivery itself, basically verifying different attributes of said product or service. (Provonost 2000, 68; Russell 2007, 11)

While Russell leaves the description to this level, Provonost goes into deeper level breaking down the process level to different processes for tangible and intangible processes. In example purchase process, or project management process produce intangible results as they consist mostly of moving information, then again tangible processes could be the product or service delivery itself. (Provonost 2000, 69)

Three levels mentioned by Russell are again audited differently. When auditing the product or service delivery level, usually different measurable characteristics are audited, and then determined whether they are compliant in non-conformity. Usually in complex products the deviation is measured in defect per million scale. Second level auditing focuses on processes and whether they follow the approved process description. At this level it is important to verify both method and results are verified, this leads to a preferred situation where result are consistent due to diligent process execution. Third level that are the management processes are perhaps the most difficult to audit as they don’t produce any tangible results. This means that good understanding of the activities is mandatory before they can be audited efficiently. Management processes should ideally contain objective, that makes the verification of the expected results easier. (Provonost 2000, 69-73; Russell 2007, 11-12)

6 Six Sigma system

6.1 Six Sigma System

Six Sigma system is perhaps one of the most known quality enhancement system in the world. It was first formulated by Bill Smith at Motorola in 1986 for their manufacturing process. Since then, Six Sigma has evolved and today it offers a set of tools to enhance quality in any environment. Six Sigma has been described as a "systematic process of quality improvement through the disciplined data-analyzing approach, and by improving the organizational process by eliminating the defects or the obstacles which prevents the organizations to reach perfection". (Desai 2010, 4)

Six Sigma system is based on ideology of virtually error free performance, and it has in build methodologies for both enhancing existing processes and creating new ones. Six elements of the Six Sigma system are:

1. Focus on the customer: In Six Sigma the processes are developed according and towards to customer requirement. This means that the success of Six Sigma can be measured by customer satisfaction.

2. Fact-driven Management: Six Sigma measures actual business performance, and all data collection is based on relation to that. This means that improvement is based on actual business information, and not statistics.

3. Focus on Process, Management and Improvement: Six Sigma's aim is to bridge the gap between actual and targeted performance. Results will be measured as customer satisfaction, that leads to more efficiency and ultimately to profit increases.

4. Proactive Management: Six Sigma methods aim to replace reactive management with a proactive one.

5. Teamwork: Six Sigma promotes collaboration, with goal that everyone would understand their relationship to external customers.

6. Drive for perfection, tolerate failure: Six Sigma encourages employees to try new methods when reducing defects. Perfect execution is the goal, but failures are tolerated while testing different methods. (Paraphrased according Holpp & Pande 2001, Chapter 2.4)

6.1.1 Statistical Quality Control

Statistical Quality Control (SQC) is a set of tools that relate to one another and are a part of the Six Sigma toolkit. These tools are as the name suggests statistical in nature and are used in monitoring process quality performance. These tools can be tailored to each individual project, depending on the actual situation the process operates. Statistical Quality Control tools are:

1. Statistical Process Control (SPC) is used to record and detect variations within a process. These variations are categorized as regular and special variations. According to SPC the process is “in-control” when special variations have been eliminated from it.

2. Process Capability Analysis measures the process output against the desired variance tolerance set for the output. In other words, it measures the capability or the process to produce what the customer requires.

3. Measurement Systems Analysis (MSA) measures the variability within the measuring system. This part includes the variation that comes from the systems or processes used to measure the output.

4. PRE-Control. This system aims to significantly lower the need for sampling by creating “traffic lanes” where outputs are categorized by their quality. If two consecutive outputs are in yellow lane the sampling frequency is reset, as is the case of just one output with red lane specifications. If 25 consecutive samples are green in nature the sampling frequency can be decreased.

5. Acceptance Sampling, a method of inspecting output by taking the whole batch of the output and inspecting it completely. Many outcomes can be interpreted from the results of this sampling.

6. Design of experiments is a systematic method to determine relationships between factors affecting a process, and the output of that process. This information is used to optimize the output. (Gupta & Walker 2007,1-224)

In this research Statistical Quality Control is used to assess and measure the new processes developed by the project team. Depending on the route that the project takes, one or multiple tools from this set will be used.

6.1.2 Six Sigma methods for process creation and enhancement

In this action research the main emphasis is on not only a working process, but multiple variants with different levels of resource usage. In essence light, medium and heavy versions of the same process will be found out through trial-and-error cycles of action research. However, the core values of the process must be similar in each of the variants, and therefore in their creation a tried method of Six Sigma is used

Six Sigma has two built in methodologies called DMAIC and DMADV. These acronyms represent DMAIC (Define, Measure, Analyze, Improve and Control), and DMADV (Define, Measure, Analyze, Design and Verify). Both methodologies are represented by cycles as illustrated in figure 3 and are inspired by Deming's Plan-Do-Check-Act cycle.

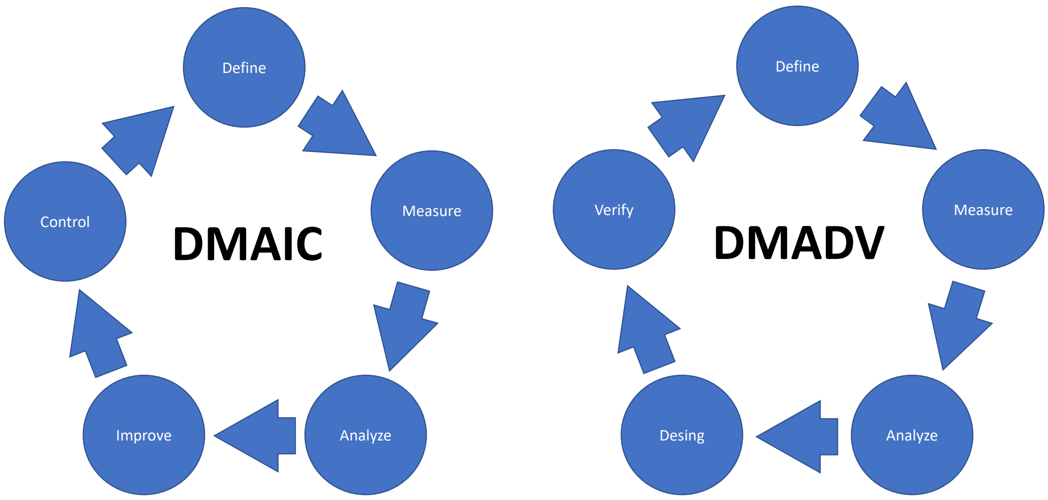

Figure 3. DMAIC and DMADV cycles

Difference between the methodologies is that DMAIC is built for improving a business process that already exists, while DMADV in the methodology of building a completely new process. (Six Sigma Daily, 2002.)

6.1.3 DMADV method breakdown

Define. In the define phase the goal of the process is defined. Guidelines for this will come from using previously gathered customer information.

Measure. This phase is about collecting relevant data. In our research it is particularly important to decide which parts of the data collected is relevant to the desired end result.

Analysis. In this phase the collected data is analyzed, and different design options, with variable life-cycle costs are made.

Design. In this phase the final form of the process is created and implemented. If previous phases are done correctly the result should be desirable.

Verify. In this final phase the performance of the implemented process is monitored to verify that the expected impact is reached.

(Paraphrased according to Mulder, 2007)

6.1.4 DMAIC method breakdown

In DMAIC, the first three steps are similar to those of DMADV. However, when their steps are defined, it becomes evident that the steps are not entirely similar:

Define. In DMAIC process the team defines the problem in the process they target. Definition must be accurate, as it makes following work easier.

Measure. This stage collects information from the process and establishes the improvement goals.

Analyze. Examine the data to identify the source of variation and create a road map to close the gap between current and targeted performance level.

Improve. Improve the process by removing cause of defects or other specified problem found during analyze phase.

Control. Control is aimed to prevent the re-occurrence of the defect. It defines control plans specifying process monitoring and corrective actions.

(Paraphrased according Seghal & Kaushish 2015, 450-452)

7 Research method

7.1 Methods used in the research

This research will be done with a combination of two methods. These methods will be run simultaneously as different layers in the process of research. Main method of the research is an action research that will be used to approach the business challenge. Action research has an open-ended approach that aims for increased understanding. Increased understanding is vital because the challenge has multiple variables, and their correlation to end-result is in essence a prerequisite of forming a useful process to address the issue.

Second method used is Six Sigma, and to be more precise the tool for process modeling. Whatever the findings during the action research might be, the objective is to create processes, as these are tangible and actionable representations of the understanding achieved during the research. To make this happen we use Six Sigma tools. Although the method in itself has research like elements, it is to run as sub process under Action research for the purpose of effectively model the processes with a proven quality-based approach.

7.2 Action research

Author Ernest T. Stringer describes traditional research in he's book as follows: "Research is systematic and rigorous inquiry or investigation that enables people to understand the nature of problematic events or phenomena". He then further characterizes research:

- A focus on a problem or issue to be investigated
- A systematic process of inquiry
- Development of explanations that lead to increased understanding

While traditional research looks for generalized answer that can be used to predict movements in the macro image, action research focuses on single business problem. Action research is based on proposition that generalized solutions must be modified and adapted in order to fit the context in which they are used. Action research is a collaborative method where the designated subjects of the results participate directly to the research. (Stringer 2014, 5-6)

According to Coughlan and Coghlan action research is an emergent process, where second action cannot be planned before the first takes place. Therefore, this access research will be implemented using action research cycles (Figure 4). Action research cycle consists of six main steps: Data gathering, Data feedback, Data analysis, Action planning, Implementation, and Evaluation. (Coughlan & Coghlan 2002, 229-230)

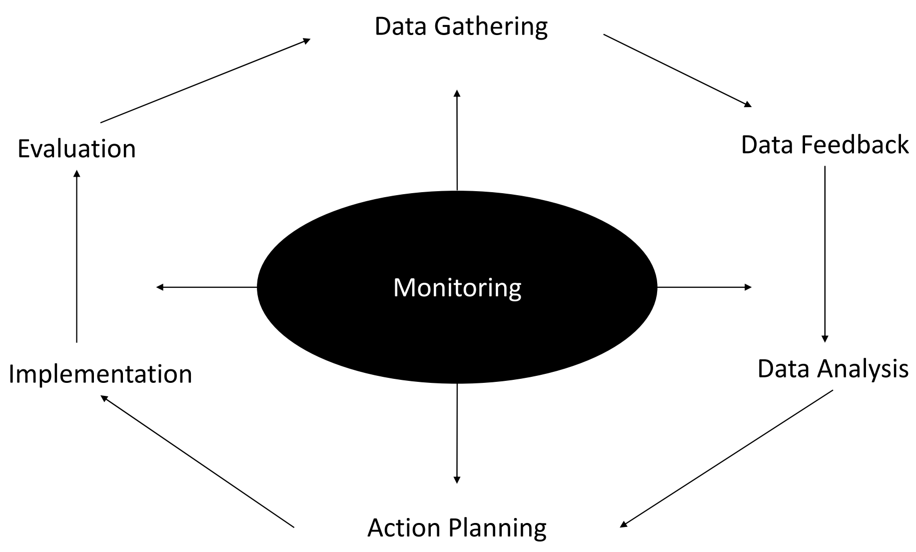

Figure 4. Action research cycle (Coughlan & Coughlan 2002, 230)

This research will consist of multiple action researched cycles. Each cycle will test a version of process that will then be modified and re-implemented after evaluation until the preferred version is found.

8 Project start and new process outline

8.1 Project start

Project was started on 11th of June 2020, with a kick-off meeting. Participants included whole project team: Managing Director, Operations Manager, Project Managers (2 persons), Security Supervisor and Lead Composite Technician. Meeting commenced with project leader's description of work methods, and the ultimate goals of the research. After this the team was given the freedom to come up with related information by brainstorming the subject. This chapter describes initial findings in this meeting.

8.1.1 Root cause of non-conformities

First point that the group raised was that the most common root cause of a repair non-conformity is misdiagnosing the defect. Although this depends on the individual in question, the group soon came to a conclusion that there is no way to control individual perception. Further, the reason for misdiagnosing were found to be insufficient skill set, technician tiredness after lengthy rotations, or personal pride in their own skills that effectively terminates the possibility that the technician would pro-actively seek help. Most defining finding was that an effective feedback loop, where management takes initiative to give constructive feedback, will probably encourage the technician to work correctly.

It was decided that in order to find these non-conformities the team has to perform acceptance sampling for the ongoing works, this is part of the Six Sigma SQC (Statistical Quality Control) toolkit described in chapter 6.1.1 and an excellent fit for this project. This would be done by reviewing the reports the technicians produced from their work on site.

8.1.2 Assessment of the total workload

Next topic discussed was the total workload. Group came to a conclusion that Bladefence would produce 80-100 reports for every four-week research cycle, and that throughout review of a single report takes 15-30 minutes, depending on the complexity of the report. In addition, the technicians need to be contacted in order to give feedback regarding the results of the review.

According to this calculation the total workload to review a single report and give feedback will vary between 30-90 minutes. Using the mean amount of 60 minutes per report the participants decided to start with 10 reports per one senior composite technician. This adds up to total of 20 sampled reports, representing up to 20 % of all reports produced. This would add one working day (10 hours) of workload per technician in the upcoming 3-4 weeks. This was considered to be on the heavy side when it comes to workload for the technicians reviewing the work.

8.1.3 Evaluation criteria

Part of the Six Sigma SQC (Statistical Quality Control) toolkit is PRE-Control that categorizes the sampled work into groups depending on their nature. This tool is used to focus the sampling in the areas where the change of a non-conformity is higher. This was discussed by participants; main topic was the criteria which would work as a guideline for picking the reports to be evaluated. It soon became evident, that there are multiple factors that should contribute to this:

1. Time the person has been with the company. (old vs new guys)

2. Complexity of the repair being done.
3. Previous performance
4. Skill level of the technician

Managing Director suggested that all the technicians should be placed in an internal points matrix for this purpose. Implementing a grading system was considered to be essential to control the resource drain of the process.

8.1.4 On-site auditing

During the meeting on-site auditing was also discussed. In general, the on-site auditing was widely regarded as the best means to ensure that quality on site meets the standards set by the company. However, the cost impact of dedicated resources travelling between sites for auditing purposes only is considered to be high.

One proposal that came from the project group was that we should use senior technicians to do audits when they arrive on site for rotations. This could be achieved by the technicians arriving a day early to the site. This could work as an interim solution before a dedicated auditing person could be employed. During this project both of our senior technicians were planning to visit sites, so some general idea of the effect of it should be available.

Auditing would include checking the working on-site, and verifying the actions both against company's general policies, and either internal, or customer's work instructions. In terms of internal auditing described in chapter 5.4, these audits would be considered as process audits.

8.2 Outline of the new process

Process creation was started by creating a SIPOC map according to the description in chapter 4.2.2. Team populated the map with relative ease, as most of the outputs were obvious:

Supplier	Input	Process	Output	Customer
Project management	Pick reports to the sampling pool	**Bladefence quality control process**	Improved work quality	External customer
Project management	Pick reports to the sampling pool		Improved reporting quality	External customer
Senior technicians	Check the reports made on-site		Feedback from work and reporting quality	Technicians
Operations manager (Process owner)	Manages the process		Statistics on non-conformity amounts	Management
			Less warranty cases in the following seasons	Whole company

Figure 5. SIPOC map

Team decided to use cross-functional process map described in chapter 4.2.1 to give visual representation to the process. This map was outlined according DMADV tool that is part of the Six Sigma methodology, this tool has been described in detail in chapter 6.1.3. Outline as follows: Define – Perform quality assurance sampling for work done on site and create a feedback loop between management and technicians. Measure – Samples will be matched against the work instructions specific to the task, and technician’s ability to input correct information to the report is also checked. Analyze – Lead technicians analyze the reports and provide feedback. Findings are analyzed in follow up meetings. Design – In initial design the project management chooses the reports to sample, and lead technician analyzes the sample and provides personal feedback to the technician in questions. Verify – Verification was due to take place in first follow up meeting in 4 weeks’ time.

Idea behind the outline was that senior technicians perform the bulk of the work, since during the season the project management has very limited resources. After the meeting following process chart was drawn using the process outline laid by the project group:

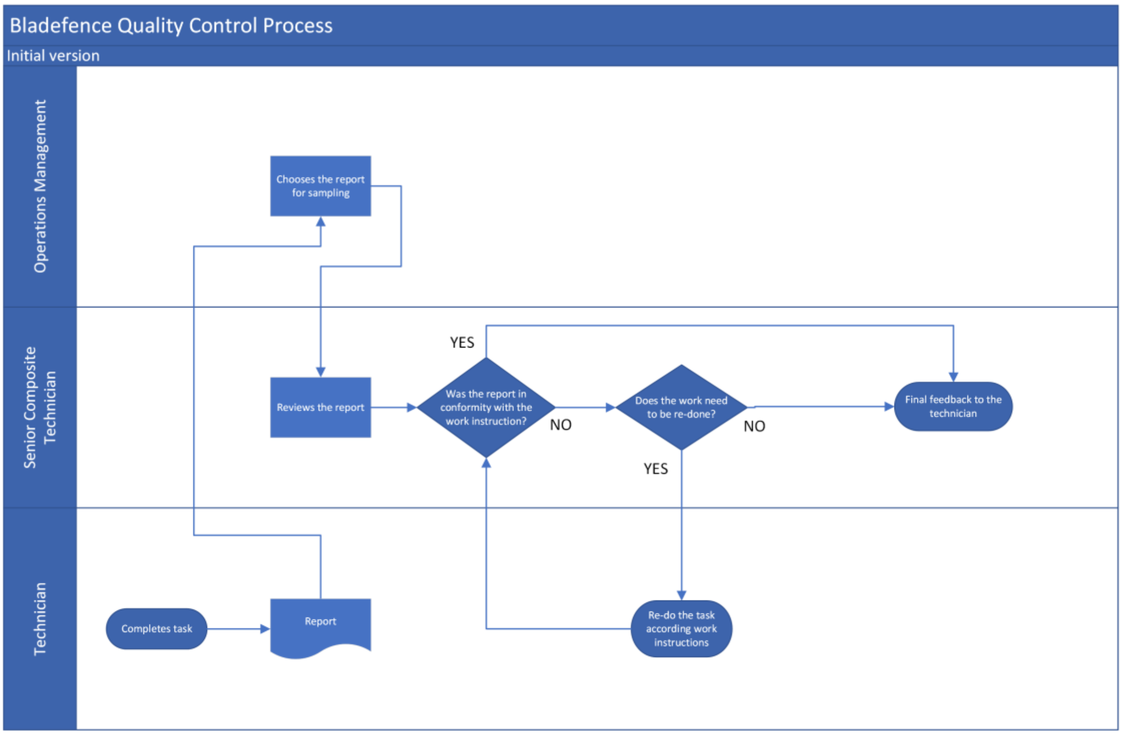

Figure 6. Initial Process Outline

Team unanimously decided to proceed with this layout for the first cycle, as it was seen as the best layout we could manage with the information on hand. Everyone agreed that changes are probable after we have executed the first loop.

8.3 Expectation before implementation

Sample amount is quite substantial, so the expectation was that non-conformities will be found. Extent and severity of these non-conformities will determine the future actions regarding the sample amounts. Expectation on the secondary impacts of implementing this type of process is more difficult to evaluate, but the general belief was that technicians would start to pay more attention to their work quality in general when they realize that it is examined closely.

9 Implementation cycles and results

9.1 First implementation cycle

First implementation cycle length was in total of five weeks in length. During this time the operational team produced an estimated total of 30 reports. Amount was unusually low, as most of the team were engaged in large repairs that take substantial number of working hours to complete. During this time the team was able to process 12 reports of the total amount giving us 40 % rate on tracked reports. This amount is higher than expected, but the low total number of reports explains this, and the rate is expected to drop moving forward.

9.1.1 First implementation cycle findings

During the first implementation cycle the team found out multiple small issues in reporting. These included various issues like incorrect measurements, incorrect wording when describing damages and other small issues in reporting. Also, one report was found to be in non-conformity, and in need of correction. Number of hours used to rectify the non-conformity were total of 2 hours. Also analyzing 8 reports during the first cycle took in total 3 working hours, rest of the 12 reports were reports that were compiled by the project management and checked during that process.

After the first implementation cycle our non-conformity rate is 8,3 %. From Six Sigma point of view, the fact that the non-conformity was found verifies that the process model works in the intended way. This also completes the DMADV cycle that was started earlier during the start of the process.

9.1.2 Sampling focus and other changes going forward

During this meeting the team agreed that we should further concentrate our sampling efforts to narrow down the list sampled work to get the most out of our resources used. Using the Six Sigma PRE-Control tool and evaluation criteria mentioned in chapter 6.1.1, the group took in play the complexity of the repair. This attribute combined with the earlier finding of technician experience level gave us a focused list for sampling that we called "sampling focus". Team agreed that the sampling focus should include two sites, where the repairs took place. Workload was expected to be 10 reports during next cycle.

Team did not want to make any adjustment in the process during this time. Also, one team member was added to group analyzing the reports. There was some talk about adding a cross-evaluation, but the idea was discarded as it would not serve the original idea of feedback loop between management and technicians.

9.1.3 Changes in Six Sigma process

After the first cycle, the team successfully completed the Six Sigma DMADV cycle, by constructing and verifying the operation of the new process. From the second cycle onwards, the team is not developing new process anymore, but enhancing the process already created. Therefore, from Six Sigma methodology perspective, we continue onwards using DMAIC method to further refine the process towards the best possible version we can achieve. DMAIC method had been described in detail in chapter 6.1.4.

9.2 Second implementation cycle

Second implementation cycle was six weeks in length and during this time the operations produced in total of 50 reports. Amount was still on the low side, although some increase in the quantities can be seen. During the six-week period the project team was able to sample 12 reports in total giving us a 24 % rate in tracked reports. This is in-line with the expectation the team had when the project started, and an expected drop after the good start for this project in first cycle.

9.2.1 Second implementation cycle findings

In second cycle, the team estimated that 12 hours in total was used to go through the 12 reports. Second cycle findings in general were similar to the findings of the first one. Multiple small issues, including use of wrong reporting template and one unnecessary step taken in one of the repair processes. There were no actual non-conformity cases in this cycle which can be considered as very good news, because the sample reports were chosen through the PRE-Control process of Six sigma.

It is noteworthy, that one of the small issues happened to the same technician that had the original non-conformity case during the first implementation cycle. When I questioned the team about his current work, they marked that his overall performance was improved, but that he still lacked in other areas of work. This highlights the need to base some of the PRE-Control process on the technician's individual skill level, as well as the complexity of the work itself.

Our current PRE-Control has been working mainly on focusing on the complexity of the repairs works in question. Team decided to add the performing technician as a factor in third cycle sampling focus. Third cycle sampling focus included works from five different sites, that were deemed necessary to follow.

9.2.2 Feedback consistency and new process layout

During the second cycle, when senior technician found the small issue with the work of the technician, that also had the non-conformity issue in cycle one. Team realized that if we would follow the process as it is, it would result to a situation where a different person would be giving the feedback to the technician than in cycle one.

All members of the project team agreed that this would lead to inconsistencies if the person giving the feedback would not be aware of the possible previous issues the same technician has experienced. To resolve this issue, it was decided that all feedback would be circulated through operations manager that would keep a record of different types of feedback given. This would give operations manager the necessary situational awareness of possible reoccurring issues. In the light of this feedback, the process layout was modified as follows:

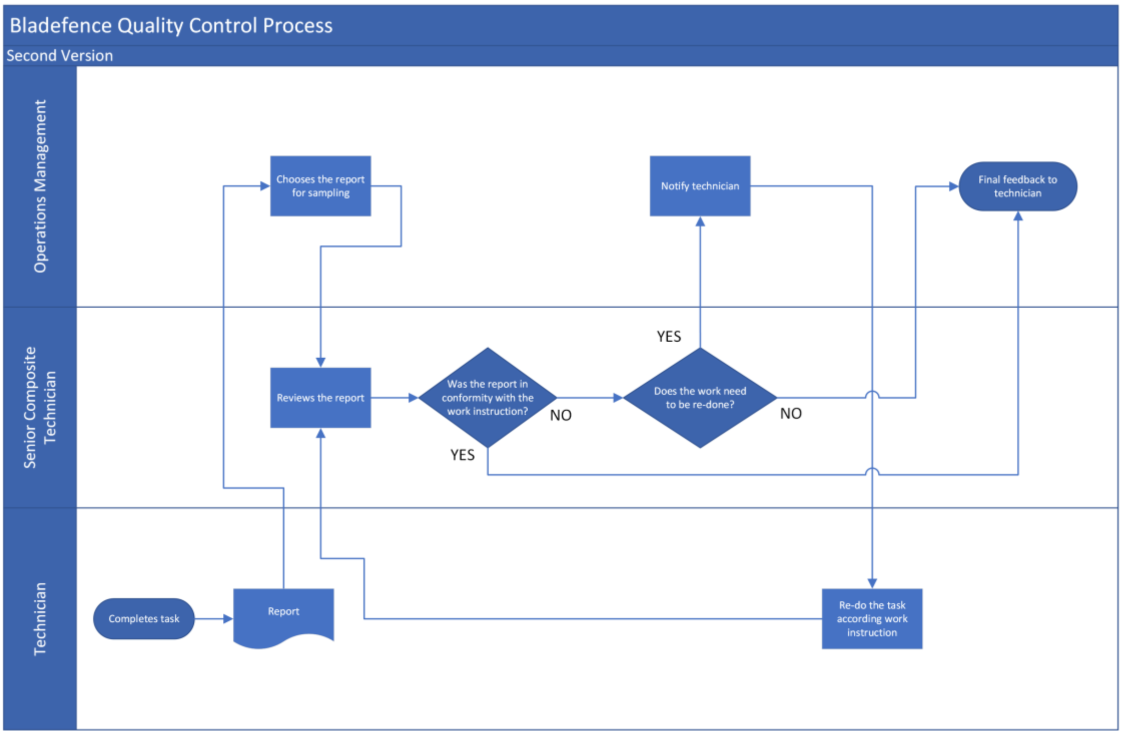

Figure 7. Second Process Outline

Other than this the process was found to work in-line with the expectations. No further changes were made.

9.2.3 Resource drain and sampling bottleneck issue

During the second implementation cycle the overall amount of work in the company started to rise. Towards the end of the cycle operations were handling a record number of projects and technicians simultaneously. As the day-to-day operational issues took over, the project management faced a backlog in report compiling. This bottleneck resulted in a situation, where no reports were available for checking, even though the resources for the job were available.

As a result, the sampling cycle time went up from about a week, to multiple weeks. This would have a very negative impact, if non-conformities were found, since the team that has done the repair would be possibly off-site by then. It is clear that if the sampling cycle is to be kept within reasonable time, it cannot be achieved with current resources during the height of the season. Operations Manager also noted that the repair work would need to be assessed against work instructions used. This varies for site to site since the work instructions might be internal ones or provided by customer. This adds complexity to the sampling process as the person checking the report must familiarize himself with the work instructions before checking the report. Complexity on the other hand, affects directly the resource drain of the process.

In a discussion with the project team, a few options surfaced as a remedy for the resource drain issue. First, the possibility to detach Operations Manager from direct project management. This would free his resources enough to tackle the difficulties with the reports should they arise. Second, the possibility to appoint a team leader to each of the technician teams working on site and involve them in reporting. Third, appoint a standalone quality manager to oversee the quality control process. Each of these would directly address the issue, but it remains to be seen which one, if any will be used in future.

9.3 Third implementation cycle

Third implementation cycle length was 9 weeks in total. During this time the operational team produced an estimated total of 60 reports. This was again lower than expected, as in the previous cycles. During this time the team was able to process 10 reports of the total amount giving us 16,6 % rate on tracked reports. This amount is lower than expected due to the excessive workload the operational team faced during this cycle.

9.3.1 Third implementation cycle findings

In third implementation cycle team used 4,5 hours to sample 10 reports. This is mainly because some reported work was low in complexity, due to our PRE-Control also following individual technicians as well as work complexity. In general, the third implementation cycle proved to be quite uneventful. There were no non-conformities in the sampled reports.

As in the previous cycles, there were minor issues like using the wrong template in the reporting system, or missing photos in the documentation of a repair. Although these findings would be considered as secondary to the non-conformities. It is clear that our reporting quality will also over time improve as the process addresses these issues directly with technicians as well.

Overall, the challenges in the process remained the same. Resources for sampling, and coordinating the process in management level, were still an issue. Further to prior conversations, it was noted that if we want to keep the sampling cycle time steady throughout the season, the best option would be to appoint a dedicated quality manager. Team was otherwise happy with the structure of the process and felt that it served our needs well. Preliminary feedback from the technicians has also been positive through the whole process.

9.3.2 Final process adjustment

As the team did not have any major changes they would have liked to implement in the process at this final stage. We looked through the whole process again. From the perspective of executing the process our prevailing issue is the apparent lack of resources. Only mitigating component is the PRE-control elimination that focuses our sampling, and therefore reduces the amount of sampling needed. We decided to add this to the process as a permanent step:

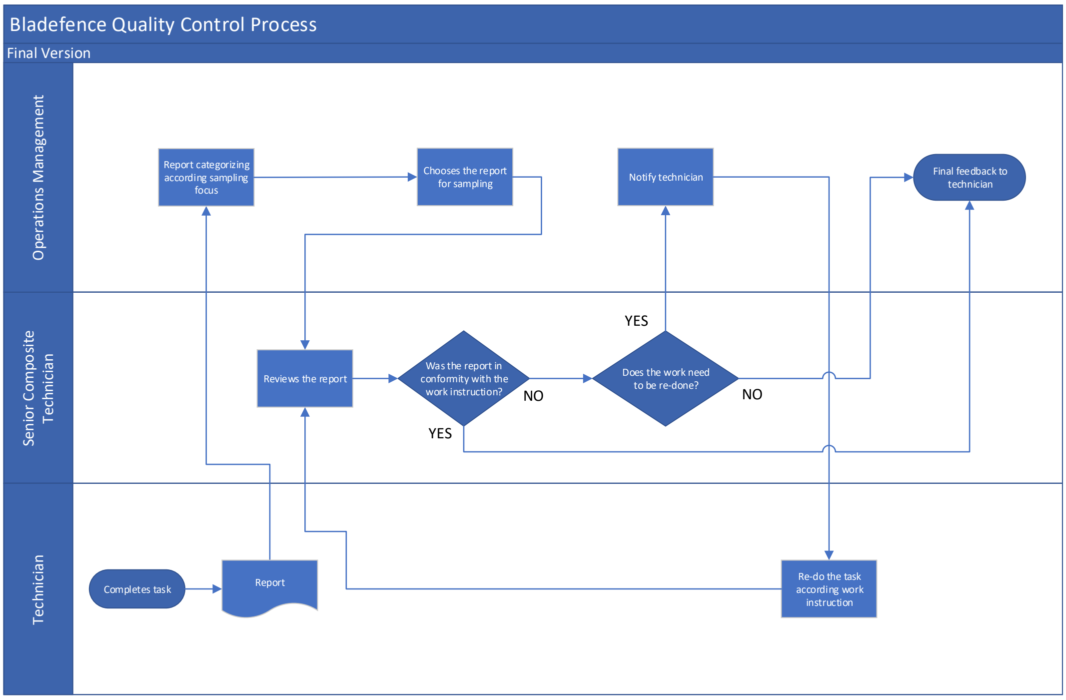

Figure 8. Final Process Outline

Afterwards, the team was unanimous in their opinion that this final template includes at least all the relevant steps in the process. This means that even though in future the active roles in this process might change, the steps should remain the same.

10 Interviews

10.1 Technician interviews – Quality process

Technician interviews were held in 16.12.2020. Interviews were conducted with a semi-structured format and the form can be found attached as Appendix 2.Two technicians were interviewed, both residents of the United Kingdom. These individuals were chosen due to their extensive experience that spans over 14 years combined, and both of them have worked in at least six blade maintenance companies prior to Bladefence.

During these interviews there was no animosity from the technicians towards the fact that their work has been checked by a senior person in the office, in fact both technicians welcomed the practice and were happy about the transparency of the process. Key finding in these interviews was that the bulk of the peer companies checked the work that the technicians did, but no feedback was given directly to the technician. There was also evidence in some peers, where bad reports have almost reached the customers due to lack of control in back office to ensure quality of reporting.

Main benefits for the technician would be having a unified way of reporting and being able to make the overall reporting quality better. One technician mentioned that this process eliminates slack reporting, where technicians do just enough to make the report look filled but are not really giving their best effort. Feedback has been helpful for the technicians, and overall, the two-way conversation is very highly respected. When feedback format was discussed, both favored a phone call and would limit written format to situations when there is nothing to discuss. When back-office is just acknowledging that everything is good, then a written feedback would be sufficient, but when critique is delivered there should be a possibility for a two-way conversation.

10.2 Senior technician interview – Site auditing

Senior technician interview was held on 1.12.2020. Interview was a semi-structured one and the interview form can be found as Appendix 3. Technician interviewed was chosen due to extensive on-site experience. Technician in question, has been a blade technician for seven years and has worked as a project manager for a year. Technician has also visited sites five times in the current year in two different countries, so he was a logical choice for site audit interview. During these visits the technician estimated that he spent about 50 working hours to conduct auditing, or similar work.

Main benefits for site auditing in his opinion was to see the quality of overall operations, and to get a feel of the level of motivation and atmosphere within the team working at site. Additionally, meeting the customer during the time on-site will give them a better understanding of the practical side of the repairs, as they usually just see the report. We also discussed of using people from other departments (i.e., finance) to do the audits but found it difficult if they do not have a basic knowledge regarding the repairs. However, an auditing checklist could be created to aid the persons in question. Also, as Bladefence teams usually work on site, the communications between office and on-site personnel could be improved by showing interest through site visits. However, there is a barrier that prevents this, and it is the training needed to enter the site, which most of the back-office personnel do not have.

Technicians would benefit from different approaches to job on hand if a person with prior knowledge of repairs would audit them. This would also be a two-way-street as persons who do not have previous site experience could gain important insight to the daily activities performed on site. In his opinion the optimal frequency for auditing would be once a month, but least we should do is visit once in every larger ongoing project. He mentioned that these types of on-site audits could be conducted by Senior Technicians during rotational changes. However, that would be predictable in nature, and therefore lower the effect of auditing.

All his visits to different sites during season have all been pre-planned and communicated to the technicians in advance. Overall experience from these visits has been positive, and there has been no negative feedback regarding the checks. Also, all the customer contacts on-site have been overwhelmingly positive, and welcomed by the customer, and there is no evidence on it impacting Bladefence in any negative manner.

He seems to think that the person with high knowledge of composite repairs would be the ones that should mainly do the auditing as well. We also touched the topic of auditing different access methods, and for rope works we would need a specially trained person to audit them properly. It was also noted that person without any training could still visit the site, if escorted by the customer, as their visitor.

11 Conclusion

11.1 General conclusions

This project was started from the expectation that there are non-conformities in the repair work conducted by the technicians, and the aim was to create and refine a process that would find and eliminate the non-conformities mentioned. As the project moved onward, it was discovered that actually there were two separate topics that required control. One was the actual work, that had very little issues throughout the project, and other was the actual reporting of the work that most of the corrective actions were done to.

Although the process failed in finding a large repair work non-conformity, we were able to test and verify multiple matters related to the process, and its qualities. First of all, everyone agreed that this is necessary process that we must have implemented in future, and all feedback from this work has been overwhelmingly positive. We managed to test different ways to execute the process, and through it all there were no big surprises. Even the issues regarding process that were the resources, were expected, and all findings confirm that this type of process will be a vital part of quality control measures in Bladefence.

In chapter 3.4 it is mentioned that the goal is to reduce the third gap of the SERVQUAL model, and address any possible variance found. From the information gathered it is safe to say, that there was only little actual variance found. This is very good from Bladefence’s perspective. However, constant verification should take place for both work quality, and reporting quality to ensure that the gap will stay small, and variance does not begin to grow, especially when the company grows.

11.2 Project length and sample ratio

Project took place during repair season 2020. Project team executed three separate research cycles, and due to increasing workload towards end of the season each cycle was longer than the previous one. Cycle lengths in days were 35, 42 and 63 respectively. Originally the goal was to execute 4–5-week cycles, so especially the final cycle was very long. Whole duration of the project was 140 days, which equals 20 weeks, this is significantly longer than expected in chapter 1.5.

In chapter 8.1.2 the total workload assessment was conducted, and the project was started with the expectation that 20 % of the whole reporting amount would be sampled in the first cycle, but as the report amounts grew, it would be very hard to maintain.

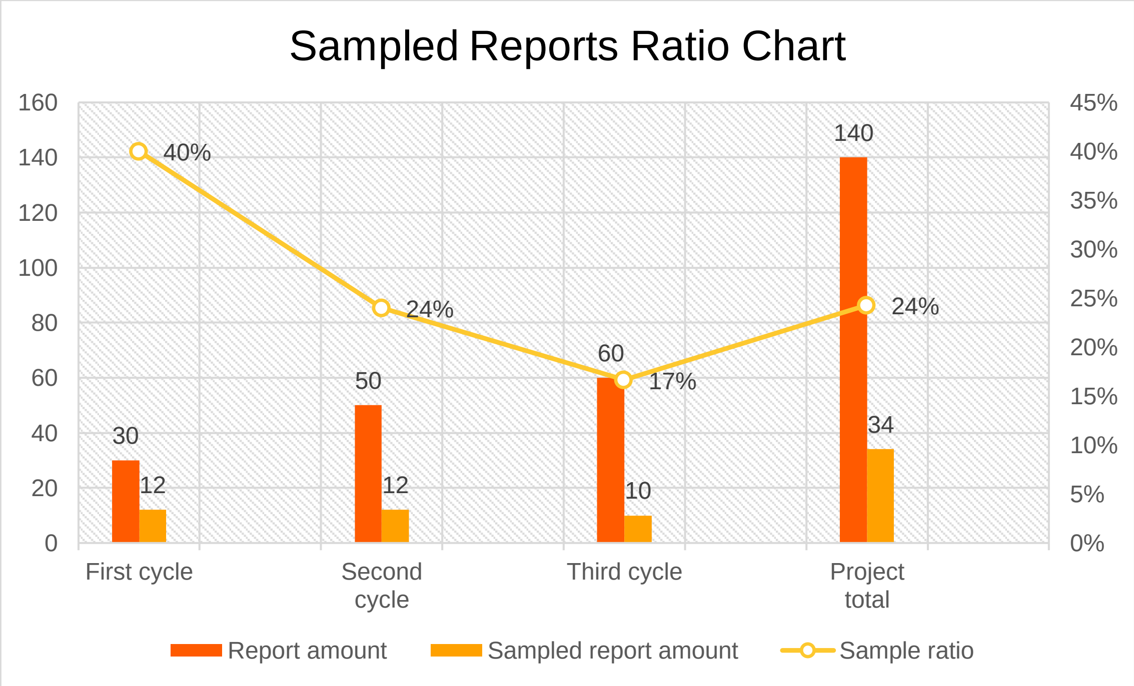

Figure 9. Sampled reports ration chart

When looking at figure 9, and thinking about our empirical findings during the project, it is safe to say that there is a clear correlation between experienced workload, and the sample ratio of reports. This is probably because same people that perform the sample checks also participate in the operational effort and are therefore directly affected by the raising workload.

Numbers also indicate that earlier expectation of the sample ratio were somewhat pessimistic. Project team was able to maintain sample ratio of 20-25 percent through all times, excluding the short period of very high workload, and even during that period very respectable ratio of 17 percent was maintained. This leads to the conclusion that 20-25 ratio is achievable without dedicated quality management resource, and that with the dedicated resource this could be pushed to 50 percent and beyond.

11.3 Non-conformities

One surprising, but without doubt the most positive result from this project has been that none of the actual repairs were found to be in non-conformity. This would suggest that we should not suffer any warranty claims from our seasons work. Season 2020 was a record year in warranty hour in Bladefence as mentioned in chapter 2.5, therefore result like this is highly promising.

In total, only one non-conformity was found. This was related to reporting, and the root cause was incorrect data capture, to be more specific, pictures included did not describe all stages of work sufficiently. Only non-conformity took two hours in total to fix, and this work could be done without revisiting the repair. All other findings were minor and did not have major impact to quality perceived by customer.

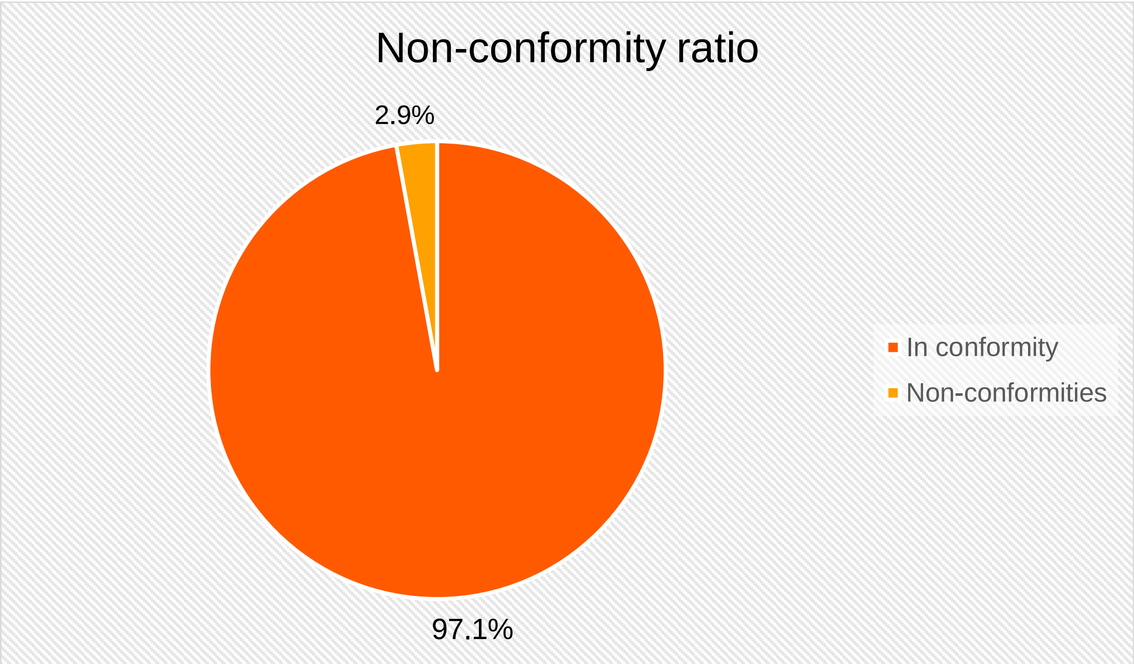

Figure 10. Non-conformity ratio chart

If numbers are used from figure 9 and 10, it would suggest that from the total amount of 140 reports produced, up to 4 could be in non-conformity if the ratio is similar 2.9 percent. However, the sampled 34 reports were PRE-Controlled according to statistical process control tools described in chapter 6.1.1. This control has ensured that the technicians and work that is most susceptible to non-conformities has been chosen for sampling. This would suggest that non-conformity ratio in these 34 reports is significantly higher than in rest of the reports. With all these factors in mind the total non-conformity ratio of 2.9 percent is an excellent result in comparison with previous performance highlighted in figure 1.

When these findings were discussed with the project team, it was suggested that the difference compared to previous years could be that our project has influenced the general attitude towards quality. This would mean that technicians, when realizing that their work is being checked, have done a decent job, whereas before they could get by with slacking. This was also mentioned in the technician interviews and was one of the expected secondary effects of implementing such process. However, since this process has only been running for one season the relation between these two facts is causal at best.

11.4 Resources

One of the most important aspects of this project has been measuring, and verifying the resources needed to effectively launch and maintain a process like this. In total there has been two project managers, and three senior technicians involved with the actual work of sampling and checking the reports and the corresponding work.

Figure 11 describes the estimated amount of time spent in analyzing the sampled reports. This time includes both the time spent in doing the analysis and the time spent giving feedback to the technicians in question. It is clearly visible that different types of reports accumulate the time differently. It is also a factor that there were only very few non-conformities, and therefore most of the feedback could be delivered via e-mail. If there would be more issues, it would affect the time consumption drastically.

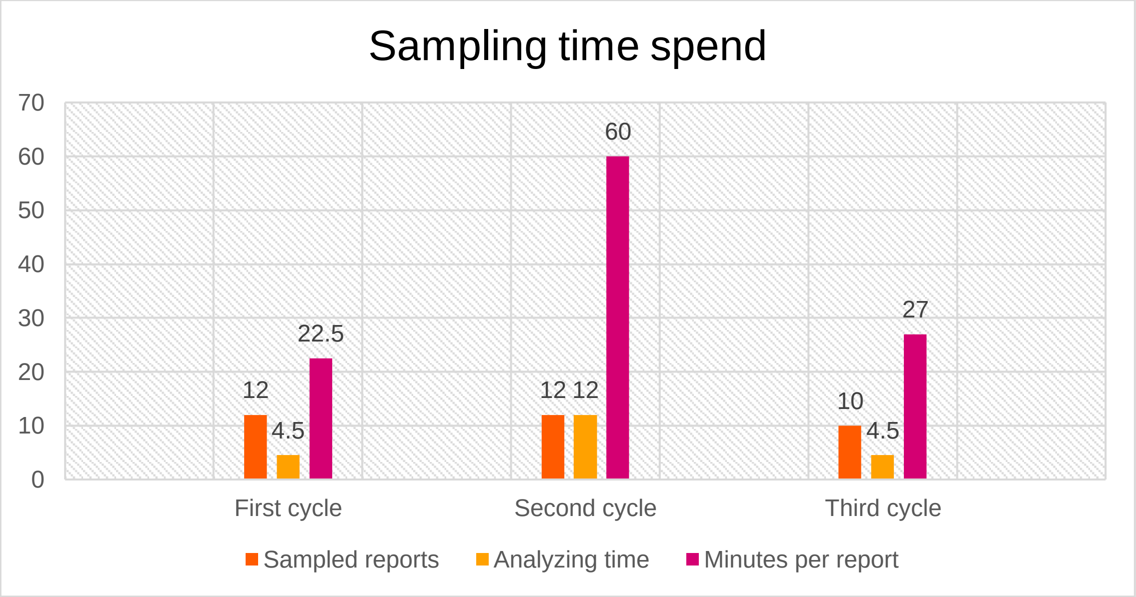

Figure 11. Sampling time spend chart

With these numbers we get the average time spend of 36 and a half minutes per report throughout whole project. This finding supports the earlier estimation made in chapter 8.1.2, where median time for both examining the report and giving feedback was estimated to be 60 minutes. Process would probably hit that average with samples that are even moderately worse.

11.5 On-site auditing

On-site auditing is harder to breakdown in numbers, as aside from the senior technician interviewed earlier, all actions that could be attributed as auditing was made as a secondary work while simultaneously working as part of the team. In addition, all actual auditing made by this senior technician, was made during visits on the site that also included other work.

Through the interview few things could be confirmed. First of all, visiting the site has benefits, that are especially helpful for project managers. Seeing both the technicians and customers on-site will lead to better communication and cooperation, and only this finding confirms that this should be implemented in some form as a part of regular schedule in operations. Secondary benefit would be confirmation of the work, and better understanding of site conditions.

Downside of on-site auditing is the resource drain. Most of Bladefence's project management works in UK, therefore site visits would require one full day of travelling to any sites that are outside UK. In earlier interview, it was estimated that about 10 hours of auditing is needed on-site, and the travelling would extend that up to three working days.

If look back to internal auditing theory in chapter 5.4, it is clear that Bladefence needs to clarify the code of conduct on sites, and other policies the staff will be audited against. Then against this backbone it is possible to build an auditing system that enables internal auditors to be efficient and fair in their practices. It requires additional investigation and planning to form a concrete plan and process for auditing within Bladefence.

11.6 Evaluation of the project results

Development of quality control process to company's core business operations is a difficult project, as it touches all levels of employees and organization. Using action research method makes it even more difficult, as the project scope tries to branch in multiple directions. Limiting the scope of this project has been the largest ongoing problem throughout the execution.

Looking back to research questions in chapter 1.7 the success can only be described as partial. Initial intention was to produce three process layups with varying resource drains. However, after the project start it became clear that the scope was far too ambitious, and simply crafting one project layout through three cycles was enough to fill the scope for the thesis. Project was able to produce a process description, that is best for the current situation, but any variations to that could not be tested or measured. Therefore, any future development to the process will again be through trial-and-error. Corrective actions that were tested during the project were limited to correcting reports. Due to no non-conformities in the actual work, correcting the actual repairs was not tested. On-site auditing benefits were researched, but the conclusions are based on a view of a single person and not validated in any way.

Project was also partial success in measuring agreed metrics described in chapter 1.8. Non-conformity frequency was measured as mentioned in chapter 11.3, also resource spend for sampling is documented well in chapter 11.4. Time spent to correct non-conformities is documented, but as described earlier is limited to only report correcting.

Time spend on auditing is the weakest measurement, as it is only based on estimations, and there is only single source of data, and no chance to cross-reference data.

Adding this together the research project achieved about 70 percent of goal set, including the main goal of starting and implementing a new process. This can be considered a good result although room for improvement definitely remains.x§

11.7 Validity and reliability

This research has both quantitative and qualitative data collection methods, and therefore needs to be evaluated accordingly. Quantitative data is collected directly from the project group and consist of numerical information sourced directly from the work. These numbers are reliable, and actual, even though they are only related to research project period. Any suggestions made only based on this data, may give approximate guidelines, but the data comes from a work done on-site and that has infinite number of variables, and therefore the findings should not be absolutely trusted.

Other parts of the information in collected on qualitative basis. Noble and Smith suggest multiple strategies to establish validity and reliability of such findings. These include accounting for personal biases, meticulous record keeping, respondent validation and data triangulation. (Noble & Smith, 2015)

Research has successfully implemented all of these, and where applicable, also made data triangulation between the qualitative and quantitative elements. Research has also used historical data to verify findings. Part of qualitative effort has been to interview subjects in all levels of the company to further verify same data points from multiple directions.

11.8 Personal reflection of thesis

Overall, I feel that this thesis has been a very educational journey. I am pleased of the results achieved on both client side, and in school. We were able to create the process, which in many ways was the main goal, it is also currently running as part of a day-to-day operations which is also an achievement worth noting.

In practical side of things, my own preparation was perhaps not as good as it could have been. I was distracted by the action research's open-ended method, and perhaps better preparation in methodologies and theories used would be beneficial, it would have made implementation of said theories easier. Leading the project went mostly according to plan. Timetable stretched and sometimes I had to push hard on the different stakeholders, to keep the project moving at all. Main thing I would like to change retrospectively, is the scope of the project, since the earliest aspirations I had were too ambitious to be achieved within the scope of the thesis.

Great experience to lead an actual development project, and all the different aspects of it. Liaising with the personnel involved, flexibility in reacting to situations where the outcome of certain parts of the project did not meet expectations, and finally keeping the ball rolling even when deadlines were missed were the key lessons learned.

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Technician Interview – Questions

1. Name and position in company?

2. Experience in years?

3. How many different companies have you worked for in the industry?

4. How do you feel about back-office colleagues checking your work in general?

    a. How does this compare to practices in other companies you have worked for?

5. Do you see any benefits for the technicians by being a part of this process?

6. Have you felt that the feedback you have received is adequate?

    a. Have you been able to learn anything for it?

7. Do you feel that you have been able to respond to the feedback?

8. How would you prefer to receive the feedback in future?

9. Any other remarks regarding quality process?

Senior Technician Interview – Questions

1. Name and position in company?
2. Experience in years?
3. How many times you visited site this season?
4. What are the main things one can learn from site audit/visit?
   a. Why have you chosen these?
5. What are the main benefits for the company, if regular audits would happen?
   a. Benefits for the team on site?
   b. Benefits for the management person visiting?
6. How many times should a site be visited in a season?
7. How much time should be spent to conduct a site audit?
8. What was the overall response from the team during audit?
9. Who should be the primary person(s) in Bladefence to perform site audits?
   a. Could an audit template be made that could be used by senior management without task specific knowledge?
10. Is there any other information about site auditing that you would like to add?