POLITECNICO DI TORINO

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MASTER OF SCIENCE DEGREE IN ENGINEERING AND MANAGEMENT

MASTER OF SCIENCE THESIS

Breakdown and categorization of production wastes into poor-quality cost

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Contents

List of abbreviations

To simplify the reading and understanding of the report, it was used common abbreviations in the report. Every abbreviation that was used can be found in the list of Hilti's or general abbreviations.

- C2020 – Champion 2020
- CCN – Customer Care Notification
- CAT 1/2 – Category 1 or 2
- BA – Business Area
- BU – Business Unit
- F&P – Fastening and Protection
- P&T – Power Tools
- FP – Fire protection
- ANC – Anchors
- INS – Installation
- DX – Direct Fastening
- MO – Market Organization
- TQM – Total Quality Management
- CoQ – Cost of Quality
- CoPQ – Cost of Poor Quality
- Ref. – Referring to (certain pages in the report)
- WIP – Work in Progress
- PDCA – Plan Do Check Act
- CAPA – Corrective Action and Preventive Actions
- OEE – Overall Equipment Effectiveness

Abstract

The aim of this study is to offer an innovative approach in order to reduce the CoPQ from an industrial point of view. The elaborate passes through the literature and three cases studies, which provide a comprehensive understanding of the advantages of adopting this approach.

The first chapter introduces the purpose of the report and the company's profile where the study was performed.

The second chapter addresses the theoretical background needed to have a comprehensive understanding of the case studies analyzed in the following chapter. It provides the writer an overview of the topics concerning the Cost of Poor Quality analysis.

The third chapter examines the case studies by defining their methodology, tools and limitations thoroughly.

The conclusive part of my research addresses the advantages of having a well-structured analysis of the Cost of Poor Quality. Moreover, it discusses how the wastes reduction can be a radical solution to improve the business quality. There are two main actors involved in this study: Hilti and the suppliers involved in the processes.

1 Introduction

The purpose of this thesis is to evaluate and analyse the importance of non-quality costs that is considered a core problem of most companies in the actual market situation. Those are challenged to provide their customers with products and services at a low cost without affecting the quality of the product and/or service. For this reason, quality costs contribute to a high proportion of the total costs of an organization and its network.

Based on the different needs of the market form the customer side and the companies one, it has always been crucial for most of the businesses to be able to redefine themselves into the dynamically changing of the quality meaning of the customers. The evolution of the meaning of Quality changed radically through the years and the hardest part for the business side is to be able to catch up the high-quality standards while reducing the costs generated in order to do so. These are the reasons why companies like Hilti, that is nowadays recognised by customers as a synonym of “Quality”, must be up-to-date with the last changes of the quality definition and agile in positioning themselves among the quality leaders. Based on all the reasons and the brief market introduction described previously, Hilti sponsored a three-year project on the Cost of Poor Quality (CoPQ) topic which the author will describe in this Master thesis based on information gathered during the internship right in the Headquarter of the Quality centre of Hilti AG, in Liechtenstein.

First of all, an introduction of the company itself and the strategy (Champion 2020) that includes the Cost of Poor Quality (CoPQ) project are needed in order to comprehend the importance of this study and its findings.

Secondly, it is important to get an overview of the research topics to understand the purpose of this study and be able to interpret the findings. Therefore, this approach started with a broad search of the theoretical frameworks which are the basis of the understanding what Quality and, especially, Cost of Poor Quality means, their applications and what are the conclusions of this report. However, it is necessary to introduce the concept of Lean Manufacturing together with the different theories regarding Quality, to be able to interpret in the right way the CoPQ. Besides, this report will evaluate the difference between Cost of Good Quality (CoGQ) and Cost of Poor Quality.

Finally, the cases studies will give a more tangible idea of the benefits outcoming from a good practice of CoPQ, how Hilti implemented it within the process and the potential of this approach within a company daily processes.

1.1 Introduction of Company – Hilti AG

As mentioned in the previous chapter, Hilti has been since the beginning of his activity, a synonym of quality within the construction industry. Their devotion to produce high-quality product is based on the success and sustainable value creation that only the team members can provide in order to make the difference. This is what inspires and empowers people within the company to set high targets and achieve them through strategies that comprehend projects like the one that allowed the author to develop this master thesis.

1 - Introduction

“Neither products, market performance nor innovation alone guarantee success and sustainable value creation – it’s the team members within the Hilti organization who make the difference. To ensure the success, team members think and act with entrepreneurial spirit, exercise sound judgment, take responsibility and possess and use the necessary freedom of choice and empowerment to act (Hilti AG, 2017).”

The Hilti Group (known also as Hilti Aktiengesellschaft or Hilti AG) was founded in 1941 in Schaan, Liechtenstein leading to a fast expansion through all over the world. With a presence in 121 countries, the Hilti Group operates a direct sales model - 75% of the people who work in Hilti are facing customers on a daily basis - and employs 25,000 people who work to support customers in all the phases of the customer journey: from the design phase to the sale of the products, from the after-sales services to continuous support through time (Hilti AG, 2018).

The company’s culture and values (Integrity, courage, commitment, and teamwork) led to a fast escalation that ended up in a well-established brand that is well known for the Quality of its product. The company is divided in two Business Area; Fastening and Protection (F&P) and Powder and Tools (P&T). The focus of this study was on F&P as the overall Area including all the four Business Units Fire Protection, Anchors, Installation and Direct Fastening.

Hilti presents a very diversified product portfolio. Nowadays, Hilti sells system solutions for construction professionals (Hilti AG, 2017):

- Engineering: Design, specifications, consulting, software;
- Measuring and aligning: Distance measuring, levelling, and aligning, detection;
- Drilling and demolition: Drilling and chiselling, diamond systems;
- Cutting and grinding;
- Fastening and installation: Direct fastening, screw fastening technology, anchor technology, installation;
- Fire-stop and insulation: Construction chemicals, fire-stop;
- Services: Fleet management, Hilti Tool Service, Repair service, Delivery service;
- Lifetime service, Training, and consulting.

With the purpose of explaining the importance of Quality within the companies' daily basis processes and, therefore the importance of the Cost of Poor Quality as part of it, the core of this thesis will be on three sample cases that the author was personally involved into during the internship. The cases will be described from cradle-to-cave (i.e. from the day the analysis of the complaints started until the appointed solution to diminish the CoPQ) trying to cover up different areas and several departments of the company aiming to show explicitly the versatility of the CoPQ methodology within different departments.

1.1.1 Structure of the company

Hilti Group has a matrix structure model (Figure 1.1). ON one side, the company is subdivided into three layers, the Market Organizations (MOs) which report directly to the Hub that in turn report directly to the Headquarter. The Hubs are the responsible MO for a certain Region and the MOs are the national main offices. The Hub executes certain business processes that before were at the Corporate Functions level. The sales force is organized geographically, by decreasing level of hierarchy: Head of Market Region, General Manager of MO, General Manager of a Region of the MO, Division Manager, Area Sales Manager (ASM), Account Manager (AM).

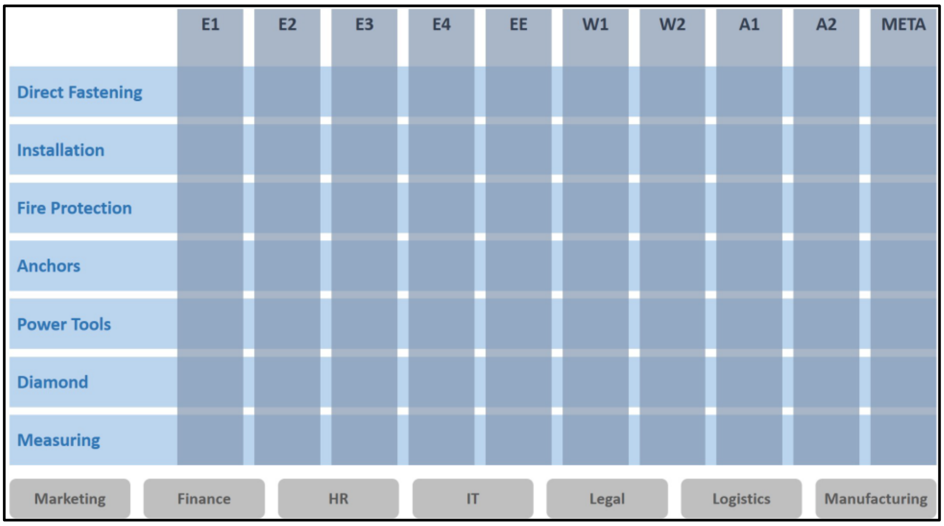


Figure 1.1- Graphical representation of Hilti's Matrix Structure, Hilti AG

On the other side, the product portfolio of Hilti is divided in Business Units which are cross functional. Each business unit has the support of dedicated partners for the different corporate functions. Finally, Corporate functions are set at the Global Level, with the MOs being responsible for adapting what is provided by the global teams to their local market.

1.1.2 Champions 2020 – Focus on Quality

Champion 2020 is the corporate strategy of Hilti, which aims to achieve sustainable value creation through leadership and differentiation. It aims to achieve market leadership through added value for its customers by offering products, services and software that provide superior productivity and safety to the customers and differentiate from the offering of its competitors (Hilti AG, 2018). The corporate strategy is aligned with Hilti's value proposition (Hilti AG, 2018):

"We passionately create enthusiastic customers and build a better future."

Growing in new areas with decentral setups and increased supplier base bring the necessity to optimize costs of Poor Quality and maintaining high Quality competence are key focus topics. Therefore, the aim of this study was to find the relevancy of CoPQ in a well-established company like Hilti and contribute to the goal that the BA F&P has within the "Champion 2020" (C2020) which started on 2016 overall the whole Hilti world. This was the umbrella under which all the renovative projects were grouped among Hilti's people and processes to create more value and improve quality perception. The focus topics of Champion 2020 are shown in the Figure 1.2:

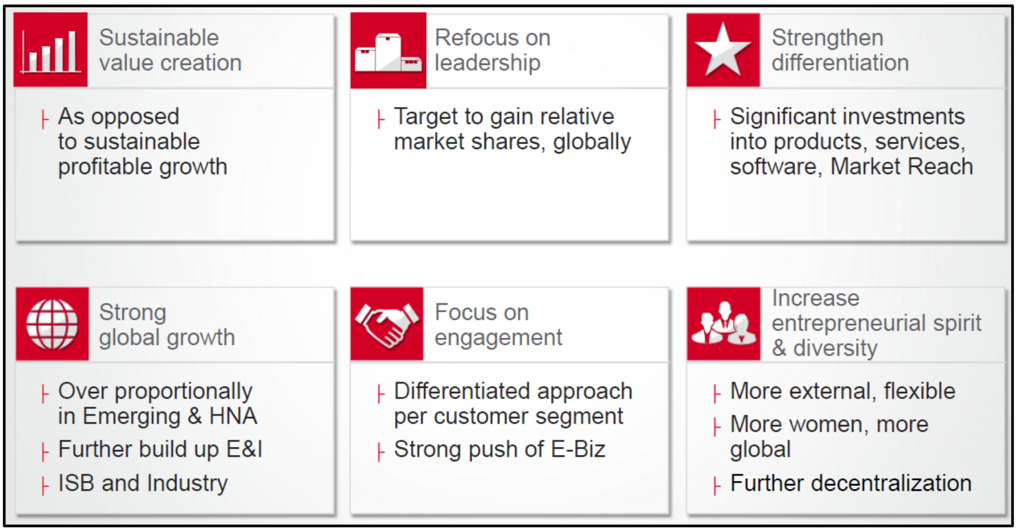


Figure 1.2 - Focus topics of Champion 2020

Summarizing in practice the key areas of interest of C2020 we could came up with the following list:

1. **Optimized Cost of Poor-Quality** - generate transparency on costs of non-quality and systematic root-cause determination with tangibly improved products, services, and processes (e.g. Time To Market, TTM quality), enabling speed and meeting market needs while leveraging digitalization.;
2. **Marketing Quality** - Pro-actively marketed quality directly to customers incl. large accounts and defined actions to beat competitors based on quality customer perception by trained AMs and explicit quality marketing material;

3. **Quality Awareness -** Conduct quality awareness activities and establish a competence & certification program with most of all functions trained and certified;
4. **Supplier Quality Development** - Install quality supplier developments plans for all key suppliers, dedicate Supplier Quality Engineers in place and fill with the required competences;
5. **People Development -** Develop quality people internationally, foster entrepreneurial thinking and increase job rotations with other functions to achieve a self-sustaining quality organization;
6. **Service Quality** - Audit service portfolio with derived improvement actions in place and based on certified service personnel and dedicated quality service employees;
7. **Software Quality -** Establish test automation framework for correct recommendations, set-up cloud-based delivery & support to minimize downtime and security risk framework to avoid data breach.

The focus of the Quality department was initially on the first four listed points before but, the n°1 priority was the CoPQ, as also illustrated in the Figure 1.3.

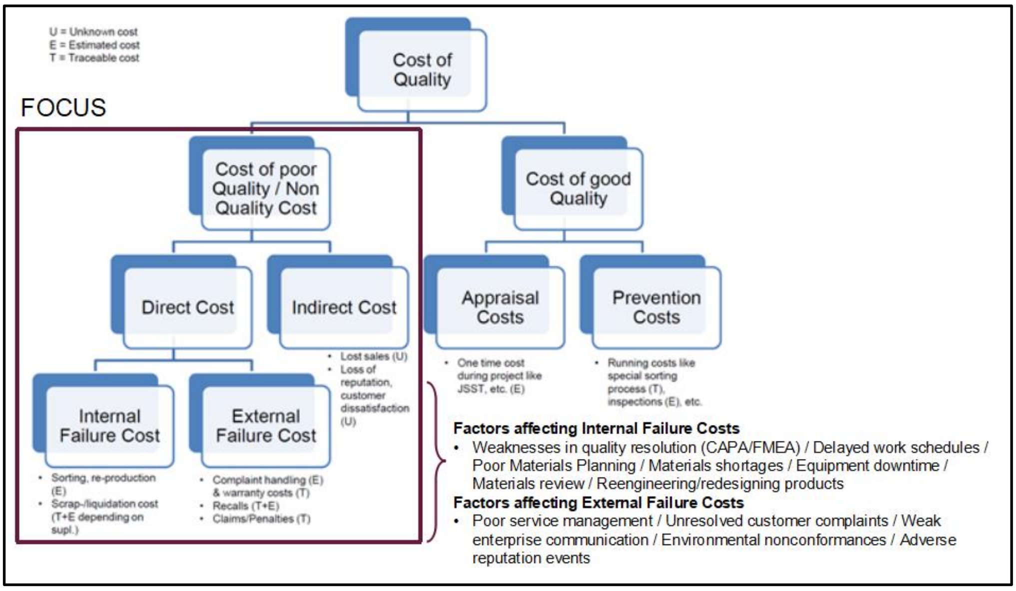


Figure 1.3 – Cost of Quality breakdown, focus on COPQ

2 Theoretical framework

The theoretical framework is divided into following sections: Lean Manufacturing, Introduction to Quality and then Introduction to Cost of Poor Quality (CoPQ).

2.1 Lean manufacturing

Nowadays, the market is becoming choosier and more selective in choosing product, as well as the competition is exponentially increasing with the asserted worth of the globalization and internet. For these reasons, it has become essential for the companies to differentiate from the competitors establishing themselves as a high-end high-quality producer by increasing the added value provided to the customer and by reducing the various kinds of waste. The concept that include and claim this methodology is Lean manufacturing which is based also on the concept developed as Toyota Production System. It is a systematic method for waste minimization which could be categorized in more than one based on their provenience:

- Muda - within a manufacturing system without sacrificing productivity;
- Muri - waste created through overburden;
- Mura - waste created through unevenness in workloads.

This approach is based on different tools which assist the identification and steady elimination of wastes (i.e. SMED, value stream mapping, Five S, Kanban - pull systems, poka-yoke – error proving, total productive maintenance, mixed model processing, rank order clustering, single point scheduling, redesigning working cells, multi-process handling and control charts).

2.1.1 The eight wastes or Muda

In Lean the value of a product or service is defined solely by what the customer requires and is willing to pay for (Liker J.K., 2009), the processes could be subdivided in two groups:

- Value-added activities that create precise solution and benefit to the customers and they are willing to pay for;
- Non-Value-added activities are the ones that are not required but take still place during processes and do not provide value to the final product/service.

The non-value-added are defined as waste and could be subdivided in 8 kinds of waste which fell in the three major areas: product, process, and machine. Those should be identified as soon as possible and reduced, but not completely get rid of since they may increase the efficiency of the employees. The eight kinds of waste are:

1. Transport includes any movement of the product or WIP from one place to another adding cost to the final product, for which the customer is not willing to pay an extra price;

2. Stocks are affecting cash flows and often is the synthon of poor processes. Having a high inventory of raw materials, WIP or finished product causes costs, depots, cover problems and prevent the possibility of improvement. However, it is necessary to maintain a certain level of stocks to be responsive to the customer demand;
3. Overproduction is considered as the amplificatory of the quality issues and risks while trying to forecast the demand;
4. Failure/Repair is the most obvious of the kind of wastes even though it is hard to detect. Quality errors are usually identified at the end of the supply chain, in other words by the customer.;
5. Waiting periods take place when two or more processes/machines are not perfectly synchronized and cause bottleneck. It is one of the crucial points where Lean Manufacturing focuses on;
6. Motion like bending, turning, reaching, and lifting, together with the movement of equipment do not add value to the finishes, therefore it is considered as waste;
7. Over processing is one of the hardest to be identified. It occurs because of tighter tolerances or higher-grade materials than are necessary, for example excessive levels of approval for a purchase requisition that provides no value to the product or service;

8. Qualification of employees is the so called “human error” as a result of the lack of adequate training or underutilizing capabilities.

2.2 Introduction to Quality

The definition of Quality has been changing from 1900 due to the different understandings of its meaning and the impact it has in the society. Nowadays, it is a concept defined by Total Quality Management and it is based on different pillars and characteristics that put the Customer Needs and the Continuous Improvement at the centre of itself. The challenge of this approach is to define the unique needs of the customers and the way the company try to meet those needs. This is because they have different expectations and needs, and sometimes they do not even know which their needs are.

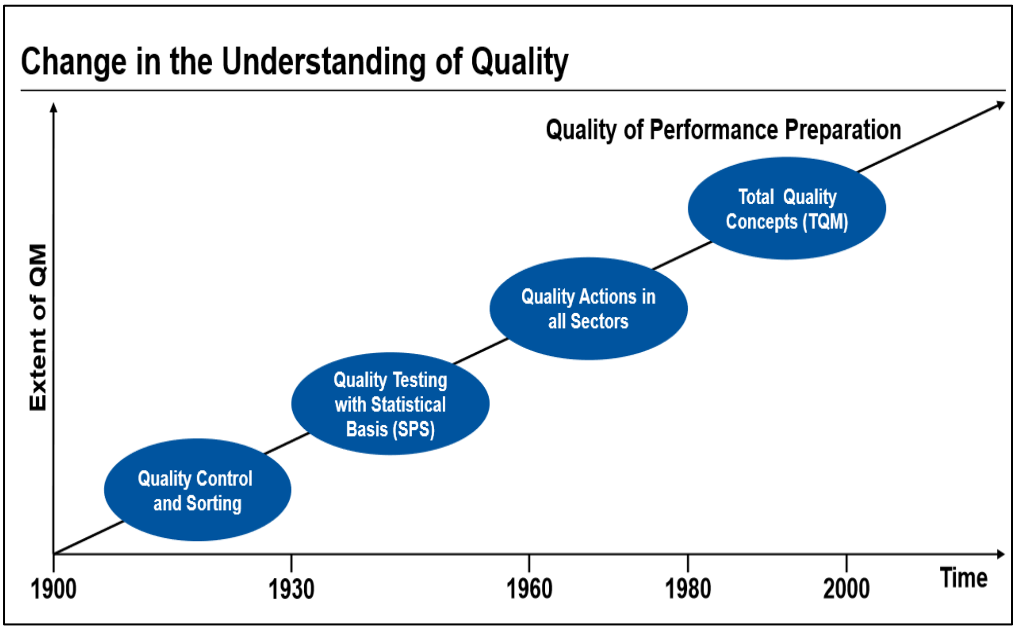


Figure 2.1 - Change in understanding of Quality - WZL/Fraunhofer IPT (2017)

As Krishnan said, quality for any individual is something that will give him/her a degree of satisfaction and delight, (Krishnan S. K., 2006). "Fitness for use" is the widely known description given by Juran in his Quality Handbook (Juran J. M. & Godfrey A. B., 1999). By this he refers to the two different meanings defined based on the relationship. Nowadays, it is still usually said that if the price is higher, the quality is higher too. But that thinking is wrong since quality can be measured based on several attributes and the level of these attributes within a product or service compared to the price. The consumer will be satisfied if the value provided by a product or service is equal or higher than the money, he/she is paying for.

“Quality is the overlap rate of explicit as well as implicit customer demands with the supplied product characteristics.”

There is no doubt that quality plays a key role in any organization and must be built not only into the product or service produced but should be built into whole the organization. To achieve this goal, there should be many sustainable quality improvement programs, though which will be possible the identification and total elimination or reduction of all types of failures events or failures within the organizational system.

2.2.1 Total Quality Management

Total Quality Management (TQM) is a management approach which aim to install and make permanent a climate where employees continuously improve their ability to provide on demand products and services that customers will find of particular value (Ciampa D., 1992).

Since it is a widely studied and discussed topic, there are many authors that emphasize its role through different approaches. Oksana Vysochynska expressed this concept through three authors in particular, (Vysochynska O., 2016):

- Juran is one of the earliest leaders in the quality field and has contributed to the building of the conceptual basis of quality management. His framework involves three sets of activities – quality planning, control, and improvement;
- Deming emphasizes the systematic nature of organizations, the importance of leadership and the need to reduce variation in organizational processes;
- Crosby focuses on reducing cost through quality improvement and stressed that both high-end and low-end products can have decent quality.

Based on that it is possible to break down the meanings based on the meanings of the words composing itself.

- Total - meaning that it considers the whole aspects of what is contributing to define the Quality (process, customer, employee, and society orientation);
- Quality – referring to the different understandings it has beside the definition of ISO 9000:2015 (quality of the company, work, potential, processes, and result);
- Management – in the sense that it must be a priority in the leadership which defines activities and support exemplar roles.

2.3 Introduction to CoPQ

The concept of Cost of Poor Quality was born around 1950 and still is quite a riddle that has not yet a well-defined procedure and set of tools to measure it.

Juran in the 1951 was the first that defined this new notion of potential costs caused by poor quality and their effects on the companies, while Feigenbaum tried to classify all the costs caused by actions needed in order to correct the internal failure (before the delivery and process failures) and the external failure costs (Tsai W. H., 1998). Sörqvist defines CoPQ as "the total losses caused by the products and processes of the company not being perfect", (Sörqvist L., 2001). Crosby defines Cost of Quality as a sum of two components (Crosby P. B., 1979), Cost of Good Quality and Cost of Poor Quality (Figure 2.2).

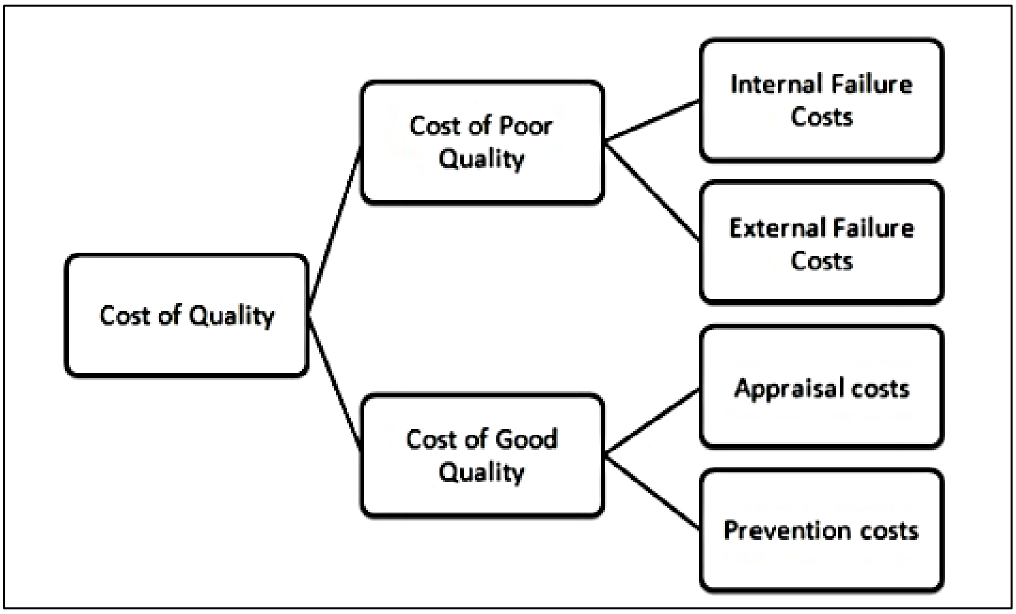


Figure 2.2 - Cost of Quality components by Crosby (1979).

These two components in turn, are composed by the Appraisal and Prevention costs which comprehend the investments incurred in order to eliminate potential future failures and the second one composed by Internal and External Failure costs for the second one which is a simple categorization of when in the supply chain occurs the failure.

Harrington on the other hand defines CoPQ as “all the cost incurred to help the employee do the job right every time and cost of determining if the outputs acceptable, plus any cost incurred by the company and the customer because the output did not meet the specifications and/or customer expectations” (Harrington H. J., 1987).

2.3.1 Classification of CoPQ

The quality department has always have been responsible for the failures of the product and processes since they have the responsibility to approve most of the proposals made by other departments. In most of the cases, this department has not really the importance that it should have because it is not a money-making department but a money saving. Nowadays, thanks to the identification of CoPQ it is possible to speak the language of the Top Management and Stakeholder of the company.

The first classification of CoPQ was made by Feigenbaum that defined the Prevention, Appraisal and Failure Model (PAF) that divides COPQ into three main categories (Feigenbaum A. V., 1991): Prevention costs, Appraisal cost and Failure costs (internal vs external), see Figure 2.3.

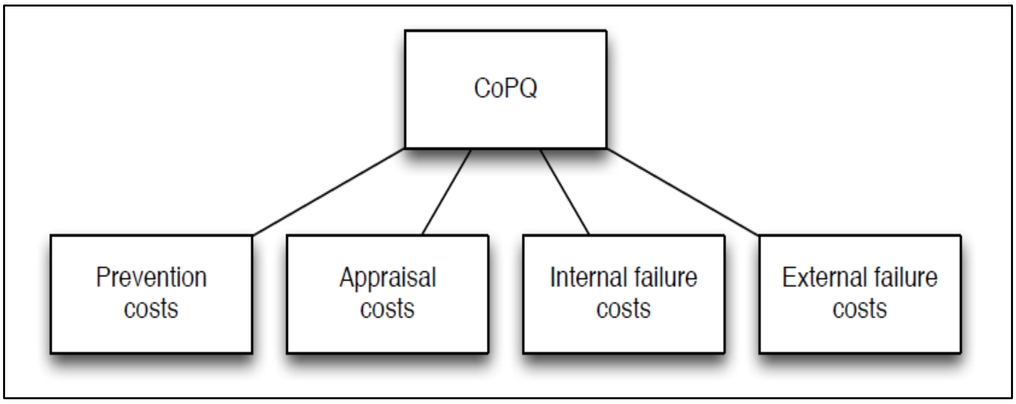


Figure 2.3 - The Classification of CoPQ according to Feigenbaum (1991)

According to Gryna the categorization of Internal and External costs could be further stretched out in internal failures to meet customer requirement and cost of inefficient processes (Juran J. M. & Gryna F. M., 1998), whereas the external failure cost is divided into loss in opportunity and customer requirements. Anyway, the author does not clarify the explicit meaning of this further sub classification, see Figure 2.4.

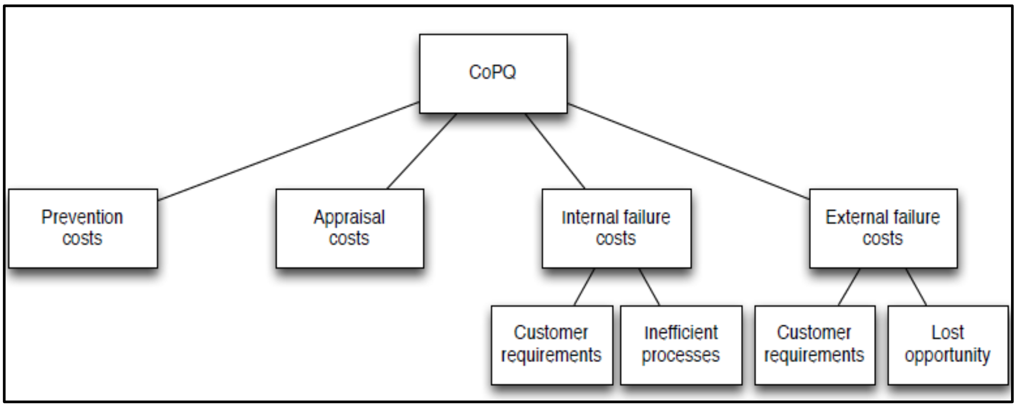


Figure 2.4 - The Classification of CoPQ according to Gryna (1999)

Furthermore, Harrington stated that the internal failure cost will only affect the company organization while the external failure cost cause problems to the customer in terms of inadequate product or service (Harrington H. J., 1987). Based to Gryna Internal and external failures are similar but differ in term of where the failure occurs, within the company or outside the company (Juran J. M. & Gryna F. M., 1998).

Appraisal costs, according to Feigenbaum, are defined as costs related to the maintenance of the quality level of the company (Feigenbaum A. V., 1991). As also described in the master thesis of Thomasson and Wallin (Thomasson M. & Wallin J., 2013), "Sörqvist develops the definition of appraisal costs, stating that those are costs arise when verifying that right quality is delivered in all steps in an organization". Prevention cost are the activities to avoid CoPQ failures to happen in first place (Campanella J., 1990). According to Juran and De Feo, prevention costs occur to minimize appraisal and failure costs (Juran J. M. & De Feo J. A., 2010).

2.3.2 Visible and invisible CoPQ

Krishnan explains how the CoPQ could be separated in two macro categories that separate it into visible and invisible regardless other classifications as showed in Figure 2.5 (Krishnan S. K., 2006). The design of an iceberg was specifically associated to this classification to give an idea of the hardness to find out most of the "hidden" costs that are the biggest portion of the CoPQ, even if they are not visible and could be only by expanding the scope and complexity of the analysis.

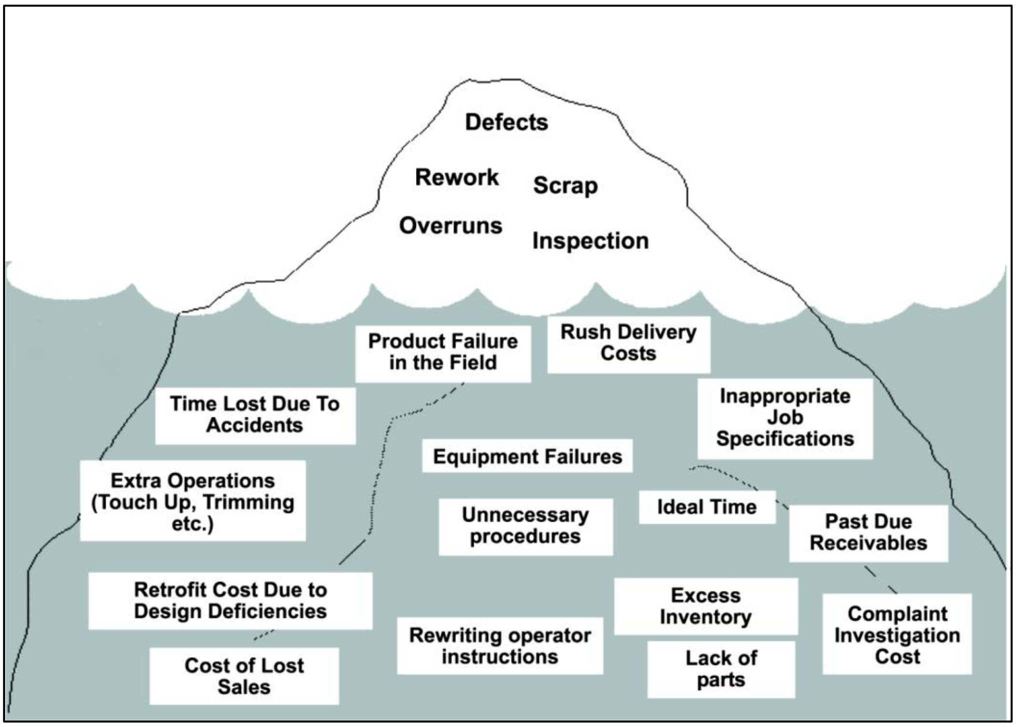


Figure 2.5 - The iceberg of visible and invisible costs (Krishnan, 2006)

Most of the invisible costs are not accessible to companies due to the difficulties to track them and measure them in a comparative way. For this reason, most of the management decision are taken based on the visible part of the CoPQ although the invisible part is considered by Juran and Gryna to be higher by four or five times the visible ones (Juran J. M. & Gryna F. M., 1998), whereas Krishnan states that invisible CoPQ as three to ten times higher than visible costs (Krishnan S. K., 2006). Nowadays, with the standpoint of Big data analysis and Industry 4.0, it could be easier to track down all the data related to the hidden failures and consider them as visible ones.

This is also the purpose of this Master thesis, to show how a leader in the construction industry like Hilti is developing the culture of tracking CoPQ aiming to reduce it and make the company Leaner.

2.3.3 Pareto analysis

The Pareto analysis is one of the most widely used method to approach the most significant factors among a set of factors (Cervone H. F., 2009). It is possible thanks to a prioritization of the factors that have the biggest impact in terms of improvement opportunities. It can be used not only for prioritising purposes but also for narrowing down the number of tasks to be accomplished by choosing firstly the one with highest impact. The Pareto principle is based on 20-80 rule in which 20% of improvement activities cause the 80% of cost improvement.

3 Empirical findings

The cases that have been identified, structured, and analysed by the author of this thesis and the Hilti's team that was part of the CoPQ optimizations' projects were cross-functional involving several departments. Since the aim of this thesis is mainly to address the procedure behind the CoPQ projects in Hilti AG, there will be stretched out three relevant cases that are covering the production, product development and logistic sides. These cases cover a good portion of the time the author of the thesis spent on this topic during the internship and they were conducted in three different Business Units/Plant (all being part of the BA F&P):

- BU ANC – case about a non-conformity during the shipment of products to the warehouse in China.
- BU INS – case dedicated to improving the Product development phase and make it more agile.

- Plant EUROFOX – case regarding the non-conformity of the specifications by the suppliers causing delays in production.

3.1 Goals and limitations

The aim of the overall Cost of Poor-Quality project within Hilti was to maximize the CoPQ improvement on a yearly basis. The initial amount was estimated when the strategy C2020 was kicked-off, in November 2016 (Top-down estimation taken for good as a relative percentage, 100%). The way the Quality department of F&P would reduce the estimated CoPQ is by generating transparency on costs of non-quality and root-causes, thus improving products, services, and processes. To be more precise, since this strategy started in 2017 and the goal should be achieved until 2020, it has a yearly amount of CoPQ to be identified, analysed, and tackled through workshops and Continuous improvement tools. Unfortunately, the data are sensible and for obvious reason are not going to be shown in this thesis, however the author thinks it is right to give an idea to the lecturer by inserting charts with relative values (percentage) instead of absolute ones.

The Figure 3.1 represents the achievements of the end of 2017, it gives a better understanding of the target which is spread over the operating years (from 2016 until 2019). It is possible to visualize the target in the red-pattern coloured box on the left (20%), the improvements planned to make each operating year in red box and the expansion of the scope per year in dark grey (pattern coloured for projections).

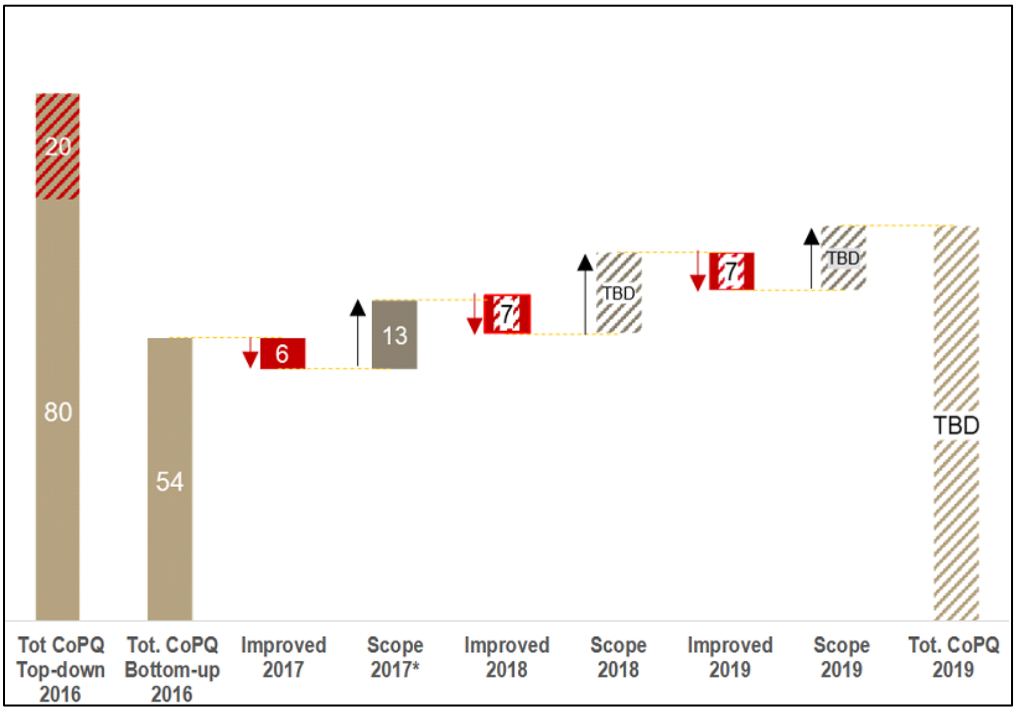


Figure 3.1 - Target 2020, CoPQ improvements over interested timeframe, Hilti AG

The analytical steps of the strategy C2020 were deducted in the following order of occurrences:

1. Year 2016 - The Management team estimated the potential impact of the CoPQ based on experience and detailed analysis of risks onto the overall F&P. As already mentioned before, this amount is going to be conventionally considered as 100%.
   The explicit goals were defined; the team needed to make every year the CoPQ costs as much transparent as possible and select the one with highest impact (i.e. amount of cost involved, customer satisfaction, etc.), to eliminate them and save 20% of the estimated overall of CoPQ starting from 2017 until 2020;
2. Year 2017/18/19 – The CoPQ team would individuate, analyse, improve and report whole the Failures (internal and external) incurred during these years and the one that were chosen to be tackled aiming to achieve the 20% of improved failures.
3. Year 2020 – The Management and CoPQ team follows up the results and set up new goals.

The Figure 3.2 shows a more detailed level of transparency which was possible thanks to the experience/expertise of the Quality managers in 2016. It displays the breakdown of the CoPQ component categorized into Plant's failure, BU's failure, liability, and Costumer Care Notifications (CCN) & warranties.

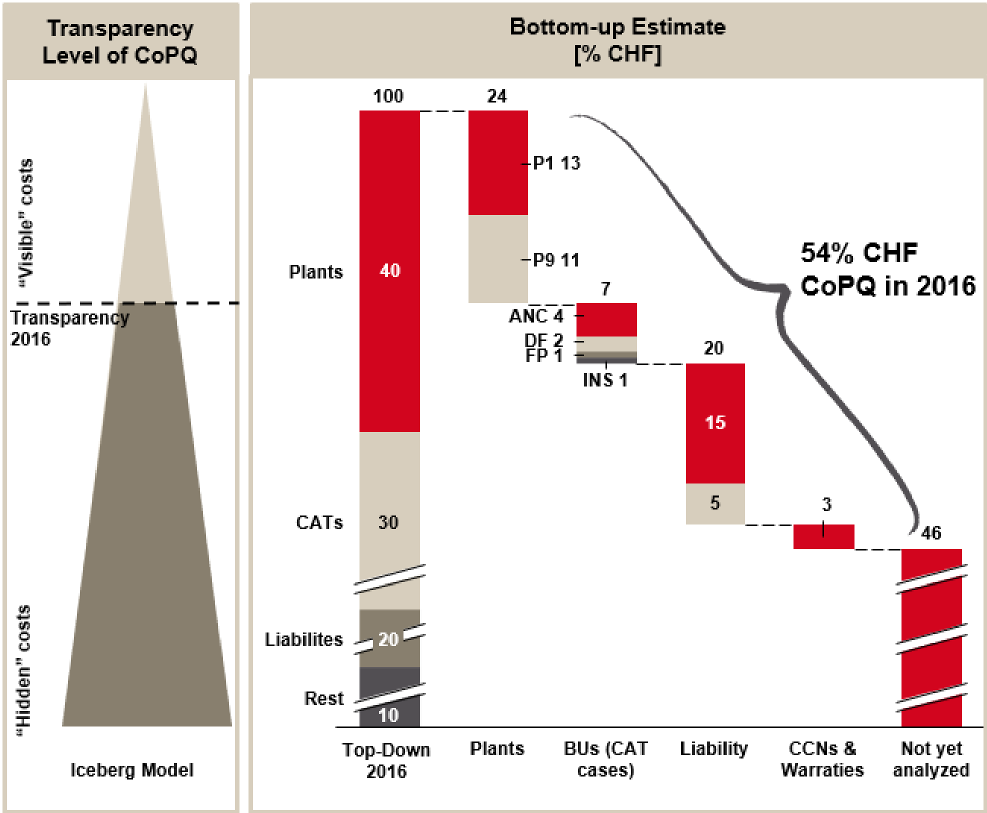


Figure 3.2- CoPQ values of 2016, Hilti AG

The structure of the left part of the Figure 3.2, Recall Ref. to the "Iceberg of visible and invisible costs" (Krishnan, 2006) used to illustrate the possible impact of the project and, therefore the level of transparency that was possible to achieve with until 2020. The aim is to adopt a uniform and standard procedure to approach and report the failures among all BUs.

As mentioned in the chap. 2.3.2, it is possible to discover and estimate the hidden part by expanding the complexity and scope of the project which was considered as a partial requirement for the 2020 strategy. It was considered as a partial requirement because the increasing complexity, that is reached by expanding the scope of CoPQ, it is hard to manage due to the large amount of data and interconnection among the variables that directly affect the production of waste.

The first bar to the left shows the first repartition of the Estimated CoPQ by the Management team with a Top-down approach during 2016. Meanwhile, by using the bottom-up approach, it was reached a total of only 54% of the amount estimated by the Management and it is broken-down into the waterfall which is the subdivision of transparent failures into the four categories previously cited. By CAT is intended the category in which is allocated the external failure. It could be divided into two pre-defined categories:

- CAT 1 – In case the damage caused by the Hilti's tool is higher than a certain amount and there are serious body injuries (most serious failure);
- CAT 2 – all the rest of the cases.

Apart from the project purposes, it is necessary to take into consideration also the reporting purposes as part of the Strategy 2020 for the Quality department:

- Enable tracking of CoPQ project status against its 2020 target (20% of the total visible CoPQ);
- Facilitate tracking of problem status from occurrence to CA/PA implementation to resolve problems and their overarching root-causes in a sustainable way;
- Provide ground for decision making & problem prioritisation.

CoPQ is based on three following criteria:

1. Use standardized criteria:
    a. All savings figures are annualized, i.e. they are adjusted to a common 12-month basis;
    b. Standardized way how to calculate each reporting values;
2. 80/20 principle:
    a. Reporting should give best possible results while burdening the QMs as little as possible;
    b. Figures and their calculation are based on 80-20 principle;
3. Leveraging best practices:
    a. CoPQ reporting is based on industry best practices;
    b. Financial controlling and reporting principles considered where applicable.

3.1.1 CoPQ process and relevant figures

The structured process was defined as soon as the project kicked-off in 2016 and improved following the logic of a “learning by doing” approach. It is shown in the Figure 3.3 how the steps are logic and lean to make it easier for the team to run through the CoPQ process in a standardized way between the different BUs and Plants.

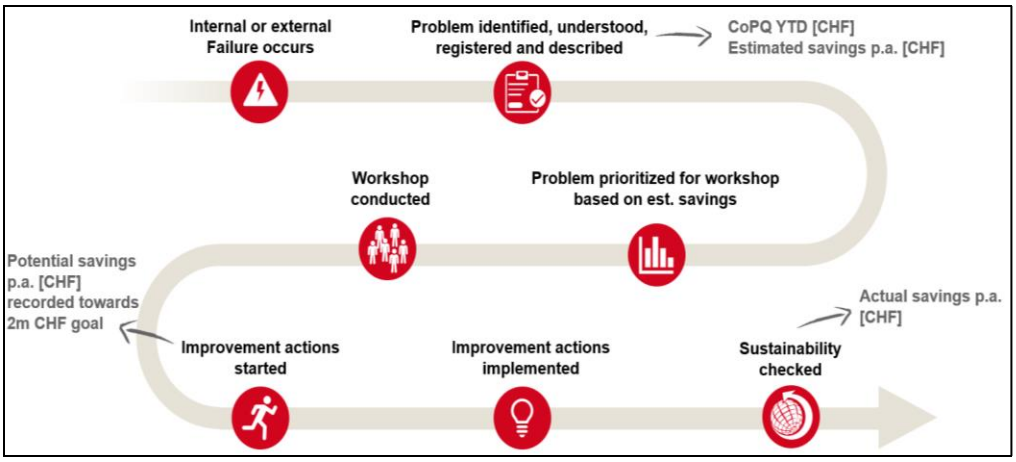


Figure 3.3 - CoPQ process overview, Hilti AG

The numerical figures, that are tracked down and considered as relevant for the final goal of the CoPQ project (Figure 3.3, written in grey), are summarized in the next Figure 3.4 with an insight of how, why and when they are calculated.

These four pillars, could be seemed as milestones used to track the progress of each case study. Moreover, it gives the possibility to the CoPQ team to measure the real achievements of CoPQ savings across the cases in the BUs/Plants. Currently, the team uses four CoPQ reporting values that could be calculated either on yearly basis or year-to-date (YTD) based on estimations/projections or fact-based. As clarified in the Figure 3.4, the target is upon the third milestone which was named “Potential CoPQ savings”.

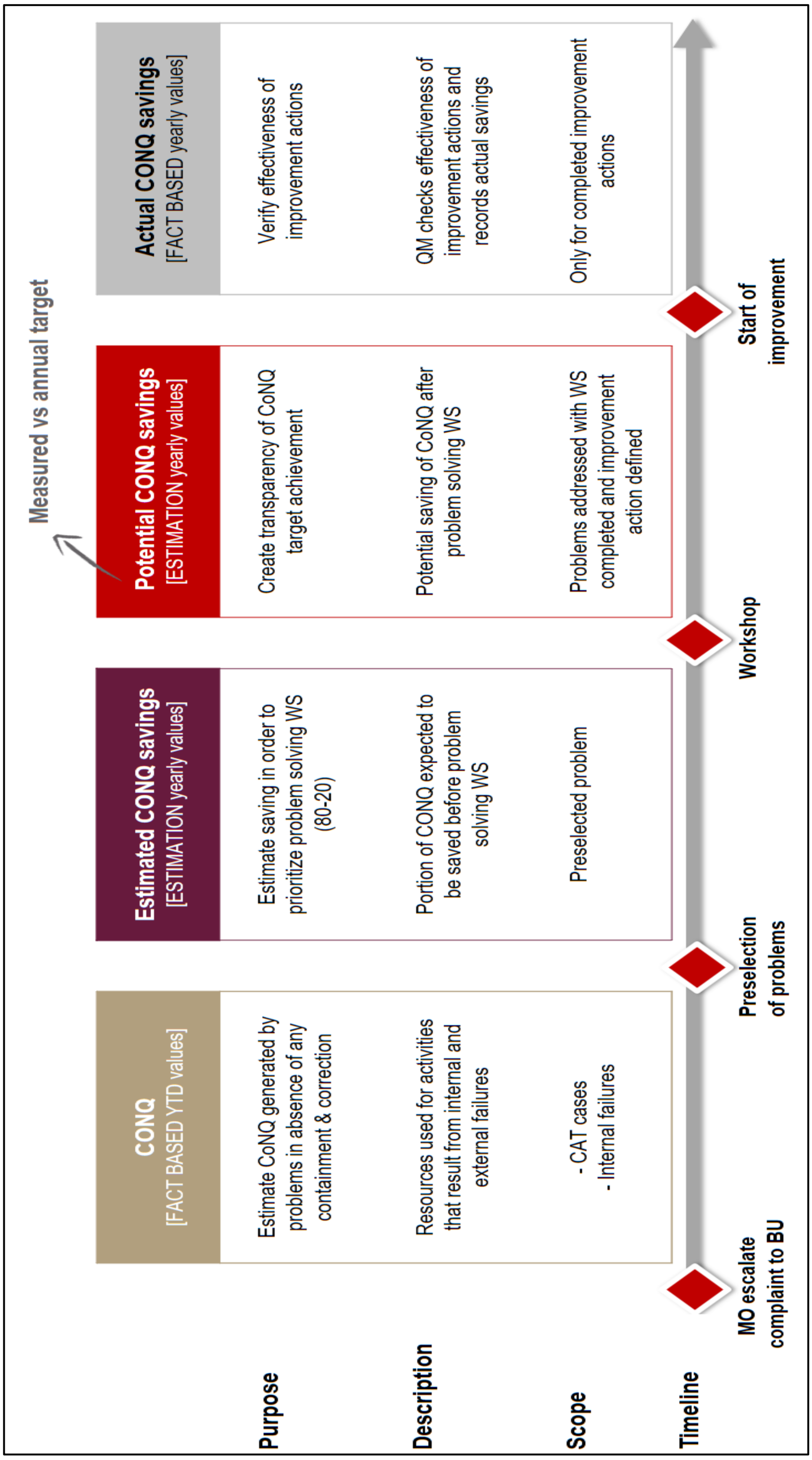


Figure 3.4 - CoPQ figures, Hilti AG

3.1.2 Area of Occurrence and R-C

To better gather and cluster the case studies, 12 Area of Occurrences (AoO) were introduced for the BUs and 20 for the Plants, Figure 3.5. The AoO are standardized categories in which problems are grouped. The aim of this categorization is to enable analysis, prioritization and reporting CoPQ figures in a uniformed way by all the Quality Managers involved. The inclusion of the single cases within one of the listed AoO was up to the experience of the QM and the further approbation of the CoPQ team. The following two pictures represent the subdivision of the failures between BUs and plants since they face different ones.

	Area of Occurrence - F&P BU
1	Customer expectiation (Customer expects better product performance)
2	Design failure (Customer requirements not met by design / specs)
3	Productions failure (Product not produced acc. to specs. by Hilti or Supplier)
4	Packaging, labeling in production (wrong packaging, quantitiy fault during production)
5	Logistics failure (Product damaged during transport, storage, Hilti center)
6	Customer advice (wrong advice to customer by Hilti rep.)
7	IFU / Documentation / Hilti Onlline (wrong docu. Etc. led to wrong product usage)
8	Software (faulty SW led to wrong product usage)
9	Delivery fault (wrong product delivered)
10	Misuse (by customer despite correct IFU etc.)
11	Unknown (or under investigation)
12	No response / no samples (closed due to missing samples, MO response)

Figure 3.5 - Area of Occurrences - BUs, Hilti AG

It is necessary to point out, that since the CoPQ methodology was born mainly for projects within the plants and not the business units, it was much more spontaneous to adopt the tools and the methodologies inside the plants rather than the BUs.

	Area of Occurrence - F&P Plants
1	**Supplier:**
2	- supplier delivered not according to specification
3	- wrong specifications received from HILTI
4	- use of different measuring methods
5	**Plant did not produced according to specifications**
7	- Worker
8	- Machine
9	- Tool
10	- Process
11	- Material
12	- Measuring
13	- Other
14	- Not assigned
13	**TTM:**
14	- wrong specifications received from HAG
15	**Design to manufacturing**
16	- Not constructed according to production requirements
17	- Design freeze (incomplete, changes)
18	- failure in construction
19	**Sourcing:**
20	- supplier (machine) did not produced according to specifications (Process)

Figure 3.6 - Area of Occurrences - Plants, Hilti AG

3.2 Methods and tools

Within Hilti the Cost of Poor-Quality process consist of six steps and is based on PDCA logic of continuous improvement. The following Figure 3.7 represents the process steps, method, deliverables, and the responsible persons for the PDCA logic that was made up and applied specifically for this purpose. The aim of the following “House of CoPQ” is to structure and standardize the approach in every BU and Plant that is dealing with CoPQ, so every process is measurable and comparable with each other in a standard manner.

It is also structured based on the four milestones (CoPQ, Estimated CoPQ savings, Potential CoPQ savings and Actual CoPQ savings) which gives a well-connected set of guidance of how it fits into the CoPQ process in terms of methodology and responsibilities.

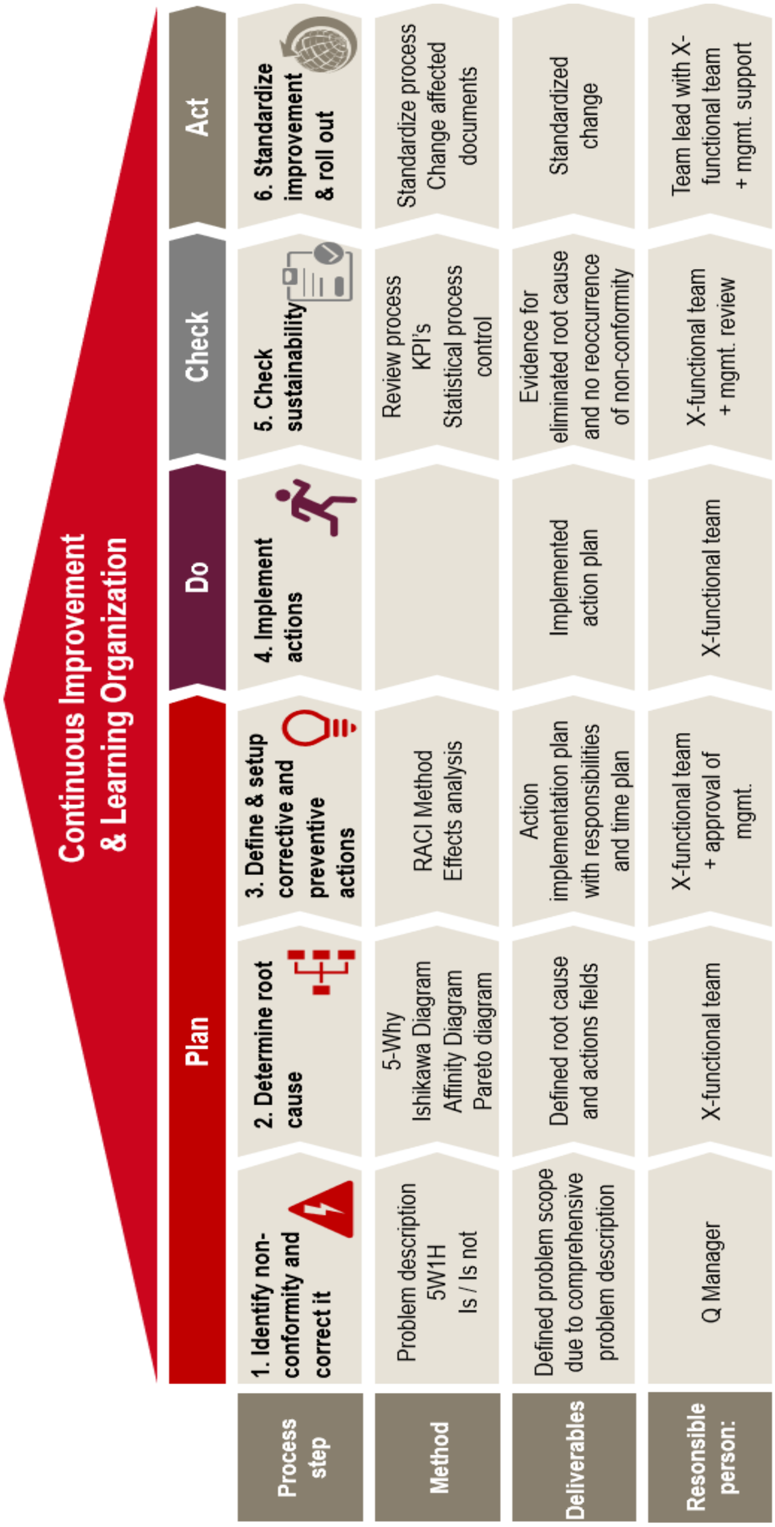


Figure 3.7 – House of CoPQ, Hilti AG

During the time being in the company, the author could apply this logic to several cases, from the phase 1, the identification of non-conformity until the implementation of the actions, phase 4. The last two phases are essential to guarantee the Continuous Improvement (CI) mindset; after a failure is identified and the preventive action is implemented, it is necessary to standardize it, so it could be guaranteed the sustainability and effectiveness of the action throughout all BUs.

3.2.1 PDCA House of CoPQ

The PDCA House of CoPQ is the guideline that all team members participated to made based on experience and a mix of theoretical and practical concepts (Figure 3.7).

The first four phases are determining the outcome of the sustainability of the solution to be implemented. In other words, the root-cause (R-C) analysis was used to dig deep into the core of the problem and eradicate it applying the CI logic.

3.2.1.1 Step 1 – Identify non-conformity and correct it

In this step, a case of internal or external failure is identified (e.g. through Customer complaint). Containment and correction of a given problem taken as soon as possible. Therefore, problem is described, and its scope is being defined. Immediate action to contain and correct the problem is needed to ensure customer satisfaction and avoid additional costs. By reviewing and describing the problem helps us understand its size and complexity and the possible impact of (not) addressing it. This helps the team to prioritize problems that must be addressed. The responsible person is the Quality Manager (QM) and the tools and methodologies available are:

- Problem description;
- 5 Why;
- Is / Is not.

3.2.1.2 Step 2 – Conduct workshop to determine R-C

For problems that are pre-selected based on their importance a workshop is to be conducted by a X-functional team. The workshop goal is to gain better understanding of the problem at hand, analyse it in detail and determine a Root Cause (ideally on system level, not on product level) and Area of Occurrence. Conducting a problem-solving workshop help the team to understand the problem in detail and determine its root cause. Thanks to the detailed knowledge of the problem the responsible QM is also able to better assess the potential savings that can be achieved through the proposed CAPA. The responsible is the X-functional team and the tools and methodologies available are:

- 5-Why;
- Ishikawa Diagram;
- Affinity Diagram;
- Pareto diagram.

3.2.1.3 Step 3&4 – Define, set up and implement setup CAPA actions

Once a problem-solving workshop has been conducted, the team need to define a preventive action (PA) implementation plan, including a time plan and responsible persons. When assessing options for preventive actions the team should always assess the expected benefits (CoPQ savings) and costs associated with implementation of these actions. This step logically follows from the problem-solving workshop, where problem Root-Cause (R-C) is identified. Definition of preventive action and a carefully crafted implementation plan with responsibilities and time plan helps fulfill the objective of problem prevention. The responsible is the X-functional team plus the approval of management and the tools and methodologies available are:

- Responsibility Assignment Matrix (RACI) Method;
- Effects analysis.

3.2.1.4 Step 5&6 - Check sustainability, standardize improvement and roll out

To check sustainability of preventive action, the responsible person needs to assess if/how often has the problem reoccurred over a comparable period (over 12 months after CA/PA implementation) and what was its impact. If the preventive action is not delivering expected benefits, the problem is to be revisited and a new PDCA circle needs to start. Sustainability check and improvement standardization are the last steps that are needed to complete the PDCA cycle. In conducting them, the CoPQ team can ensure that the implemented preventive action delivers the intended benefits/savings. Having checked the improvement sustainability, Actual CoPQ savings should be reported. The responsible is the X-functional team plus the approval of management and the tools and methodologies available are:

- Review process Key Performance Indicator's (KPI);
- Statistical process control;
- Standardize process;
- Change affected documents.

3.2.2 Tools used for Root Cause Analysis

The tools available for the CoPQ process are represented in the Figure 3.8 with a specific focus of three standardized tools used in every case that enable the success and comparability of the results. These tools are addressed in particularly to find out the real Root Cause behind a failure. The others could be considered as secondary tools.

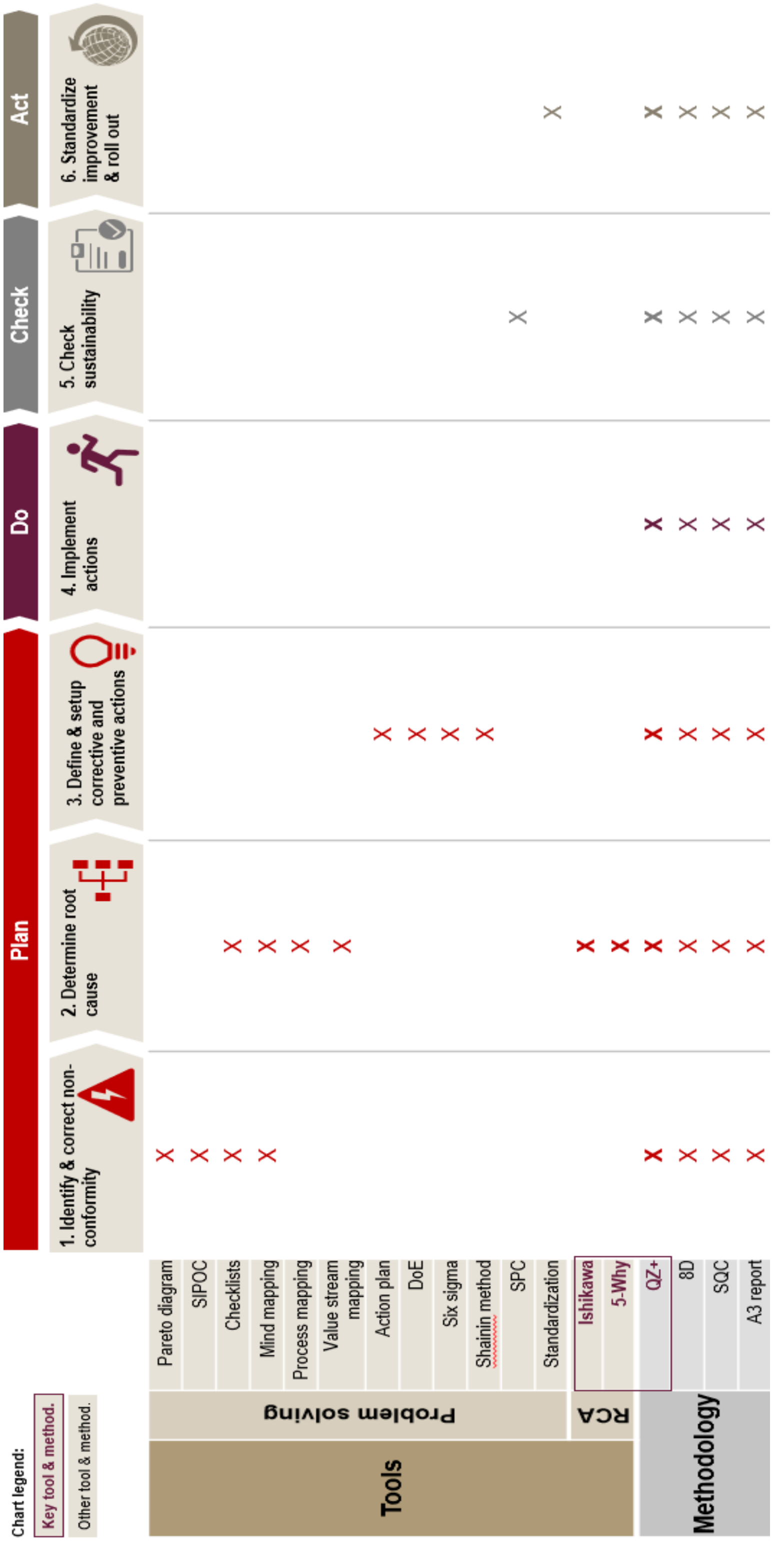


Figure 3.8 - Tools used in the CoPQ process, Hilti AG

3.2.2.1 Quality Circle Plus (QC plus)

QC plus is a structured procedure for solving problems sustainably. It combats the root cause of the problem, not just the symptoms. In doing so, problems are tackled at an inter-disciplinary level. The main target of QC plus is to solve moderately complex to complex problems on a sustainable basis. In doing so, we further develop both the social and technical competencies of employees. The team can carry out a solution in a short amount of time. The problem description is limited to the most important features and all the main aspects are covered through the QC plus procedure.

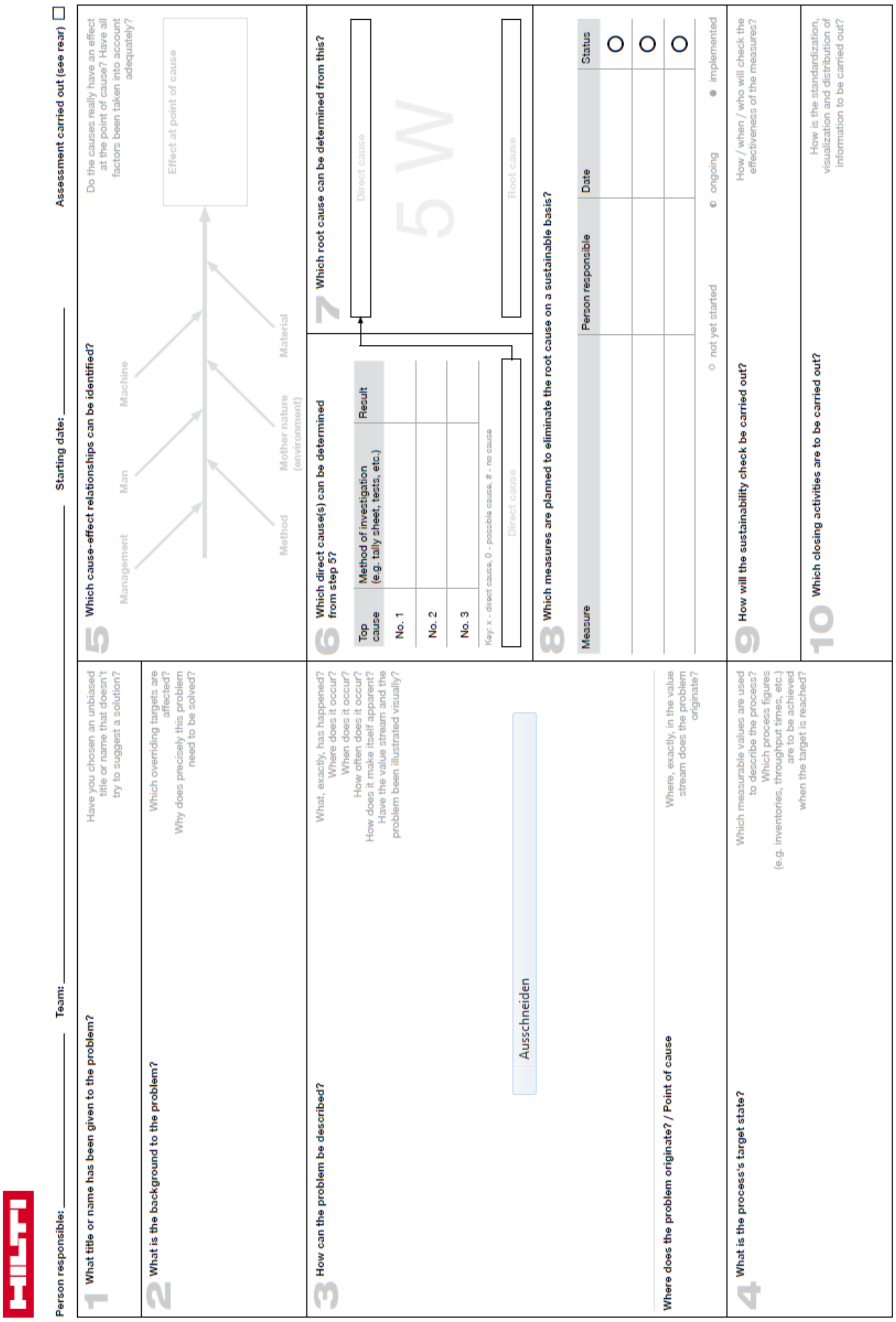


Figure 3.9 – QC plus template, Hilti AG

3.2.2.2 Ishikawa (Fishbone) diagram

Ishikawa diagram (fishbone diagram, cause-and-effect diagram) is a diagram showing causes leading to a specific event (effect). The causes are typically structured in 6 main categories: Management, Man, Machine, Method, Environment, Material. The diagram helps us understand all causes that contribute to a specific event (which resulted in customer complaint or internal failure). Each potential cause is traced back to find the root cause, often using the 5 Whys technique.

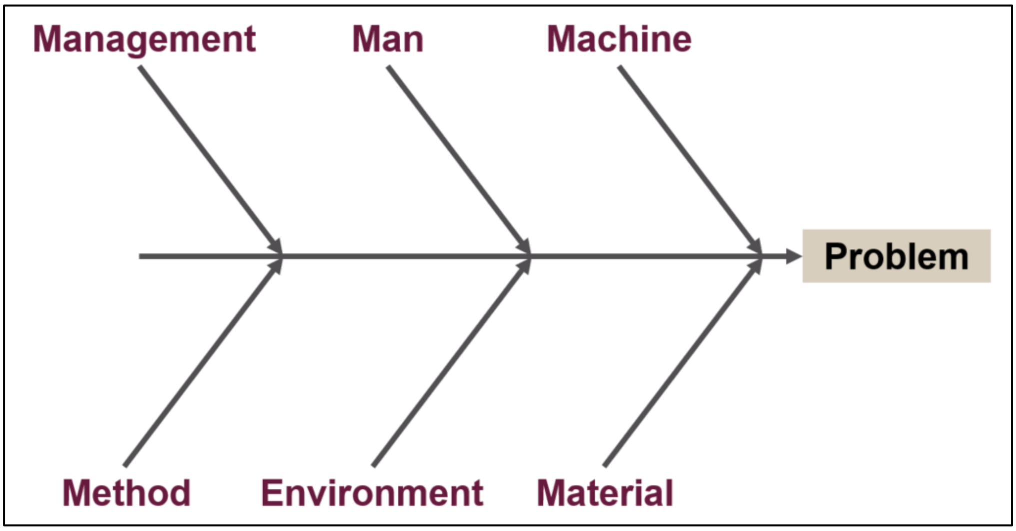


Figure 3.10 - Ishikawa diagram template, Hilti AG

3.2.2.3 5-Why

5-Why is an iterative interrogative technique used to explore the cause-and-effect relationships of a problem. The primary goal is to determine the root cause of a problem by repeating the question "Why?" Each answer forms the basis of the next question. The number "5" in the name derives from an anecdotal observation on the number of iterations needed to resolve the problem – in reality, less than 5 or more than 5 iterations may be needed to find a root cause.

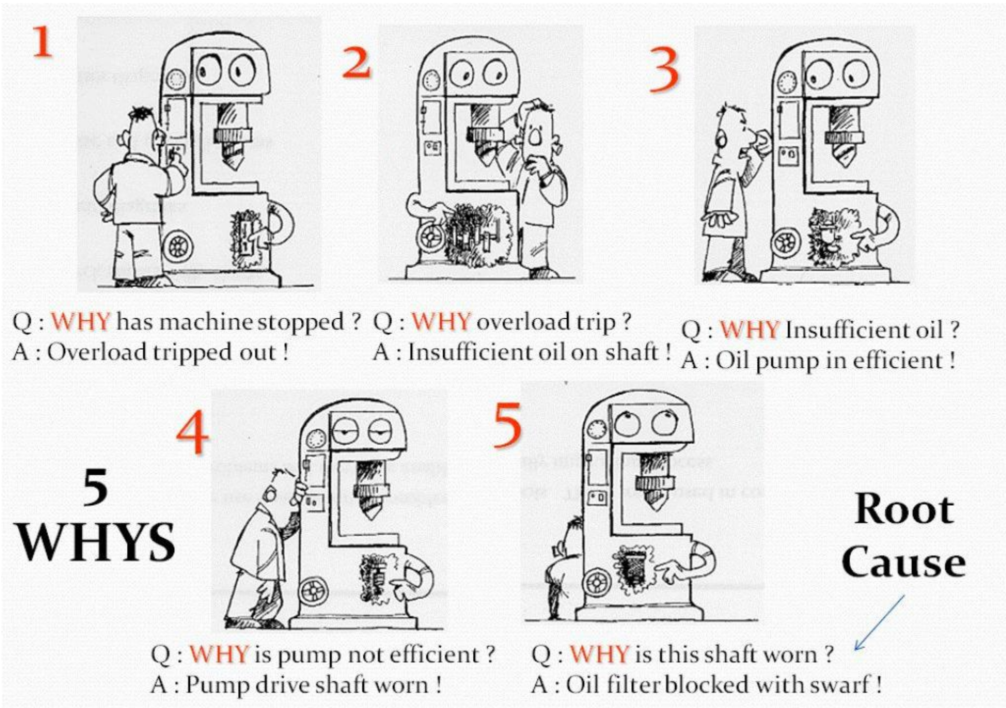


Figure 3.11 - 5 Why example, Hilti AG

As shown also in the example of the previous Figure 3.11, the main target of 5-Why is to identify a root cause (or multiple root causes) of a problem. In doing so, we use employee`s knowledge of the problem and their persistence.

3.3 Case study I – Product development

The first case is going to be presented based on the relevance of its impact and priority attributed by the CoPQ team and it is about the Time to Market (TTM) case, especially in the BU INS. It was addressed by several department of the BU INS due to its multidisciplinary affection and complexity.

The development of new products in Hilti is accomplished in a Stage and Gate method that is structured down in five Stages and six Gates with a total of three main deliverables.

To not expatiate too much on irrelevant details, the author decided to describe only the problem that occurs in stage five or to be more precise during the QN gate. The QN is a document that together with QA and QE compose and certify the transaction from a product development to a product ready to be sold.

- The QE is made during the Design phase and is a set of requirements, mainly regarding the design, that must be respected and subscribed from the Departments involved in order pass the Stage.

- The QN is the most important document since it must be signed up by all the components of the team to launch the product in the market. It represents the last gate before the product reaches the customers.
- The QA is the last gate of the whole Stage and Gate approach and has the functionality to report the early monitoring (one year) of the product and the trend in the markets.

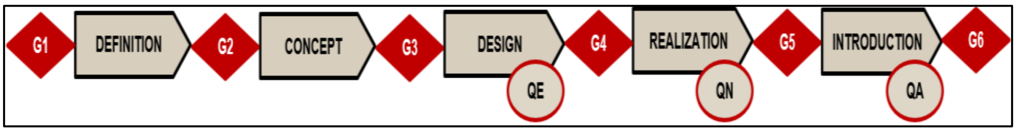


Figure 3.12 - Product development process, Hilti AG

3.3.1 Problem description

Because of the cruciality of the QN release and the timeframe it took to have all the signatures and prerequisites required to pass the gate, the initiative of the management team was to fist get to know better the problem and then come up with sustainable solutions.

To dig-dive into the real Root Cause, it was made a detailed analysis over a hundred QN documents, that for obvious reason we will not extrapolate the absolute total value but refer at it as 100%, and roughly 3000 touchpoints (Figure 3.13).

1	Document number no-rev	Year	Document number	Document link	QN creation date (A)	QN signature date (B)	Rating at first issue	First issue document	QN completion LT (B-A)	QN upload LT (C-A)	Category	Doc type	Overall OK	Overall NOK	1.2 Internal Stipulations	1.3 Stipulations for communication with Supplier	3. Open issues from the previous tests	4. Checklist order / incoming goods inspectio
8	NE 18-109	18	NE 18-109	NE 18-109.pdf	16/05/2018	12/06/2018	A	y	27.00		Connectors	QN report	0	0				
16	NE 18-030	18	NE 18-030	NE 18-030.pdf	13/03/2017	27/04/2018	B	y	410.00	11.00	Connectors	QN report	32	8	8	5	B	A
18	NE 18-028	18	NE 18-028-01	NE 18-028-	12/03/2018	05/06/2018	C	n	85.00		Connectors	QN report	2	0	1	2		
19	NE 18-028	18	NE 18-028	NE 18-028.pdf	12/03/2018	29/03/2018	C	y	17.00		Connectors	QN report	0	2	1	1		
23	NE 18-023	18	NE 18-023	NE 18-023.pdf	05/03/2018	05/04/2018	B	y	31.00	39.00	Connectors	QN report	10	5	4	2		A
29	NE 17-224	17	NE 17-224	NE 17-224.pdf	29/11/2017	08/01/2018	C	y	40.00	7.00	Connectors	QN report	12	7	3	4		A
30	NE 17-222	17	NE 17-222	NE 17-222.pdf		11/12/2017	A	y			Connectors	QN report	0	0				
39	NE 17-197	17	NE 17-197	NE 17-197.pdf	28/02/2018	05/04/2018	B	y	36.00	7.00	Piperings	QN report	20	0	0	1	A	A
45	NE 17-181	17	NE 17-181	NE 17-181.pdf	05/09/2017	20/12/2017	B	y	106.00	2.00	Channels	QN report	29	5	0	11	B	A
47	NE 17-179	17	NE 17-179	NE 17-179.pdf	06/10/2017	06/11/2017	B	y	31.00	1.00	Connectors	QN report	19	4	2	2		A
51	NE 17-165	17	NE 17-165	NE 17-165.pdf	28/07/2017	11/12/2017	B	y	136.00		Connectors	QN report	6	1	1	7		
55	NE 17-161	17	NE 17-161	NE 17-161.pdf	17/01/2018	05/04/2018	B	y	78.00	48.00	Connectors	QN report	31	6	4	6		A
57	NE 17-159	17	NE 17-159	NE 17-159.pdf	01/09/2017	22/04/2018	C	y	233.00	- 18.00	Connectors	QN report	25	11	7	12	A	B
59	NE 17-153	17	NE 17-153	NE 17-153.pdf	17/07/2017	05/04/2018	B	y	262.00	39.00	Connectors	QN report	29	2	3	6		B
61	NE 17-151	17	NE 17-151	NE 17-151.pdf	22/03/2018	05/04/2018	B	y	14.00	39.00	Connectors	QN report	30	5	6	4		A
66	NE 17-132	17	NE 17-132	NE 17-132.pdf	20/11/2017	05/04/2018	B	y	136.00	6.00	Connectors	QN report	27	8	4	6	A	A
68	NE 17-128	17	NE 17-128	NE 17-128.pdf	05/02/2018	09/02/2018	B	y	4.00	11.00	Connectors	QN report	27	11	7	9	A	A
70	NE 17-125	17	NE 17-125	NE 17-125.pdf	13/11/2017	09/02/2018	B	y	88.00	12.00	Connectors	QN report	17	2	5	4	A	A
72	NE 17-109	17	NE 17-109	NE 17-109.pdf	25/04/2017	08/02/2018	B	y	289.00	4.00	Channels	QN report	22	4	0	2	A	A
73	NE 17-107	17	NE 17-107	NE 17-107.pdf	07/06/2017	19/02/2018	A	y	257.00	1.00	Connectors	QN report	0	0				
82	NE 17-087	17	NE 17-087	NE 17-087.pdf	28/04/2017	08/02/2018	B	y	286.00	1.00	Piperings	QN report	34	5	1	14		A
85	NE 17-082	17	NE 17-082-01	NE 17-082-	25/08/2017	04/04/2018	C	n	222.00	- 238.00	connectors	QN report	0	0				
86	NE 17-082	17	NE 17-082	NE 17-082.pdf	29/05/2017	31/07/2017	C	y	63.00		connectors	QN report	2	3	0	0		
90	NE 17-078	17	NE 17-078	NE 17-078.pdf	24/08/2017	20/12/2017	A	y	118.00	14.00	ıchors, not BU II	QN report	0	0				
96	NE 17-070	17	NE 17-070-01	NE 17-070-	18/07/2017	13/06/2018	B	n	330.00		Channels	QN report	0	0				
97	NE 17-070	17	NE 17-070	NE 17-070.pdf	18/07/2017	05/12/2017	B	y	140.00	1.00	Channels	QN report	31	2	2	2	A	A
103	NE 17-062	17	NE 17-062	NE 17-062.pdf	22/03/2017	11/05/2017	B	y	50.00	- 15.00	Connectors	QN report	26	9	2	0		A
105	NE 17-060	17	NE 17-060	NE 17-060.pdf	19/04/2017	11/12/2017	B	y	236.00	3.00	Piperings	QN report	28	3	4	3		A
113	NE 17-042	17	NE 17-042	NE 17-042.pdf	23/02/2017	13/11/2017	A	y	263.00	- 75.00	Connectors	QN report	0	0				
121	NE 17-033	17	NE 17-033-02	NE 17-033-	21/08/2017	22/12/2017	C	y	123.00	- 45.00	Connectors	QN report	14	8	2	4	C	C

Figure 3.13 - Categorization of raw data, Hilti AG

Usually the departments involved are: Technical Product leader, Marketing, Testing, Product Manager, Supply and Quality.

The Quality department, in which the author took an active role, had the scope to make sure all the agreed requirements are satisfied and that the process get to the last gate smoothly and correctly. The document is divided in 16 chapter for which there are one or several tasks depending on the requirement to be fulfilled. Every chapter and subchapter were rated by the team with A, B or C. The rating was done during the check-up meetings and once every chapter was rated in case there was not any C-rated chapter or subchapter, the product could escalate the Gate 5 and be launched in the market.

If it was compressively rated as an A, it meant that every requirement is completely and exhaustively fulfilled, from the most important requirements to the secondary ones. In case something was B-rated it meant that some "secondary" requirement was not fully respected and that there was needed a stipulation to pass the gate which was not yet considered as a waste of resources but a normal procedure. The stipulation could have been internal or external and were basically some guaranties that the missing requirement was going to be accomplished within a certain amount of time. The C-rating meant that something related to the security or testing of the product was not accomplished and the product was not able to pass the gate unless the requirements were totally pleased. The B and C rating were causing "loops" which were basically the repetition of some steps needed to get the product into the market therefore, necessary to be considered as non-value-added activities but wastes. To understand what the real problem was, the first question that needed to be answered was:

"what is the impact and the size of the loops?"

After the first level of analysis, the following Figure 3.14 and table summarize the size of the non-A-rated at first issue and the average delay that the loops (needed to adjust what was missing at first check) triggered. In the Figure 3.14 it is evident that this stage had necessity and space for improvement.

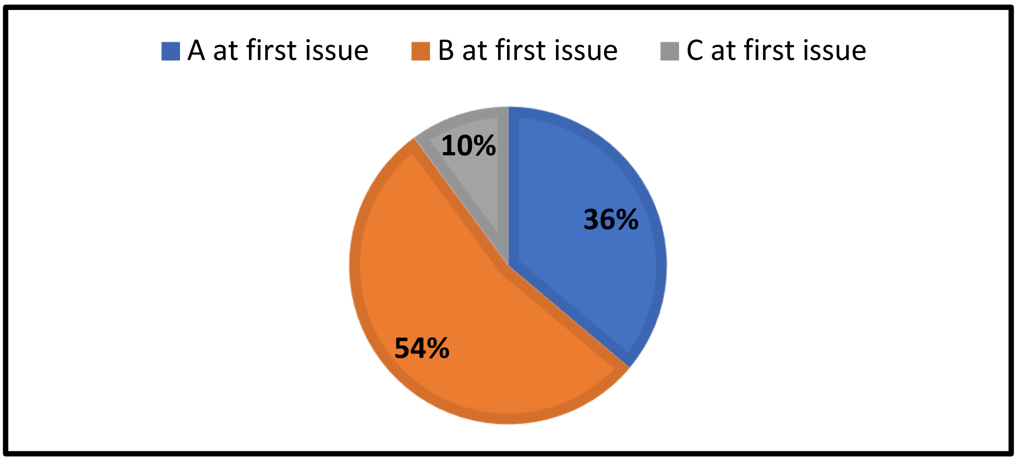


Figure 3.14 - Rating of QN documents at first issue, Hilti AG

It delights the size of the Loops and the potential for improvement within only the QN approval.

The Table 3.1 - Average days for QN release, Hilti AG shows the findings of the impact in terms of timeframe the loops were having on the release of the QN document (from the kick-off meeting until the launch in the market).

Avg.	**Min**	**Max**	**>90 days**	**<90 days**
146 days	16	706	60%	40%

Table 3.1 - Average days for QN release, Hilti AG

Since that every loop was roughly 30 days and normally it should take around two months and half, it is evident that to release a QN document were needed in average around three extra loops leading to wastes in terms of time and money.

3.3.2 Discussion

As soon as the first step of the PDCA House of CoPQ (identify nonconformity) was over, the next step was to use the QC plus as a guideline to proceed in a structured way toward the identification of the Root-Cause.

The direction identified as potential roots were several and by crunching data and inserting to the analysis the experience of many people who were interviewed, it was possible to shrink down to three possible relevant segmentation of the problem: supplier, product's category, and time-based failures. These four possible roots were wide enough to not be able to be faced with a normal procedure; the 5 Why and/or the Ishikawa diagram but it was necessary to structure the findings in charts and diagrams and link them with a structured tool, the QC plus tool.

In the Figure 3.15 is shown the outcome analysis divided in three main blocks and the actions taken based on them will be explained in the results Ref. Chapter 4.2.

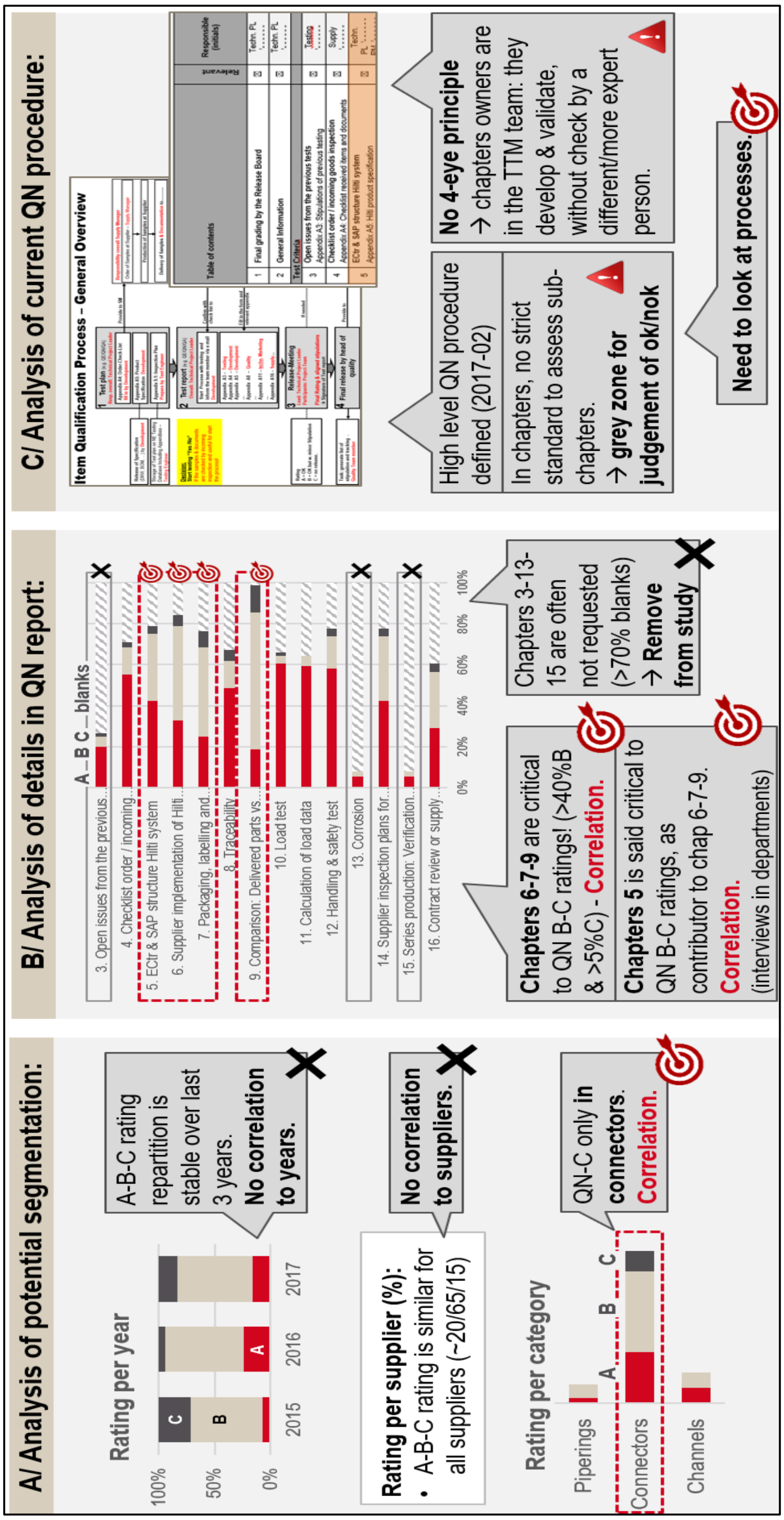


Figure 3.15 - Classification of the outcome analysis, Hilti AG

The first block (A/Analysis of potential segmentation) is subdividing the problem into the three problem-segmentation introduced before and shows the result of the gathered cross-checked information. There was not an evident correlation with the timespan considered or the supplier involved in that QN meanwhile, it was obvious the correlation with the kind of category of product involved in the process;

The second block (B/Analysis of details in QN report), extrapolates the exact chapter (i.e. department) that was mainly involved in the delay and its rating not relevant to the target (idealistic: all QN are A-rated and within an average of 2.5 months duration), see Figure 3.16;

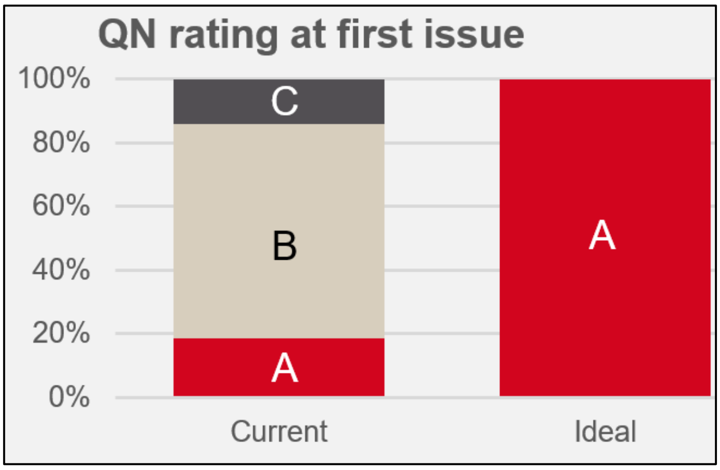


Figure 3.16 - Actual vs Ideal rating of QN, Hilti AG

The last block (C/Analysis of current QN procedure), is already centring the origin of the problem. In this part of the analysis, the experience of the people involved, and lean managers played a crucial role. The procedure was not standardized and the overall QN procedure was considered as a closed system since no "external party" was double checking the goodness of the team QN work.

3.4 Case study II – Logistic application

The following case is related to the logistic of the product HDA (Anchors) within BU ANC, which was shipped, via seas to the Market Organization (MO) China and then to the clients in the Asian area. The product is produced in the Plant 18 in Hungary, for this reason it was necessary to include them in the workshop. The results expected to come out of the workshop were supposed to be the same as the workshop done the previous year by BU INS over the same kind of problem; sea freight shipment to MO China which cannot accept the products due to the white rust on top of most of them (it does not affect at all the functionality of the product but its appearance). It seemed to be clear the root-cause (R-C) and the solution applied was working so nobody further investigated until during the 2018 it happened the same problem in another BU (ANC) and to make sure that the solution found was hundred percent reliable and challenge its week points, the CoPQ team decided to make another workshop without considering the previous findings.

Figure 3.17 - White rust on Anchors, Hilti AG

3.4.1 Problem description

After the order is received in the BU that a certain customer is interested in buying a certain amount of a specific product, it is communicated to the Plant 18 the request and all the process starts until the product reaches the MO responsible pf the last mile delivery. In this case there are four main protagonists: BU ANC, MO China, Plant 18 (P18) and the client CNNC. The first complain received by the BU was in the beginning of September 2017 because the client found imperfect coating (white rust) in most of the HAD and returned them back. and P18 decided to adopt easy counter measures to avoid the problem like making mandatory to use gloves and make the packaging (shrink wrapping) much more resistant then it was before. As soon as the corrective solution cited before were implemented, the replacement was sent. The problem this time faced with different numbers but still causing customer dissatisfaction (delayed delivery and low quality perceived):

3.4.2 Discussion

For the reasons previously discussed, it was decided to face again the problem trying to dig deeper into the real root cause and from a distinct perspective then it was tackled before. The outcome of the workshop conducted directly in P18 is represented by the Figure 3.18 and Figure 3.19. The first necessary step was to individuate the potential macro areas.

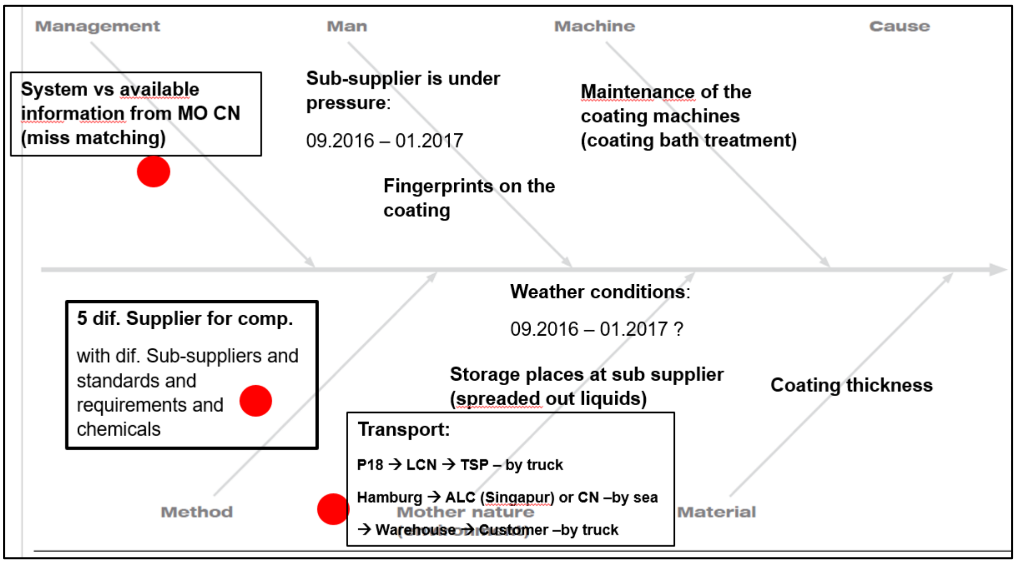


Figure 3.18 - Outcome of the workshop (Ichikawa) conducted in P18, Hilti AG

This figure represents the Ishikawa that the experts involved in the workshop came up with to cluster the information and prioritize based on the experience and what was the outcome of the discussion during the workshop. As soon as the factors that could have influenced the cause were determined, there were prioritized three of them as the ones that had major impact on the failure. Therefore, transport, mismatching info and supplier were the areas individuated as more relevant for the case. Once the macro area where to investigate had been individuated, it was necessary to use the 5-Why (Figure 3.19) for understanding the details behind these macro areas. The next step was to assign specific tasks to the people involved to verify which one was the real root cause.

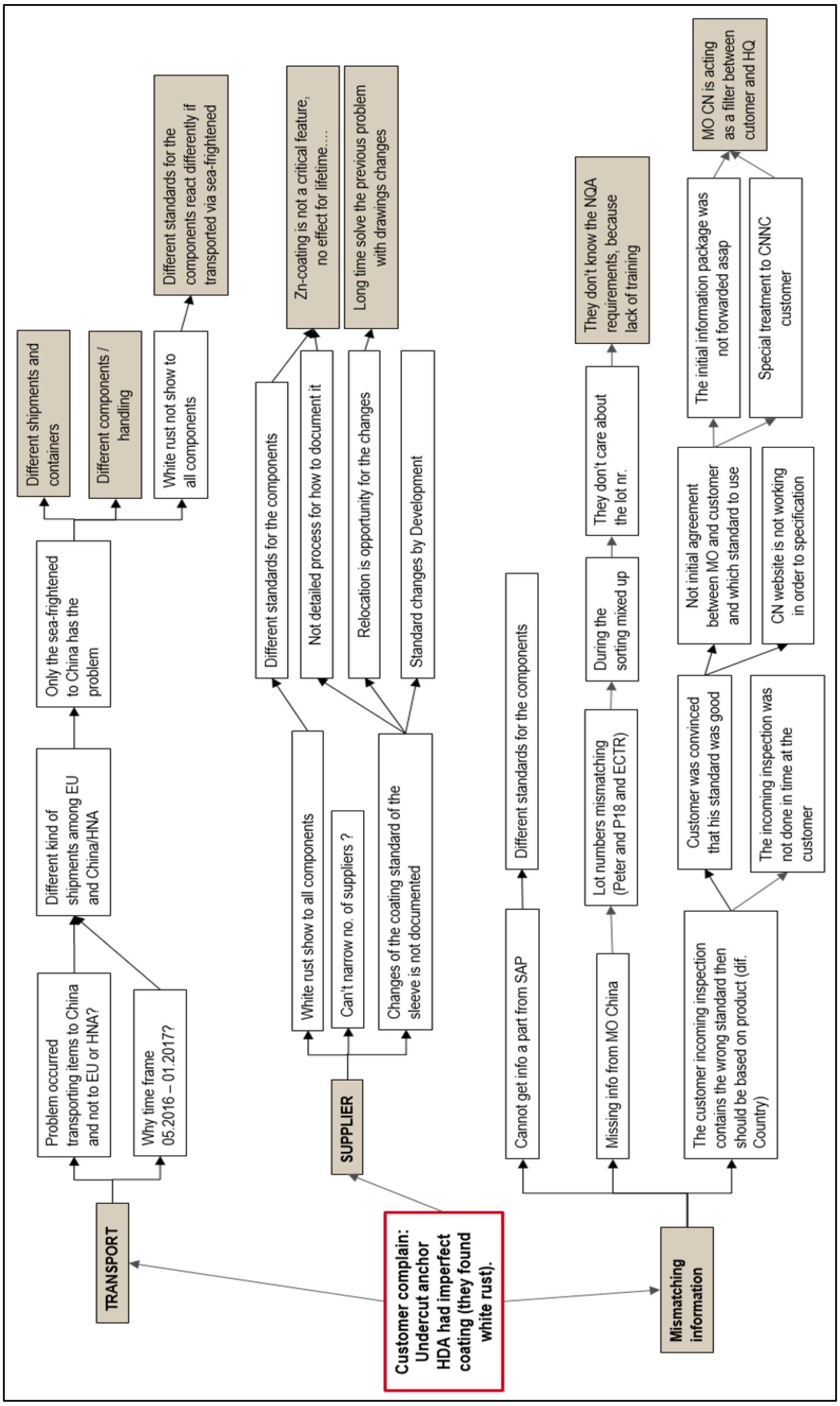


Figure 3.19 - Outcome of the workshop (5-Why) conducted in P18, Hilti AG

As introduced in Chapter 3.2, the aim of the overall CoPQ project is to track down the failures analysed and especially the solution developed. To understand more the problem, it could be introduced the following Figure 3.20 that represents graphically how the failure is showing off in terms of white rust. The reaction of H2O, O2 and the coating (noncarbonate, which helps to hinder the red rust which is worst in every sense).

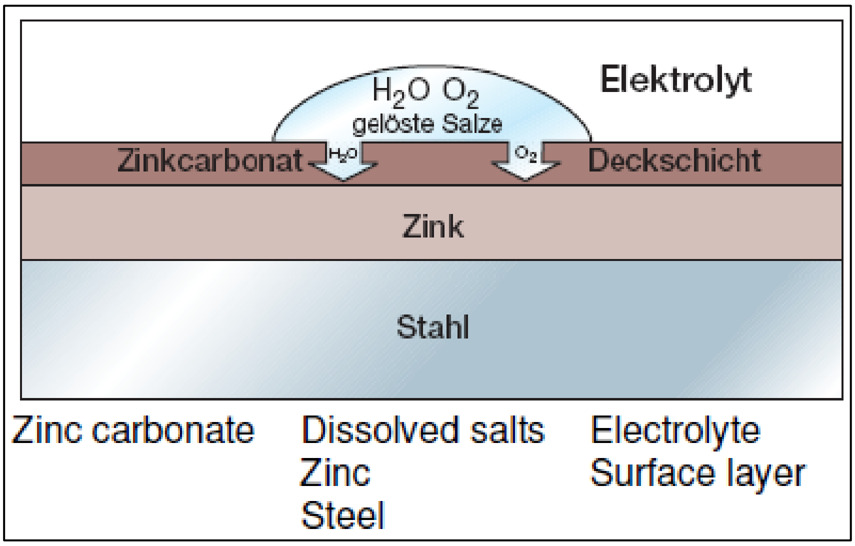


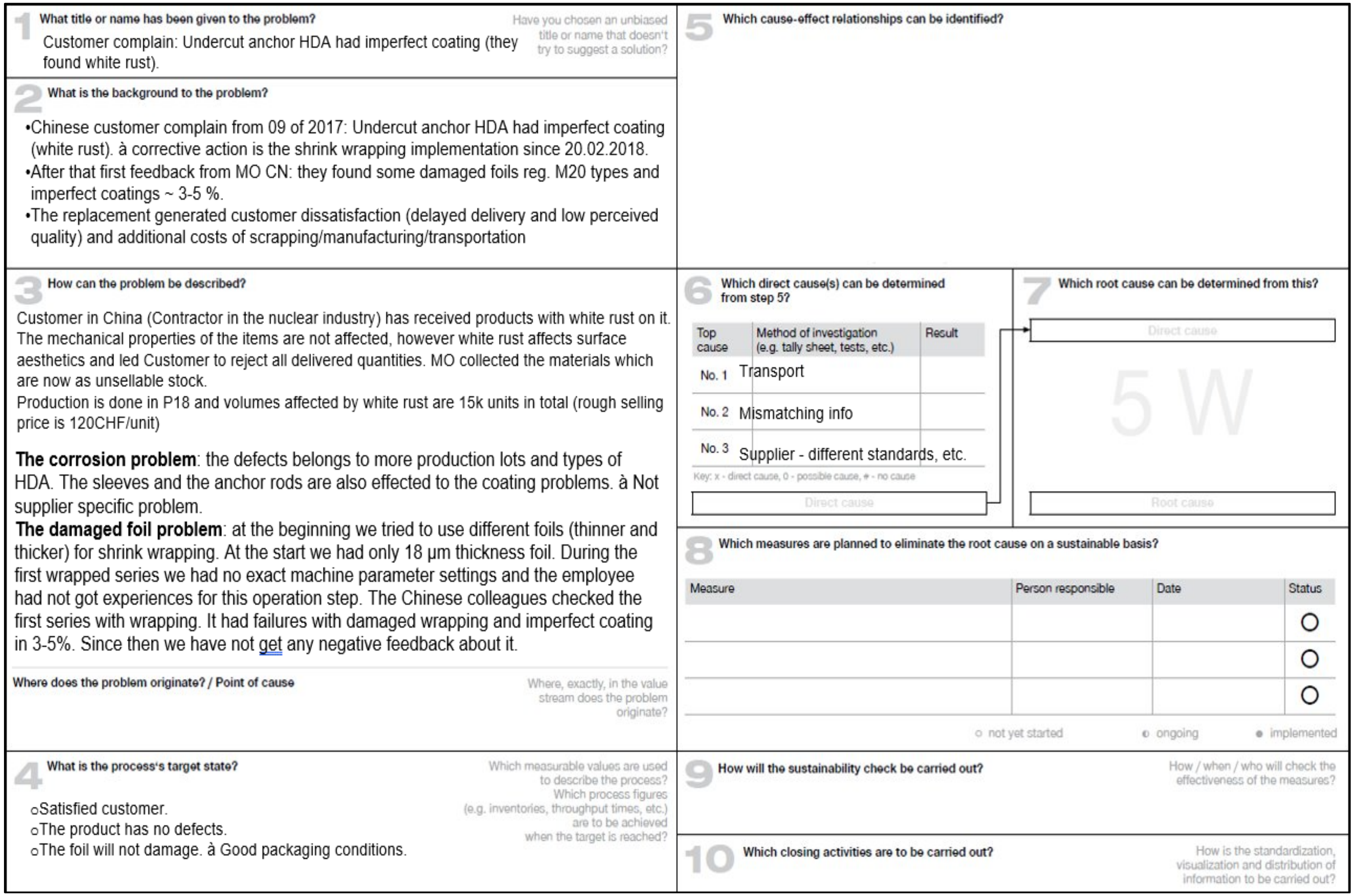
Figure 3.20 - How is created the white rust, Hilti AG

The chemical reaction between the molecules of H2O, O2 and the first layer of Zinc carbonate produces the undesired visual effect of white rust in the sleeves and anchor roads.

The next Figure 3.21 represents the final results are grouped in the Quality Circle Plus (QC+) format. The steps 5 and 7 of QC+ are already been discussed in the previous paragraph by the Ishikawa and 5-Why diagrams (Figure 3.18,Figure 3.19) individuating the three main causes of the problem and deep diving for more detailed analysis of the root cause (management, supplier and transport). The Steps 8 and 9 are out of scope since the target of the project was based on the estimated Potential CoPQ savings represented by the Step 8 in the QC+.

Meanwhile, on the right side of the QC+ are described the methods used and the findings toward the root cause, on the left side it is describes the problem background and the detailed report of how and what consequences it had upon the customer.

To keep track of the progress, it is possible to associate the YTD phase of this case study is at the end of the Process step n° 3 of the Deming cycle (Plan - Do - Check - Act) adapted to the House of Quality as described in the Chapter 3.2.1.



1 What title or name has been given to the problem?

Have you chosen an unbiased title or name that doesn't try to suggest a solution?

Customer complain: Undercut anchor HDA had imperfect coating (they found white rust).

2 What is the background to the problem?

- Chinese customer complain from 09 of 2017: Undercut anchor HDA had imperfect coating (white rust). à corrective action is the shrink wrapping implementation since 20.02.2018.
- After that first feedback from MO CN: they found some damaged foils reg. M20 types and imperfect coatings ~ 3-5 %.
- The replacement generated customer dissatisfaction (delayed delivery and low perceived quality) and additional costs of scrapping/manufacturing/transportation

3 How can the problem be described?

Customer in China (Contractor in the nuclear industry) has received products with white rust on it. The mechanical properties of the items are not affected, however white rust affects surface aesthetics and led Customer to reject all delivered quantities. MO collected the materials which are now as unsellable stock.
Production is done in P18 and volumes affected by white rust are 15k units in total (rough selling price is 120CHF/unit)

The corrosion problem: the defects belongs to more production lots and types of HDA. The sleeves and the anchor rods are also effected to the coating problems. à Not supplier specific problem.
The damaged foil problem: at the beginning we tried to use different foils (thinner and thicker) for shrink wrapping. At the start we had only 18 µm thickness foil. During the first wrapped series we had no exact machine parameter settings and the employee had not got experiences for this operation step. The Chinese colleagues checked the first series with wrapping. It had failures with damaged wrapping and imperfect coating in 3-5%. Since then we have not get any negative feedback about it.

Where does the problem originate? / Point of cause

Where, exactly, in the value stream does the problem originate?

4 What is the process's target state?

Which measurable values are used to describe the process? Which process figures (e.g. inventories, throughput times, etc.) are to be achieved when the target is reached?

- Satisfied customer.
- The product has no defects.
- The foil will not damage. à Good packaging conditions.

5 Which cause-effect relationships can be identified?

6 Which direct cause(s) can be determined from step 5?

Top cause	Method of investigation (e.g. tally sheet, tests, etc.)	Result
No. 1	Transport	
No. 2	Mismatching info	
No. 3	Supplier - different standards, etc.	

Key: x - direct cause, 0 - possible cause, ≠ - no cause

Direct cause

7 Which root cause can be determined from this?

Direct cause

5 W

Root cause

8 Which measures are planned to eliminate the root cause on a sustainable basis?

Measure	Person responsible	Date	Status
			○
			○
			○

○ not yet started ◐ ongoing ● implemented

9 How will the sustainability check be carried out?

How / when / who will check the effectiveness of the measures?

10 Which closing activities are to be carried out?

How is the standardization, visualization and distribution of information to be carried out?

Figure 3.21 - Outcome of the workshop in P18, Hilti AG

3.5 Case study III – Production application

The following case study was tackled by the CoPQ team in cooperation with the supplier right in the facility EUROFOX based in Wien. The EUROFOX facility buys aluminium profiles (Figure.3.22) from an international supplier and transforms it in the final product ready to be shipped directly to the customers.

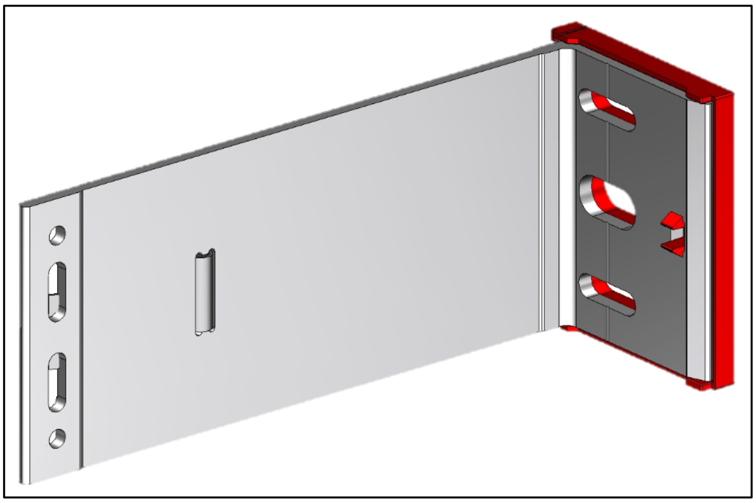


Figure.3.22 - Aluminium profiles, Hilti AG

There is a wide gamma of products modelled in this facility based on the customers' requirements, so the considerable number of units produced, and the variety of the products empowered the CoPQ team to have a close look to the real root-cause of the non-conformities incurred in this facility.

3.5.1 Problem description

At the production facility EUROFOX are built sub-structure for ventilated facade systems. There are different dimensions required by the customers and, therefore produced in the facility but all of them are mostly made from the same raw material, a 6m aluminum profiles. These are processed in different steps (i.e. sorting, stamping, packing, handling etc..) before becoming the final product which is sold in the market. During 2018 the quality of arriving raw material declined significantly and that was the trigger point from which the CoPQ team decided there was a potential of improving (Figure 3.23).

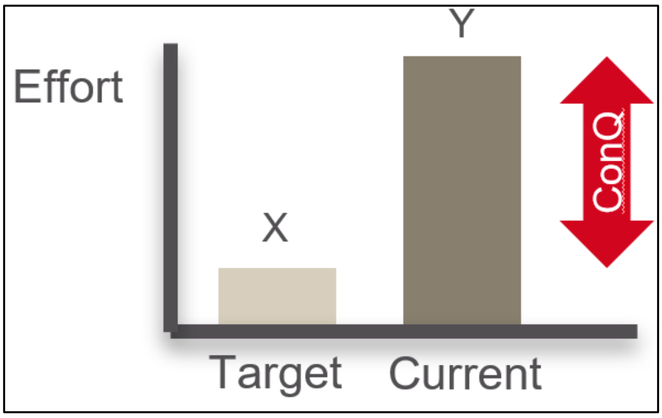


Figure 3.23 - Target vs Current situation in EUROFOX, Hilti AG

Increasing variation of raw material delivered from the supplier led to major internal non-conformances. Because of to the compact packages, sorting and handling non-conforming 6m profiles were time intensive (i.e. the process which were mainly causing extra costs), they were the starting point from where the investigation started. Moreover, due to the previous reasons, it was compulsory to double-check each profile manually and that required extra time needed to sort (waste). As showed in the Figure 3.24. It also interrupted the production flow due to its time-consuming process of replacing non-conforming profiles in the value creation process.

Figure 3.24 - Criticalities in the production stream in EUROFOX, Hilti AG

These deviations from original profiles needed by EUROFOX started to increase beginning of February causing an increasing gap between the ideal situation (target) and the actual one (current).

3.5.2 Discussion

The target of this workshop was a 98% interruption-free production process which required a minimum amount of non-conforming profiles. Whenever there were non-confirming profiles, it was necessary to send them back to the supplier, wait until the new profiles were ready and doublecheck again the conformances of the new profiles. This loop caused extra effort (wastes) from both sides of EUROFX and the supplier. The overall impact in terms of time effort and money (written in as a relative value for non-disclosure agreements between the author and the company, Hilti AG) is shown in the Figure 3.25.

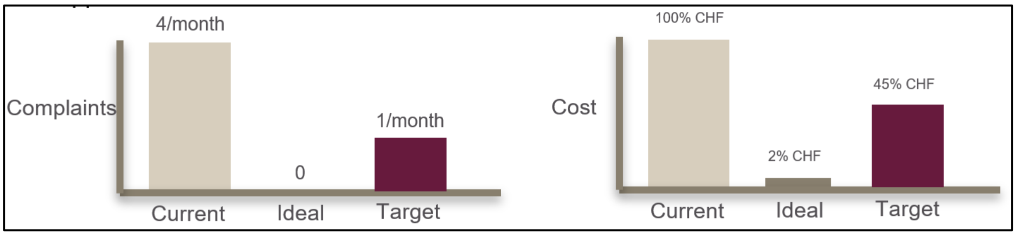


Figure 3.25 - Time and money effort in case of Current, Ideal and Target situation, Hilti AG

As introduced before in the methodology section (Ref to Chap. 3.2.), the 5-Why was used to accomplish Cross-functional root cause workshops conducted with supplier of profiles.

Once estimated the overall impact that the production failure of the supplier had and acknowledging the effects that it was causing to the production and profitability of the overall chain, it was possible to have an overview of the total impact and the effects instigated. The next step was to detain a workshop with all the Hilti's representatives of the activities affected by this failure and the ones that could bring a valuable experience for detecting the failure. Therefore, it was necessary to involve also the supplier to have a more complete perspective of the potential causes of the failure which had an active role in detecting the root cause. Several quality tools were used during the workshop to moderate and keep the track of the process in structured way.

The workshop lasted quite a few days of brainstorming and discussing on the possible root causes. Thanks to the QC+ and the 5-Why methodology, it was possible to came out with four potential roots. It was necessary to verify which one was the real root cause and which were just contributing factors or even false paths. To do so, everybody had some verification tasks to accomplish before the follow-up meeting, with respect to the four possible roots showed in the Figure 3.26.

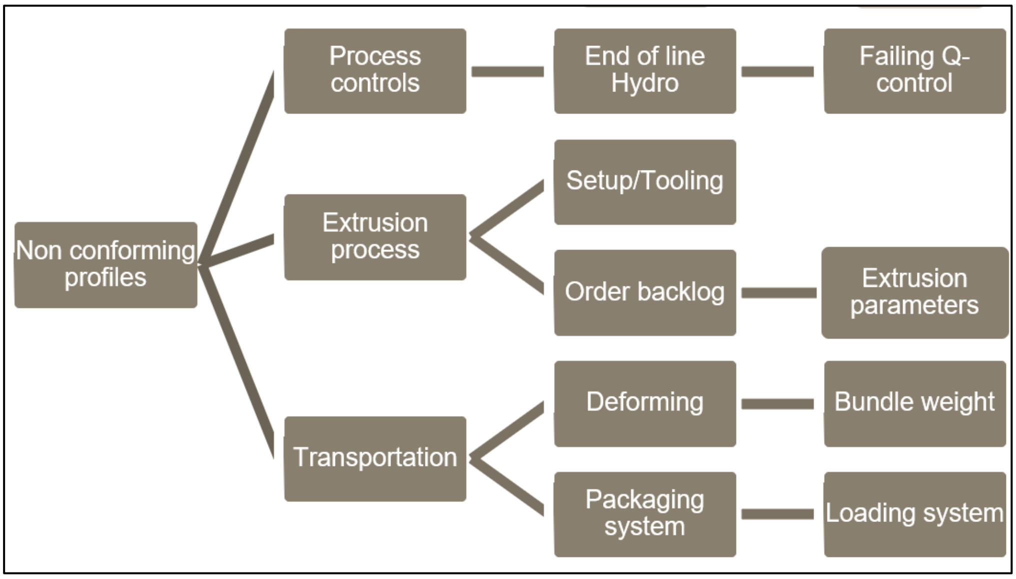


Figure 3.26 - Applied 5-Why to EUROFOX case, Hilti AG

In the follow-up meeting, all the tests made on the four roots were discussed and analysed taking in consideration different perspectives, the Hilti's departments and the supplier ones. As soon as it was clear the real cause of the failure (Figure 3.27), it was necessary to make some more tests in order to be sure about it and later on proceed with the preventive actions.

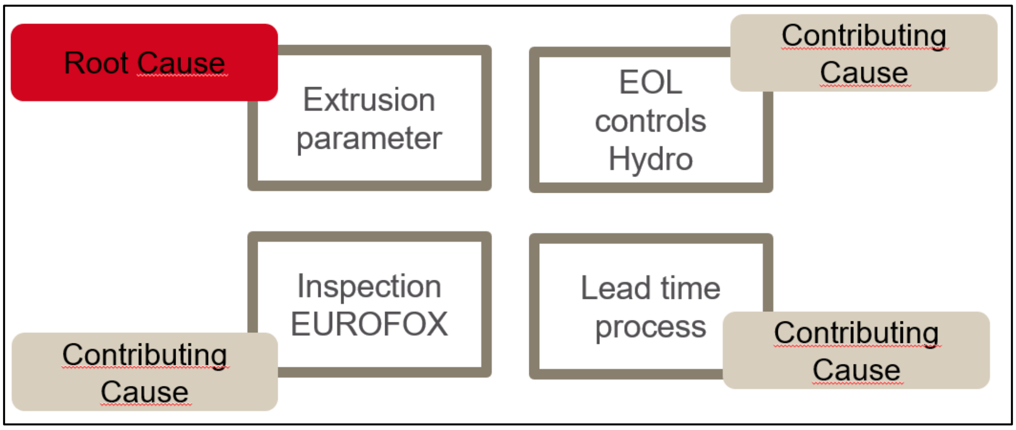


Figure 3.27 - Detection of real root cause in EUROFOX, Hilti AG

The timeframe to take the actions agreed in the follow-up meeting and monitor the results so that every stakeholder involved was satisfied by the outcome was roughly three months and most of them were directly related to the provider side. The supplier had a significantly increased the incoming order volume and they needed to increase their Overall Equipment Effectiveness (OEE) to be competitive and not losing market opportunities in terms of sales. Therefore, they enhanced the extrusion speed that led to higher process variation.

In the Figure 3.28 is represented the outcome of this case study which shows the learnings that the Cost of Poor Quality team decided to embody in an A3 format which is almost the same of the Quality Circle plus (QC+). In this case the format is completely comprehensive of the details of the case, starting from the first appearance of the failure until the resolution of it.

Like in the QC+, the first three steps are about the description of the appearance of the failure (Stage I of the House of Quality, identify non-conformity and correct it). Form the fourth until the sixth explains how the root causes are determined and analyzed (Stage II of the House of Quality, determine root cause). Finally, from seventh until the ninth defines the planning of the preventive actions and the implementation of themselves comprehending also the sustainability plans for the future (stage III and IV of the House of Quality).

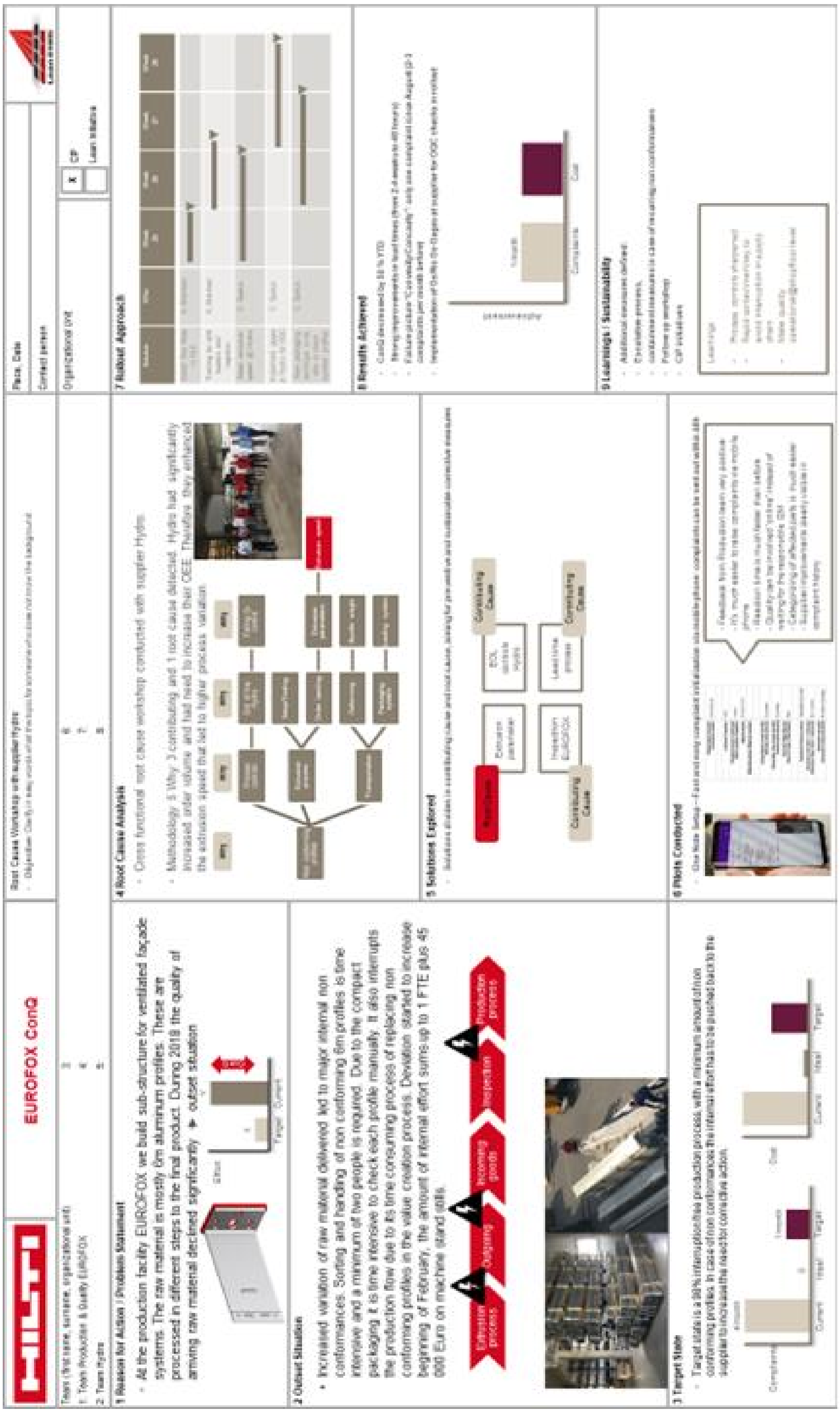


Figure 3.28 - Outcome of the workshop in EUROFOX, Hilti AG

3.6 Numerical results

The following charts show the impact that the Cost of Poor-Quality team had and the figures that came out during 2018 by adopting this novel approach of CoPQ. Moreover, it is visible the contribute that each BU has on the final target sub-divided by the four categories presented in the beginning of the Chapter III. As already mentioned, the target of this project was based on the third column of the Figure 3.29 shown below (Potential CoPQ savings).

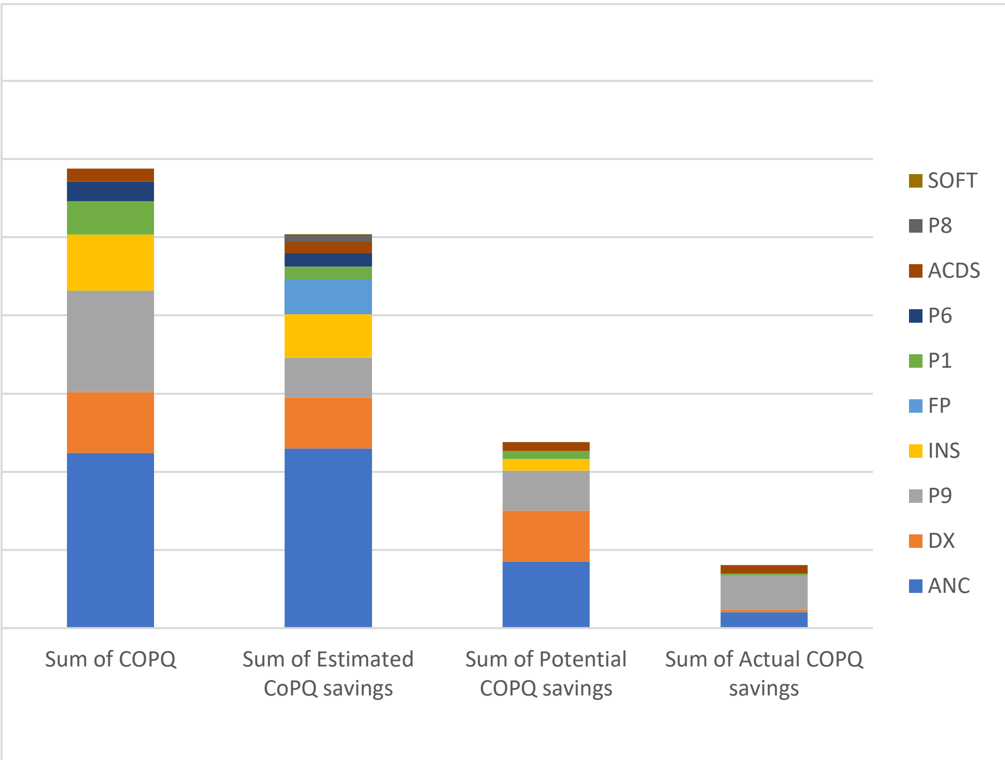


Figure 3.29 - CoPQ values, Hilti AG

Since the target for the 2018 FY was to make 7% out of the final target of 20% within the timeframe 2017-2020, it is possible to say that the results reached during the first half of 2018 was almost double of the target (14%) as shown in the chart below.

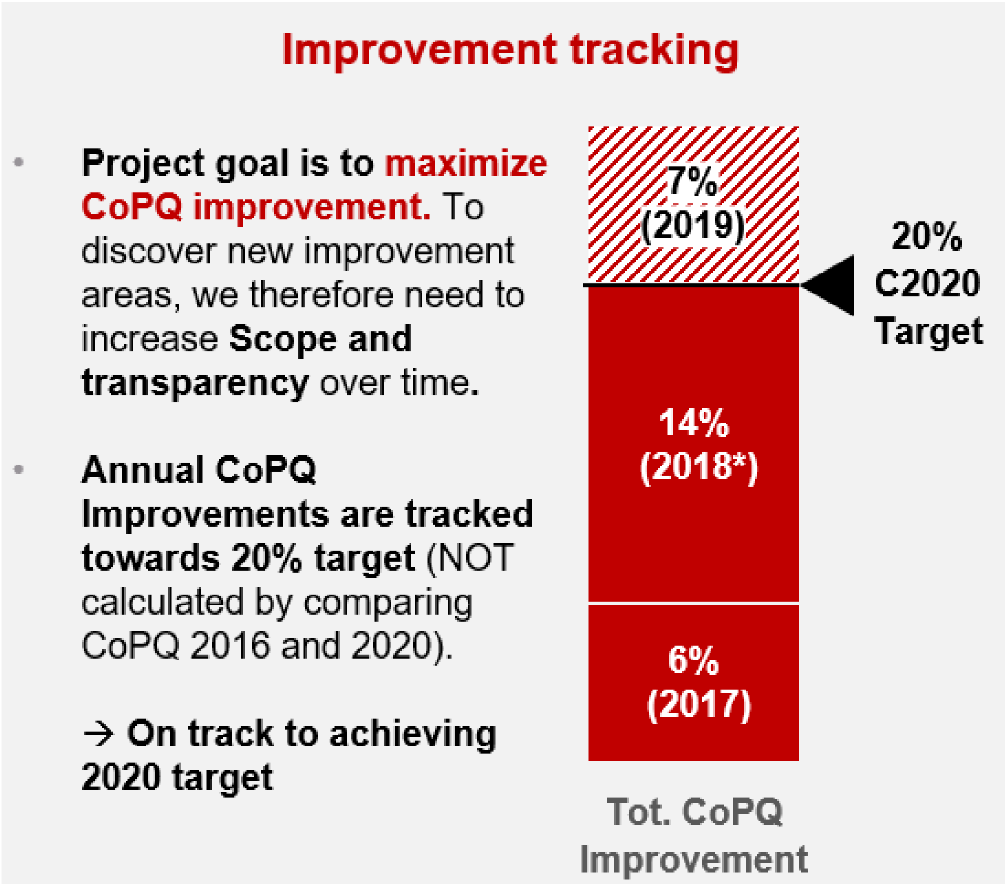


Figure 3.30 - Improvement tracking, Hilti AG

This great achievement comes from a series of factors that influenced the harmony of the CoPQ team and therefore the results. Once the team developed an awareness of the strategy and tools used in this manner, in order to make visible and transparent the wastes coming from failures, the results achieved show the real added value that this approach brings to the process of identification and mitigation of the failures.

Breaking down the results achieved (Potential CoPQ savings) into Area of Occurrences (Figure 3.31), it is possible to categorize and prioritize the intervention needed to solve the failures. The categorization was done based on the experience of the Quality Managers and finally approved by all the team so there was a common way of managing the Business Units and Plants failures in terms of how to label them into the AoO listed in the Figure 3.31.

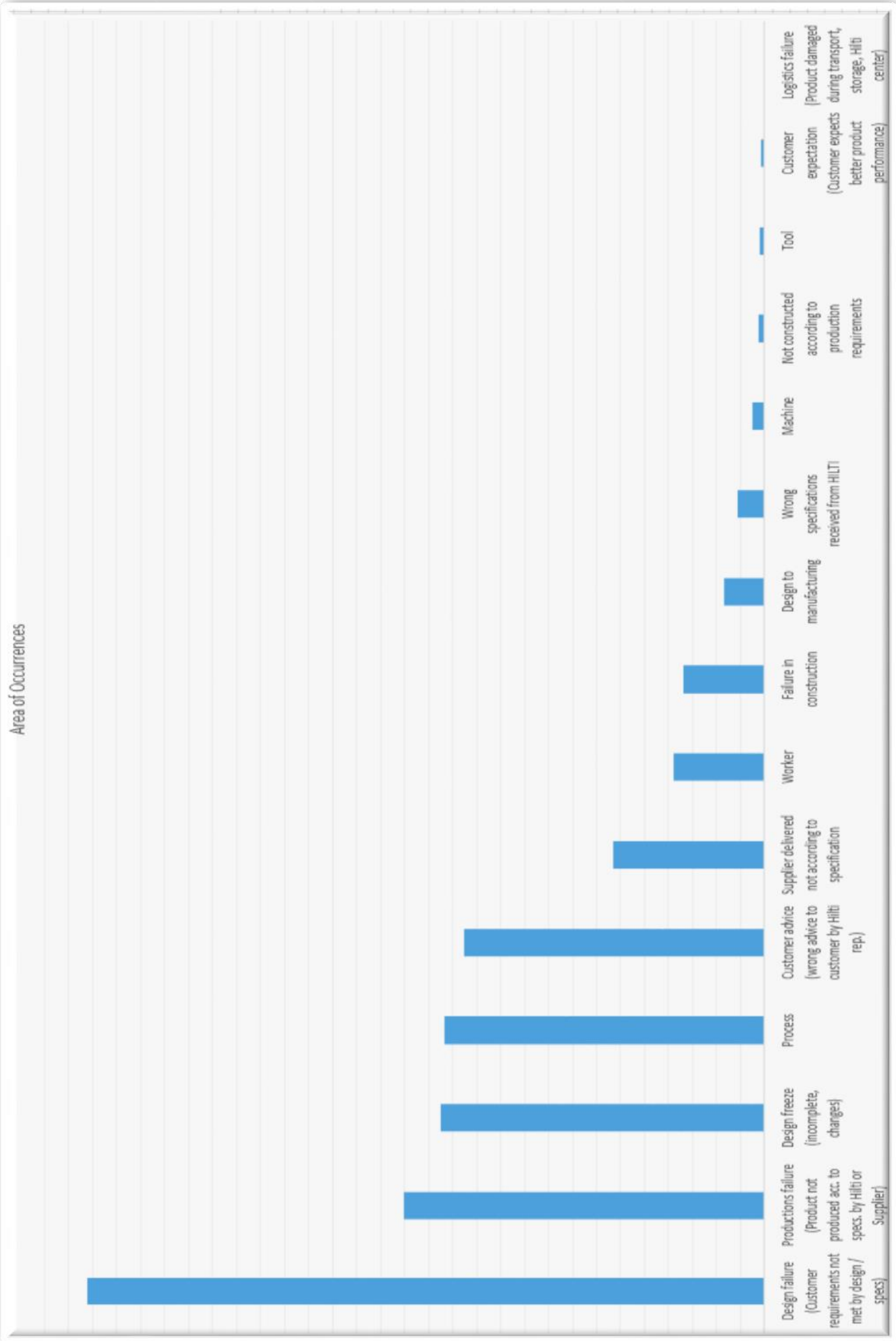


Figure 3.31 - Potential CoPQ savings braked down in AoO, Hilti AG

Finally, we can get to the aggregate numbers that enable to understand the final picture of the results achieved over the years by the CoPQ team. The following Figure 3.32 shows the effective results from 2016 until the end of 2018 and with some projection over the Financial Year 2019.

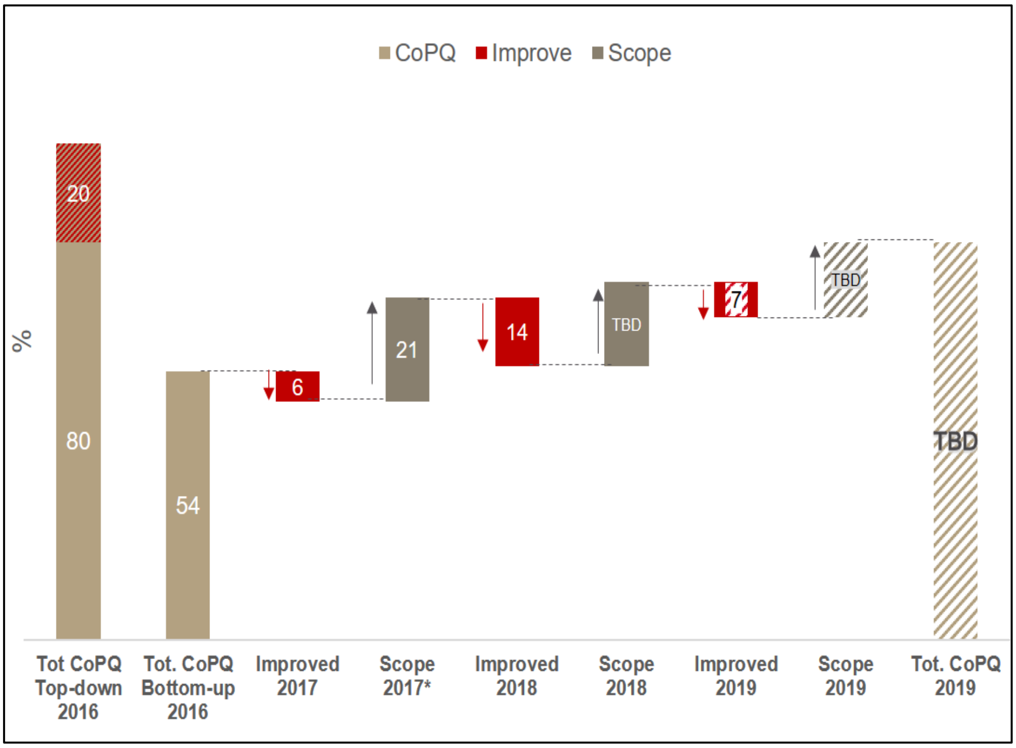


Figure 3.32 - CoPQ results overview in persentage, Hilti AG

It is clear the impact that the CoPQ team could achieve thanks to the structured methodology. It allowed them to continuously understand, the spots of the different processes that could be improved, by optimizing and focusing on the ones with the biggest impact in terms of costs

4 Conclusions

In current literature, it has been found that there is a lack of research regarding practices of how to measure and monitor CoPQ. This Master thesis has shown a practical example of identification of CoPQ at a case company and further a step by step guide for practical implication for identification. This has been realized by interpreting a process-based investigation for identifying visible and invisible CoPQ in each step of a general process. The Process describing the step by step guide to find, choose and measure CoPQ and the process-based framework are the main contribution of this master thesis. Therefore, this master thesis has opened for further research in this area. It has been concluded that to monitor and control CoPQ in a company, it is important to start measure. Therefore, the company needs to start creating an awareness regarding what CoPQ is and how they affect the company. Hence, it is necessary to expand the horizon regarding the consequences in order to understand the chain of involved people and not only see the problem. Since the environment is changing, the framework needs to be continuously revised and adjusted to the prevailing environment and to identify new invisible costs or new incurred problems that need to be measured. Furthermore, as the framework uses generalizations and average standard costs, the framework cannot be completely reliable. Consequently, the average standard costs need to be changed and updated as the processes of the company are improved.

It is very important for the company that this is followed, since the measured CoPQ otherwise can be inaccurate. Whereas the measurements in incorrect, it will point at areas of improvements that are not accurate and money will be invested in unnecessary activities. It has been seen that the processes to solve problems are not fully standardized for all the different departments, this makes the work with CoPQ time-demanding and complex. Consequently, the company needs to use standardized processes when solving problems. In case the company would standardize their processes, the developed framework could be used in each department of the company, thus the complexity of monitoring CoPQ would decrease. Standardization of processes would further make the estimations and generalization more accurate, since the processes from different departments would look more similar and consequently not as rough estimates and generalizations need to be done. To refine the model and find new ways to interpret costs, the operators should be more involved in the work with CoPQ. Since the operators have valuable input in improvements of daily activities, a forum for continuous improvements can be created where the operators can participate. It also is important to communicate the importance of CoPQ and consequentially why it should be measured. By Creating an understanding of the importance, the likelihood of correct reporting increase. The more thoroughly the reporting are made, the more reliable the measurements.

To conclude, examining the Cost of Poor Quality allows the enterprise to identify, prioritize and monitor quality improvements. One way of saving costs is to spend money in the right place, by which is meant that spending more on prevention costs and appraisal costs early in the product life cycle lead to lower total Cost of Poor Quality. This means that by spending more money on prevention activities, the money spent on appraisal, internal failure, and external failure activities can decrease, leading to that a lower cost in total is spent on activities that is related to quality. As a conclusion for the whole work, it is perfect to mention the quality guru Deming's evergreen statement of 1982:

"Defects are not free. Somebody makes them and gets paid for making them."

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