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Development of QA/QC Setup for NOR delivery projects

Catalyst Deliveries, Wärtsilä

Thesis

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Thesis Abstract

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Supervisors: Tomi Ylikantola (Wärtsilä), Kimmo Kitinoja (SeAMK)

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This thesis is related to the development of Quality Assurance & Control (QA/QC) Setup for the Catalyst Deliveries in Wärtsilä, located in Vaasa, Finland. The purpose of the research conducted in this thesis was to form a specific comprehension of the risks involved within the delivery process and with it to steer the development of the QA/QC setup.

The main research process in this thesis to assess the risks in the delivery process was based on the Failure Mode and Effect Analysis (FMEA). To adopt a comprehensive methodology as FMEA, a pre-study and qualitative research was designed to compensate the resources otherwise required. The qualitative research in the form of the Quality Survey were planned to identify the risks, but also to recognize the general and individual needs and expectations. The quantitative research, supported by the qualitative research, was done to establish the basis and to determine how the quality inadequacies can be avoided when developing the conclusive purpose of this thesis, QA/QC Setup. The research was carried out within the Catalyst Deliveries and for its stakeholders participating in the delivery process. The data gathered from the qualitative interviews enabled the formation of the FMEA study by contributing insights from the operative project environment. The results from the FMEA study gave a direct indication of where the quality concern is most evident. The documented findings from the qualitative research were utilized when developing the required quality activity to reflect the desires and challenges recorded from the operative level.

Tailor-made QA/QC Setup for NOR delivery projects was created as an end result of this thesis. The setup presents the necessary activity, procedure and actions to secure the quality conformity within the delivery process. A separate project to implement the QA/QC Setup was announced after the completion of the development process and will go into the operation during the first half of 2014. The relevant information and additional development targets were generated to ensure the smooth implementation and seamless functionality of the QA/QC Setup.

Keywords: Quality, QA/QC, Failure Mode and Effect Analysis

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Tämä insinöörityö käsittelee laadunvarmistusmallin kehittämistä katalysaattorien toimitusprojekteihin. Kohteena oli Wärtsilässä toimiva Catalyst Deliveries, joka sijaitsee Vaasassa. Tutkimuksen tarkoituksena oli tunnistaa ja ymmärtää katalysaattorien toimitusprosessissa laatua vaarantavat haasteet ja riskitekijät. Tuloksia hyödynnettiin ohjaamaan laadunvarmistusmallin kehitystä vastaamaan asetettuja tavoitteita.

Tutkimusprosessi pohjautui vika- ja vaikutusanalyysiin (engl. FMEA), jolla toimitusprosessia koskevat riskit kartoitettiin. Esitutkimuksen lisäksi työssä suoritettiin laadullisia haastatteluita. Näiden perusteella vika- ja vaikutusanalyysiin muutoin tarvittavia resursseja voitiin kompensoida. Työ tehtiin Catalyst Deliveries -organisaatiossa ja sen sidosryhmille, jotka osallistuvat toimitusprosessiin. Tutkimuksen aikana kerätty informaatio riskeistä operatiivisessa ympäristössä mahdollisti riskianalyysin tekemisen. Vika- ja vaikutusanalyysin tuottamilla tuloksilla voitiin kehitystyö suunnata tarvittaville alueille.

Lopputulokseksi laadittiin räätälöity laadunvarmistusmalli kohteena olevaan toimintaympäristöön, jossa on kuvattuna tarvittavat toiminnat, menettelytavat ja tehtävät laadullisten vaatimuksien turvaamiseksi toimitusprojektissa. Työn valmistuttua, julkistettiin erillinen käyttöönottoprojekti, jonka tavoitteena on implementoida malli operatiiviseen käyttöön kahden ensimmäisen osavuosineljänneksen aikana vuonna 2014. Käyttöönottoprojektia varten, työssä tunnistettiin myös muita kriittisiä kehityskohteita, jotka tukevat laadullista tekemistä ja laadunvarmistusmallin saumatonta toimivuutta.

Avainsanat: laatu, laadunvarmistus, laadunhallinta, vikatila- ja vaikutusanalyysi

TABLE OF CONTENTS

Tables and figures

Abbreviations

QA/QC Setup	Quality Assurance & Control setup, a concept which combines these two areas of quality management.
SCR	Selective Catalyst Reduction, a technology which converts harmful NO_x molecules back to harmless H_2O and N_2 molecules by means of urea.
NOR	Nitrogen Oxides Reduction, a term adopted by Wärtsilä for its SCR Solution.
FMEA	Failure Mode and Effect Analysis, systematic technique to analyze failures and their effects.
FAT	Final Assembly Test, a procedure to inspect product conformity.

1 INTRODUCTION

The world’s leading internal combustion energy provider Wärtsilä has a portfolio of a complete range in engine auxiliary modules including Selective Catalytic Reduction (SCR) solutions. Wärtsilä has delivered SCR solutions since the 1990s, but in order to response to the increasing demand of emission and customer requirements, Wärtsilä began developing their own solution from which the first ones were delivered in the year of 2011. Catalyst Deliveries, part of Wärtsilä Corporation, is responsible for delivering SCR solutions. Wärtsilä’s desire to advance as a market leader, every product must fill the customer’s requirements especially in quality. This thesis analyses how Catalyst Deliveries can assure the fulfillment of the customer’s quality requirements within the delivery process by developing a QA/QC Setup.

The term QA/QC stands for Quality Assurance & Control, a concept which is currently being developed in Wärtsilä as well. The model combines these areas of the quality management into a single common end-to-end concept. The QA/QC program in Wärtsilä aims at unifying the variations between the businesses and to ensure that the defects are not passed to the customer. (Wärtsilä Compass 2013.)

The thesis consists of the relevant theoretical studies which form the framework of the subjects researched in the empirical part. The empirical part is structured around the quantitative research which is supported by the qualitative research. The purpose of the qualitative part was to identify the potential quality risks within the delivery process. The opportunity was used to document both the general and individual needs and expectations as well. The purpose of the quantitative part is to evaluate the criticality of a certain process based on its affects to the quality in case of failure.

The thesis begins by describing the background and main purpose why Catalyst Deliveries has a need for a quality setup. This is followed by an introduction to the Wärtsilä corporate environment including Catalyst Deliveries. The next focus is on understanding the theory behind the quality and its relation to the case. Then the thesis approaches to the research process and methods from which we enter into the empirical part.

1.1 Background

Catalyst Deliveries has set one of its main strategies to secure that customer expectations related to the quality, reliability, delivery time and cost will be fulfilled. Currently available procedures and activities do not adequately assure that these goals are met during the delivery process. Therefore a comprehensive setup to conform quality is required. Within Catalyst Deliveries, the present systematical QA/QC related activity occurs mainly during the Final Assembly Test (FAT), which is conducted before the shipment leaves to the customer (Appendix 1). The Final Assembly Test, although important in itself, does not provide sufficient guarantees ensuring quality during the whole delivery project. QA/QC related activity can be considered to be far more than inspecting the products at the end of the production line. In order to prevent any misaligned efforts, quality related activity must be broader. Furthermore, a corporate level strategy instructs to strive for a first time right -culture. Focus in this thesis is mainly in Catalyst Deliveries internal operative environment and its processes.

1.2 Research problem

How can Catalyst Deliveries assure that the quality according to the customer requirements will be fulfilled? What needs to be done and where in order to produce the evidence that the quality requirements are met? Further questioning can be done by asking; does Catalyst Deliveries provide enough resources for our stakeholders and internal customers to produce the quality to satisfy our common end customer? Therefore to be effective the problem is to find out which phases are essential and what is required to manage the potential risks concerning the quality, cost and time in a delivery project.

1.3 Research process and methods

In order to elaborate the comprehension of the situation, the following approach for collecting and valuing the information were used. The qualitative interviews from the stakeholders collaborating with the deliveries and from the personnel of

Catalyst Deliveries were the main method for collecting the raw untreated information. Another perspective was received from the customers in this case the business units. The preparations for the qualitative research were done by accumulating greater knowledge from the project operative environment and each interviewee's specific relation to the delivery project in form of the pre-study. Furthermore, the corresponding process steps were benchmarked from similar areas within the corporate to gain a better impression of the potential challenges and opportunities. The reason for the qualitative approach was to increase the state of knowledge and pushing insights (Mariampolski 2001, 9).

The quantitative analysis, more specifically Failure Mode and Effect Analysis (FMEA), followed for the delivery process by adding values to each relevant process step. The profound information collected from the qualitative interviews was exploited to conduct a valid analysis. The combination of the qualitative and quantitative researches was utilized to triangulate the in-depth findings from the data collection into specific parts of the delivery process. This supported the realization of the required quality measures. The researches formed the foundation for the development of QA/QC setup. Based on the objective, the target environment and the given time schedule, these methods were considered to be the most effective. FMEA was chosen, due to its being one of the most important early preventive actions in the system, design, process, or service which will prevent failures and errors from occurring and reaching the customer (Stamatis 2003, 21).

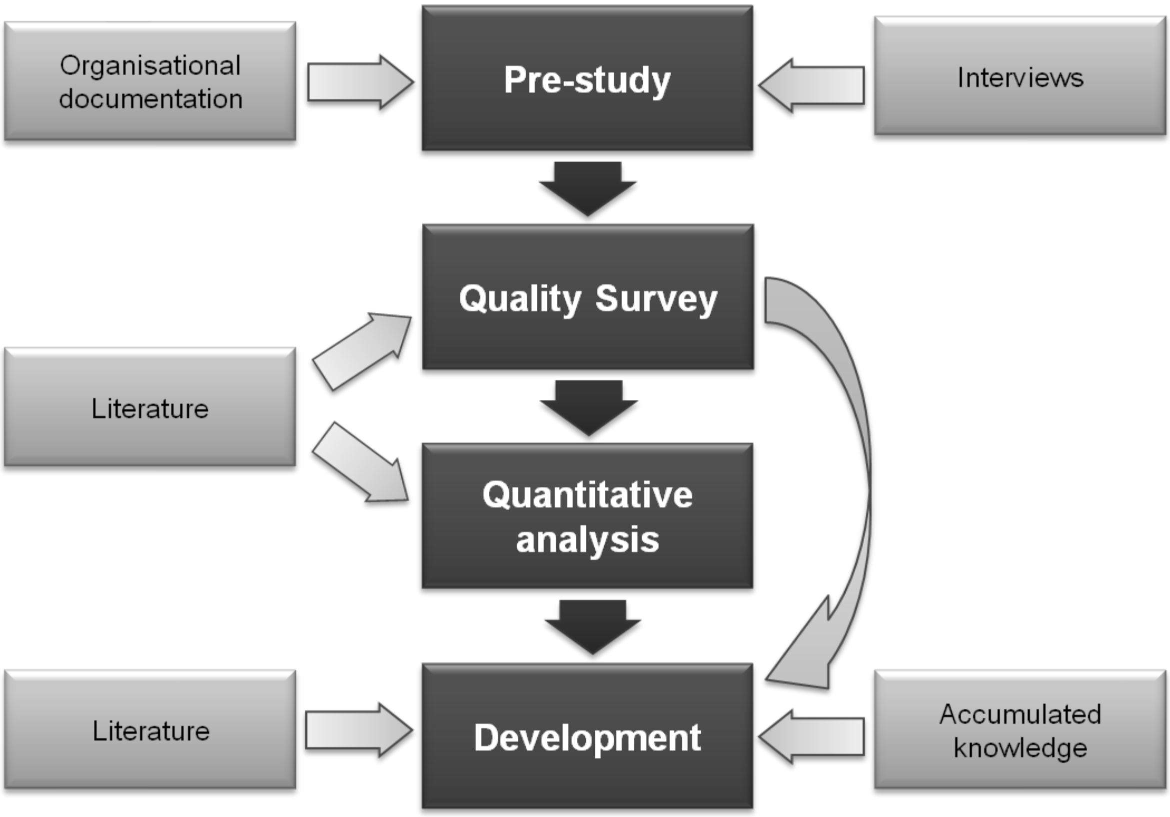

Figure 1. Functionality of the research and development process

1.4 Structure and scope of the thesis

Structure of the thesis is divided into three main segments, first being theoretical background examination regarding the quality and research methods. Second segment deals with the empirical research process where the focus for the development is determined. Finally after the findings, thesis addresses the development of the quality setup. The core focus in this research was in Catalyst Deliveries internal process environment during a NOR delivery project. Concerning the immensity of the theme and activity involved, certain entities not feasible for the objective were left out. The scope was designed by identifying the most essential and focusing on delivering concrete value adding results. Thesis will not concentrate directly on developing the contents of documents, manufacturing process or design process, nevertheless information from these areas were used in developing the QA/QC Setup.

1.5 Objective

Catalyst Deliveries' strategy is aligned according to Wärtsilä's utmost ambition to deliver value adding solutions to its customers. Objective for this thesis ascends from the target to secure the fulfillment of customer expectations related to quality, reliability, delivery time and cost (Wärtsilä, Catalyst Deliveries, 2013). This means developing a comprehensive quality measures for the Catalyst Deliveries, which improves not only performance but most importantly achieves assurance from the quality conformity.

Therefore, the purpose is to ensure that during the delivery process deviations from optimal heading do not happen, which might cause non-conformity. The approach towards the objective comes from investigating and analyzing the quality challenges with the qualitative and quantitative researches, and utilizing all documented information and knowledge to develop a setup where required quality activity is defined. Furthermore, the product offered by Catalyst Deliveries is still over going final stages of development. Pilot projects are in progress where product maturity is tested. Comprehensive quality setup can substantially reduce or even eliminate potential quality challenges faced by the product and delivery process.

1.6 Theory foundation

The theory framework concentrates on the essential areas of the quality regarding the objective. Understanding the principle from the theory behind quality as a definition is necessary as well quality management in form of quality assurance & quality control. Quality related theory is extended to risk management and identification which are fundamental for the research process. Theory from qualitative interviews follows which leads to into examining the quantitative analysis where substantial focus is centered.

2 WÄRTSILÄ - CATALYST DELIVERIES

Wärtsilä is a global leader in complete lifecycle power solutions for the marine and energy markets. Wärtsilä group consists of following business units: Power Plants, Ship Power and Services. These business units are supported by PowerTech, which is accountable for ensuring industry leading technologies and production capabilities for each of the business units to excel in their specific areas. (Figure 2.)

Wärtsilä's net sales within year 2012 were 4.7 billion euro which led to operating result of 515 million euro. Personnel within Wärtsilä were 18,887 at the end of year 2012. This adds up to 114 nationalities in 70 countries which are located in 160 places. Wärtsilä's core business is to offer diesel and natural gas engines, propulsion systems, power plant solutions and all related services and original spare parts to its customer. Wärtsilä has a wide range of solutions to offer in its engine portfolio starting from low- and medium-speed diesel engines to gas, dual- and multi- fuel engines. Already provided engine solutions totals over 180 000 MW in market with countless variations of installations throughout the world. (Wärtsilä Compass 2013.)

Catalyst Deliveries is part of the PowerTech and operates in Delivery Centre Vaasa (DCV). DCV is responsible for assembling delivering engines and generator sets sold by Ship Power and Power Plants, including machining of core components. DCV is the main R&D centre for 4-stroke engines as well. The centre is supported by technology units for 4-stroke engines in Trieste, Italy, Turku, Finland and Bermeo, Spain. Within DCV, Catalyst Deliveries is responsible of supplying catalytic emission solutions for business units Ship Power and Power Plants. (Wärtsilä Compass 2013.)

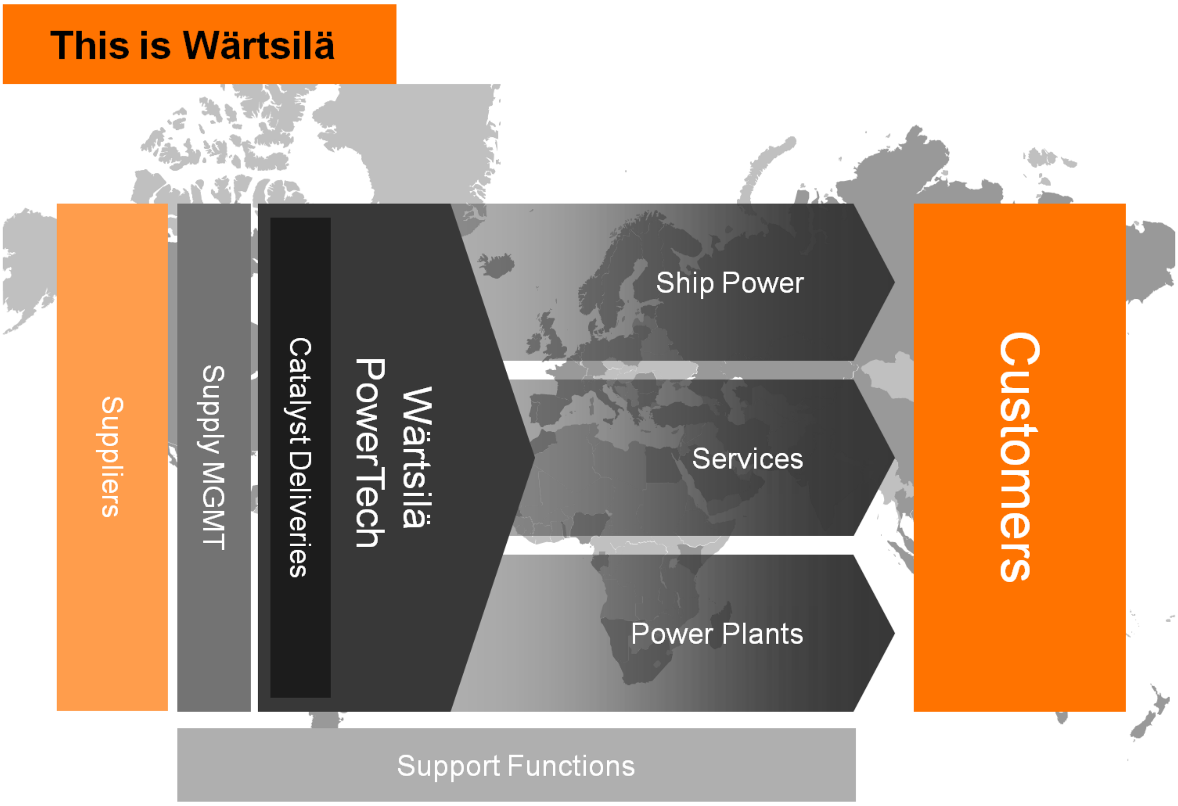

Figure 2. Illustration from Wärtsilä Corporate structure

2.1 Introduction to NOx emission control

The major portion of the nitrogen oxides (NOx) are generated in the high temperature spots during a combustion by the reaction between the atmospheric nitrogen and oxygen. Nitrogen oxides cause eutrophication, smog, acidification and formation of harmful lower atmosphere ozone in the presence of volatile organic compounds (VOC) and sunlight. In order to avoid harmful effects from realizing several standards and regulations have been declared by various organizations and agencies. Organizations are mainly divided controlling emission depending whether engine is for marine or for power plant application. One of the most prominent agency is called International Maritime Organization (IMO). It is an agency of the United Nations which has been formed to promote maritime safety. Agency has introduced exhaust gas emission regulations to the marine industry which are better known as IMO Tiers. (Wärtsilä Environmental Product Guide.)

The first IMO Tier 1 NOx emission standard entered into force in 2005 and applies to marine diesel engines installed in ships constructed on or after 1.1.2000 and prior to 1.1.2011. The IMO Tier 2 NOx standard entered into force 1.1.2011 and replaced the IMO Tier 1 NOx emission standard globally. The Tier 2 NOx standard applies for marine diesel engines installed in ships constructed on or after 1.1.2011. The IMO Tier 3 NOx emission standard will enter into force from 1 January 2016, but the Tier 3 standard will only apply in designated emission control areas (ECA). So far, the North American coasts and the US Caribbean Sea has been defined as ECA. The IMO Tier 2 NOx emission standard will apply outside the Tier 3 designated areas. NOx limits are dependable on the engine speed as shown it the figure 3. (Wärtsilä Environmental Product Guide.)

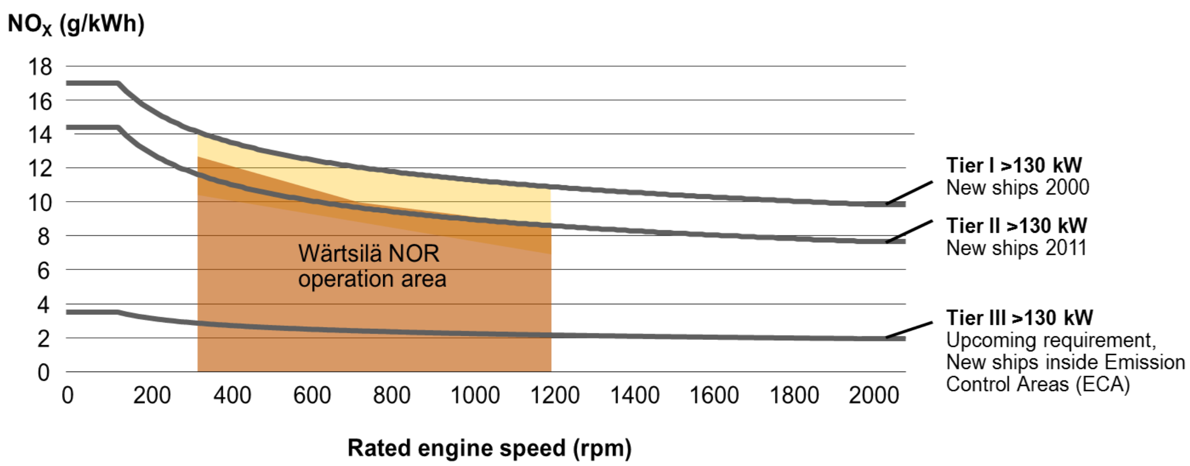

Figure 3. Emission TIER levels (Wärtsilä Compass 2013)

2.2 NOR technology and system

Wärtsilä has adopted the term NOR for its catalytic emission solution which comes from Nitrogen Oxygen (NOx) Reduction. The solution is based on the Selective Catalyst Reduction (SCR) technology. The SCR technology reduces the level of nitrogen oxides from the exhaust gas by adding urea water mixed reducing agent into the exhaust stream before the catalyst elements. The water evaporates from reducing agent as it is injected into the hot exhaust gas. The high temperature also decomposes the urea ($(NH_2)_2CO$) into ammonia (NH_3) and carbon dioxide (CO_2):

(1) $(NH_2)_2CO + H_2O \rightarrow 2NH_3 + CO_2$

Exhaust gas NOx emissions are transformed into molecular nitrogen (N_2) and water (H_2O), as they react with the ammonia on the catalytic surface:

(2) $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

(3) $6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$

The catalytic elements are located inside a metallic casing structure called reactor. The end products of the reaction are pure nitrogen and water, i.e. major constituents of ambient air. The efficiency of the catalytic reduction depends on a number of factors, including the dosage of the reducing agent, the amount of catalyst elements and the exhaust gas temperature. (Wärtsilä Environmental Product Guide.)

2.2.1 Reactor and catalyst elements

For each engine, a single reactor is installed into the exhaust gas pipeline. The reactor is a steel casing which contains the catalyst elements. The catalyst elements are located in element frames inside the reactor. The brick-shaped SCR catalyst elements have a honeycomb structure to increase the catalytic surface area. Vanadium pentoxide (V_2O_5) is used on the surface of the elements to enable the catalytic reaction. NOx reduction capacity of the SCR system is maintained by changing the catalyst elements at regular intervals. Soot blowing prolongs the lifetime of the catalyst elements by eliminating the build-up of solid matter on the front surface of the catalyst elements. (Wärtsilä Environmental Product Guide.)

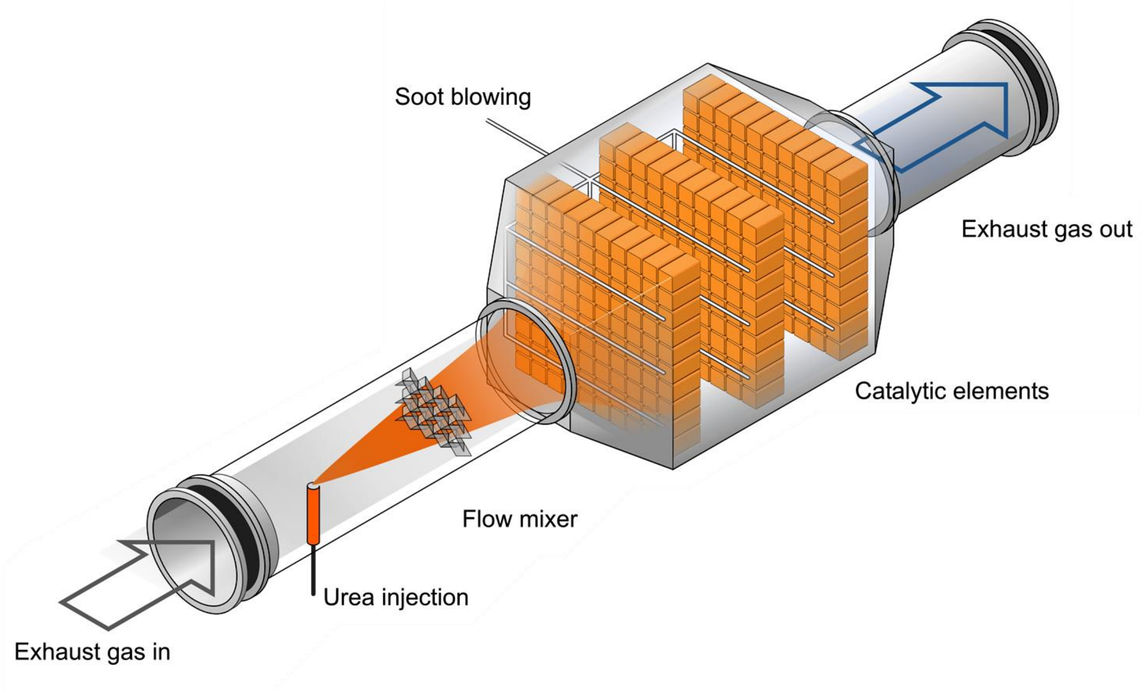

Figure 4. Functional principle of NOx reduction with SCR technology (Wärtsilä Compass 2013)

2.2.2 Injection Unit / Mixing Unit

The urea injection unit is located on the exhaust gas pipe before the SCR reactor. Each engine has one injection unit and reactor in the exhaust gas line. After the injection of the reducing agent, the exhaust gas flow passes through a mixing pipe, where urea to transforms into ammonia and mix homogeneously before it reaches the catalyst elements. (Wärtsilä Environmental Product Guide.)

2.2.3 Auxiliary modules

The urea pump unit supplies urea to the dosing system and maintains a sufficient pressure in the urea lines. The main components of the unit are electrically driven pumps, which are mounted on a frame together with the necessary accessories. Suction filters protect the pumps and the downstream equipment from impurities.

The dosing unit regulates the correct urea dosing rate for the injection system and adjusts the urea flow accordingly by a control valve. The components in the unit are mounted inside a cabinet, forming a compact module. In addition to the equipment for reducing agent, the dosing unit includes components for compressed air regulation. (Wärtsilä Environmental Product Guide.)

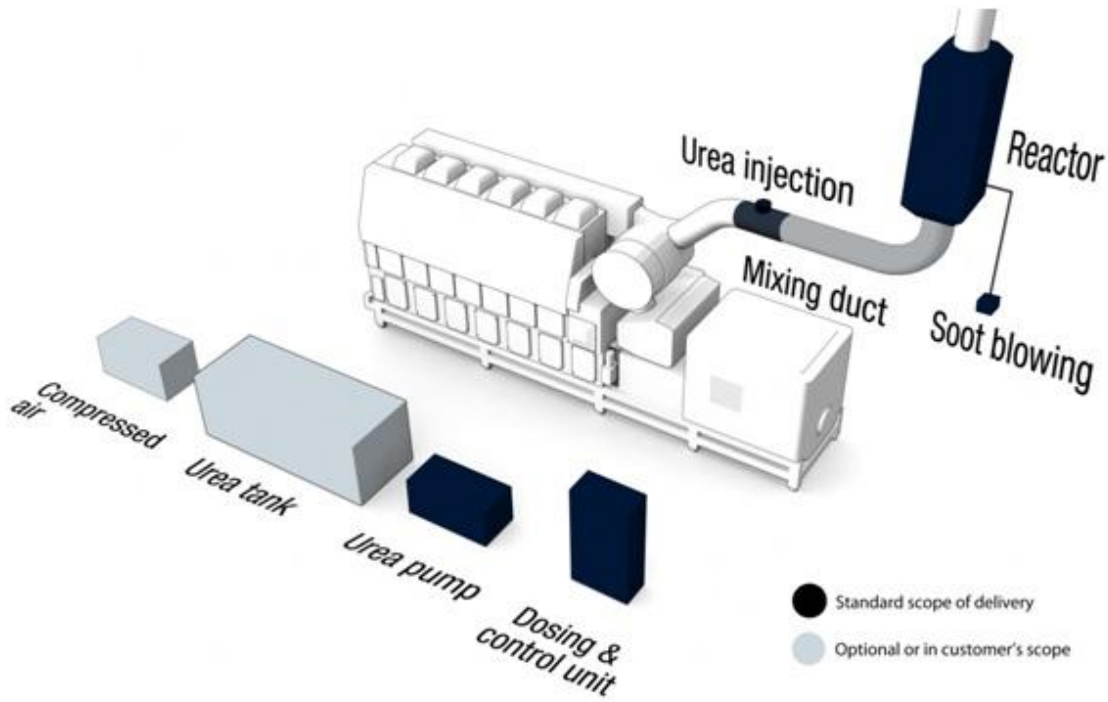

Figure 5. Illustration of Wärtsilä NOR system (Wärtsilä Compass 2013)

3 QUALITY IN BRIEF

Definition of quality can be explained in a variety of different ways but one way or another they come together by ensuring customer satisfaction with as little cost as possible i.e. “fitness for use”, a phrase developed by Joseph M. Juran (Gryna 2001: 4). Fitness in this case means the quality character determined by the customer’s requirement, whether it is, for example, quality of design or quality of conformance (Juran 1962, 2;4).

Ability to fulfill these requested characters lies in understanding what needs to be provided. Potential quality inadequacies can be caused by two major issues. Customer requirements are not understood which leads into deviating results from the customer’s original desire, and/or there is an inability to realize how requested requirements, according to customer’s desire, can be secured. Furthermore, driving as lean process combination as possible while maintaining the previously agreed quality standards. These can be considered be the result of an improper quality activity, whether it is in marketing, management, engineering, manufacturing or when providing a service. (Gryna 2001, 314-319.)

When previous points would not be an issue, it is important to acknowledge that output of a customer may have insufficient information or requirements are inefficiently presented, which leads into the same end result. Clarifications are often left with the responsibility of the provider. Lack of reconciliation may lead to uncertainties, whether each corresponding participant shares the same exact vision. “In order to assure quality, it is therefore necessary first to ensure that all the requirements for the total presentation are known”. (Stebbing 1989, 2).

Gryna explains that customer satisfaction and loyalty is gained by product features and freedom of deficiencies. In order to elaborate, product features correlate the level of quality desired, thus higher price can be implemented. Lack of deficiencies means direct cost efficiency through reduced rework, scrap, failures, defects and any other quality non-conformances. These two components together reflect how quality can be defined and efficient combination of these components leads to the ultimate purpose of quality – profit. (Gryna 2001, 6.)

Traditional quality activities are considered to be concentrated into manufacturing, while the modern approach to the quality attainment requires all activities within every function and organization to be encompassed. External customer is the primary importance which can include first of all the ultimate end customer, but also stakeholders, suppliers, partners and any other intermediate processors. (Gryna 2001, 4-5.)

Timo Hannukainen (1992, 11) states that definition of quality can be divided commonly into four categories:

- Product based (Features)
- Action based
- Customer based
- Value based

Hannukainen explains that quality based on the product can be measureable. It is a combination of features within the product which are distinctively specified. The quality non-conformance stands out as a deficiency of a certain feature or attribute. The action based quality relies in conforming requirements and providing proactive means to execute first time right. This leads to cost efficiency by preventing problems before they appear. Customer based quality is about fulfilling the expectations. Service and the experience received from the product affects the customer satisfaction, whether it fulfills the expectations or not. The value based quality means relation between quality and price. Expensive product with comprehensive features is not quality product according value based quality thinking because it would available for limited people only. (Hannukainen 1992, 11.)

3.1 Quality Management

Conception from the quality can be based on the relation to the product or service whether it is management or operator. Each person should be responsible of the quality within a company, although responsibility of certain quality aspects may vary. The operator who conducts the process is responsible from the non-conformance only when following three terms are effective (Gryna 2001, 442):

- Quality requirements must be clear and understandable
- Feedback must be received to level the performance
- There must be a chance to attune the performance i.e. corrective actions

The management is responsible to ensure that these terms are met and thus provide the operator to self-control the achievement of quality objectives. Major concern lies in organization, communication and coordination, whether previous aspects are acknowledged or not. Appropriate quality comprehension for management and superiors are essential to steer the direction to quality attainment, especially when most important quality issues are cross-organizatorial. Management responsibility is to provide resources to empower the operator with the quality responsibility to execute his task correctly. (Juran 1962, 2;13, 2;21-22.)

Quality objectives and measurements must correspond to each action according to its position within the organization. Different segments within the organization interpret the quality objectives differently, and therefore can influence into the overall transparency and awareness of required quality goals. Upper management must reflect the corporate quality targets in such a way that is can be adopted comfortably by the operator. Usually the reflection is done by the middle management which acts as an interface between these two segments, thus obliged to be bilingual. (Gryna 2001, 222.)

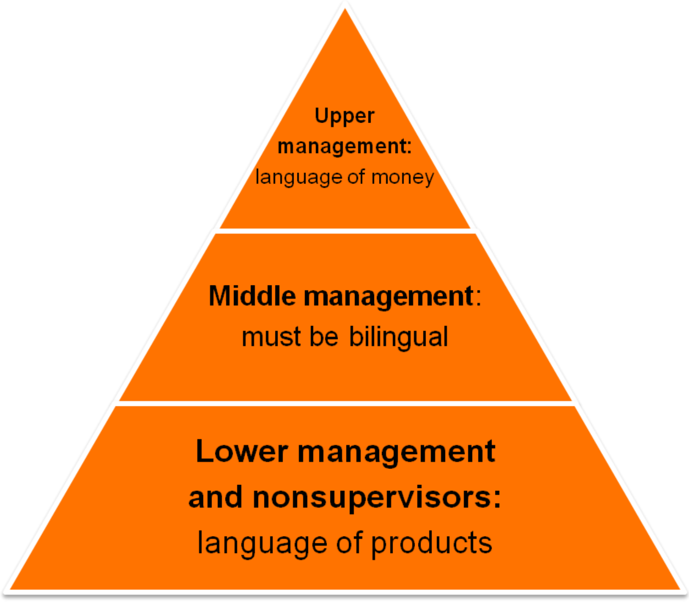

Figure 6. Common languages in the company (Gryna 2001, 223)

In this thesis, the definition of the quality assurance stands for the activity of providing facts to demonstrate that the quality requirements will be met. It is an activity which aims to establish a state of confidence from the quality conformance based of factual information. Confusion for the term derives from common naming of a department as Quality Assurance, which consists of quality management activities such as quality planning, quality control, quality improvement, quality audit, and reliability (Gryna 2001, 659).

The concept of quality assurance functions proactively to provide means to avert quality problems from realizing. With throughout implementation of quality assurance and practiced constantly in everyday activities with support from senior management will enable succeeding in getting it “first time right”. ISO 9000 defines quality assurance as “a part of quality management focused on providing confidence that quality requirements will be fulfilled.” Decisions based on lack of evidence can cause false confidence for the following operation. Therefore, assumption based decisions can cause chain reaction within whole process. “The assurance comes from evidence – a set of facts”. (Gryna 2001, 659.)

When regulation is introduced to measure the quality performance of a process, it can be called quality control. Quality control is closely integrated into the process, where actual performances are compared against requirements, specification and standards, and in case of difference trigger corrective actions. (Juran 1962, 2;11.) According Gryna (2001, 132) quality control usually locates in following junctures:

- At the change of jurisdiction meaning where movement happens between companies of major departments
- Before embarking on an irreversible path
- After creation of a critical quality
- At dominant process variables
- At natural windows for economical control

Figure 7. Illustration from the functional quality management structure

3.2 Risk management and identification

The objective of risk management is to achieve better project quality outcome regarding schedule, cost and performance by identifying risks and ensuring adequate mitigation of significant effects. It involves many aspects from accumulating feedback to monitoring and reviewing processes. Risk management process is consistent ongoing activity which requires integration within the project management processes and functions. Risk management, therefore is not entirely own stand-alone process, rather than part of normal project management procedures, and responsibility of each stakeholder and participant. (Cooper, Grey, Raymond & Walker 2005, 13-14.)

Figure 8. Critical Success Factors for Project Risk Management (Practice standard for Project Risk Management 2009, 6)

“A risk cannot be managed unless it is first identified” (Project Management Institute 2009, 25). The process of risk identification starts by establishing context where the structure for risk identification and assessment is developed by familiarizing the target environment and specifying the objective. Inputs include key project documents, such as execution plan, schedule, scope, engineering designs and studies as well any other relevant documentation to the project. Identifying the risks follows where purpose is to ascertain potential outcomes which might endanger the project objective. Risk identification requires comprehensive approach to avoid risks to be left unnoticed. Preferred method to govern each potential risk is appropriately structured brainstorming. The purpose of brainstorming is not to limit the identification process with such mechanisms as predefined checklists or questionnaires. It aims to assess potential conditions interactively and creatively without judgment. Information utilized in the process may include historical data, theoretical analysis, empirical data and analysis, opinions and concerns of the project team and stakeholders as well other experts. Other risk identification techniques can be examination of other similar experience and activity as well post-project completion reports which can be included in the brainstorming process. Although, best source of information are usually the members of the project team, however additional data may turn out to be useful when managing risky environment. Best practices and user experience including benchmarks can direct focus where routinized way-of-work may cause potential risks to be overseen. Further support can be derived from relevant published literature and research reports, including appropriate theory regarding failure modes or equipment reliability. (Cooper et al 2005, 16, 38-39, 43.)

Valid, as relevant, comprehensive, accurate and timely information as possible, is essential, in order identify risks and understanding the likelihood, and the consequences of each risk. Project Risk Management Guidelines (2005, 38) suggests following techniques depending on resources to be utilized in the risk identification process:

- Brainstorming
- Examination of local and overseas experience with similar activity and projects including post-project completion analysis reports
- Surveys and questionnaires
- Interviews and focus group discussions

4 RESEARCH METHODS

4.1 Qualitative interviews

One of the main ways that an organization can begin to understand the needs, values, perceptions, and expectations of its employees is through carefully planned survey feedback program, rather than assuming what might be the situation (Bowditch & Buono 1982, 11). Quality Survey can be regarded as quality audit but without limitations. Audit may leave unexpected issues unraveled whereas survey enables the discovery of alarming situation for which there exist no present alarm signals. (Juran 1962, 21-13.) Quality Survey generally means a broader assessment of quality, including finding out opportunities and employee perceptions on quality, which cannot be covered using a questionnaire with predefined criteria (Gryna 2001, 676).

Considering the immense broadness of the theme involved, a diverse approach regarding Quality Survey is required to achieve as much valuable information as possible. Mariampolski states that exploratory approach intends to expand the researchers' current state of knowledge, as well as generate ideas. Explanatory approach presumes findings to provide profound and provocative insights into needs, behaviors and feelings. (Mariampolski 2001, 23.)

Qualitative research applies when a strategy is to go beneath the surface. It can yield a holistic overview of customer behavior which provides insights into emotions and motivations. Most importantly, the achievement of understanding happens in real time through a personal confrontation with respondents. Insights are not channeled through graphs and statistical tables but evolve as researchers confront actual customers. (Mariampolski 2001, 55.)

For all qualitative researchers, validity of documented results plays a key role whether the research is successful or not. Validity comes from the ability to produce correct answers. Answer can be considered to be correct, when process of engagement between researcher and different respondents produces same answers repeatedly with reasonably similar measures. The approximation from target personnel is achieved by the saturation point where all variations within segment have been considered or when the investigator has reached redundancy after receiving identical responses among the target environment. (Mariampolski 2001, 57-58.)

4.2 Quantitative analysis

“Suggestions for improvement can be found easily; the problem rather is to identify the most important ones so as to be able to make a choice and to assign priorities” (Werther Jr, Takala & Sumanth 1999, 4). This can be thought further, by not centering into identifying the importance of an improvement, but rather into identifying the gravity of a certain process based on the potential failures it faces and use this to focus the development. Quantitative analysis can provide means to focus into the most essential by using a numerical data from either statistical records or analytical study. It is used when phenomena of an objective requires enumeration or probabilistic projections for decision making i.e. to assign priorities. (Mariampolski 2001, 24.) Objectives in the thesis can be considered processes which probabilistic projections are defined with a risk analysis called Failure Mode and Effect Analysis.

W. Edwards Deming explained that when deviations within a process are reduced or eliminated, it will lead to better quality and cost efficiency. His philosophy recommends utilizing statistical methods and systematically progress to improve quality. Therefore, quality involves continues ongoing recognition of the difference to eliminate “special causes” while controlling normal variation. (Hallikainen 1992, 19-20.) Deming’s philosophy can be seen supporting a quality methodology such as Failure Mode and Effect Analysis where risks are systematically being pursued to enable mitigation and eventual elimination of risks which leads to better quality and customer satisfaction.

4.2.1 Failure Mode and Effect Analysis

Failure Modes and Effects Analysis (FMEA) is a quality related tool associated with risk management and reliability analysis. Conclusive purpose of the FMEA is to fulfill customer satisfaction by managing risks from forestalling ideal execution. Failure Mode and Effect Analysis is an extensive method to assess how the failure modes both existing and potential can be prevented from affecting the end user. It provides a comprehensive overview from the target environment, whether it is system, design or process. The FMEA approaches the objective by determining which risk has the greatest concern, and what kinds of actions are needed to prevent the problem before it arises. Properly conducted FMEA produces valid framework for decision by focusing on evaluating risks and their effects. This enables significant cost advantages when implementing risk-mitigating measures. American Society for Quality defines “A Failure Mode and Effect Analysis as an engineering technique used to define, identify and eliminate known and/or potential failures, problems, errors and so on from the system, design, process and/or service before they reach the customer”. (Wärtsilä Compass 2013.)

Failure Mode and Effect Analysis was first used in aerospace industry which can be considered to be more safety and quality sensitive than most other industries. There it was utilized in the mid-60’s to assess safety issues. (McDermott, Mikulak & Beauregard 1996, 3.) From there its effectiveness was recognized by various areas of industries, where it was further developed to correspond to their specific needs. Nowadays FMEA’s can be applied into several diverse environments and objects as well started in various different development phases. Stamatis (2003, 24) specifically recommends starting an FMEA:

- When designing new systems, designs, products, processes, or services
- When change is directed to these entities regardless of reason
- When new applications for these entities are found
- When improvements for these entities are considered

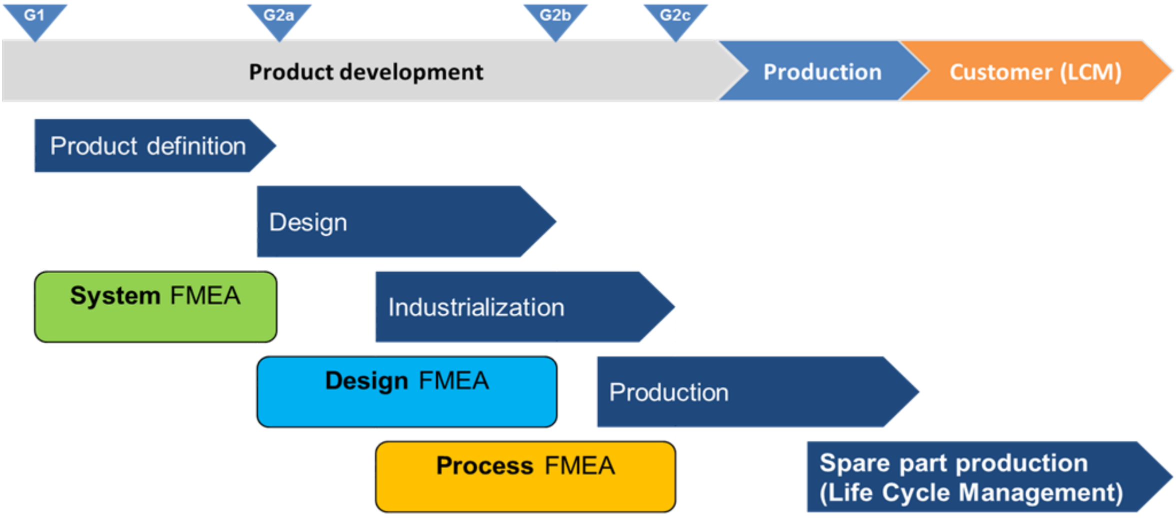

Figure 9. Usage of FMEA in product development (Wärtsilä Compass 2013)

The international quality standards suggest adopting the usage of FMEA's as a part of company's quality management. For example, QS-9000 [ISO/TS 16949] standard clearly directs to use FMEA to improve defect prevention rather than defect detection (McDermott et al, 11). This can be also considered the case when developing the QA/QC Setup, where the objective is to acknowledge what needs to be done and when, to prevent quality risks from happening. FMEA is not limited to only providing means to prevent risks from occurring. Due to its comprehensive methodology, it offers many other beneficial implications when utilized. Guidelines for Failure Mode and Effect Analysis by Dyadem (2003, 6;2) lists following benefits for conducting FMEA Study:

- Ensures that the potential failures and their effects on the system have been identified and evaluated, consequently helping to identify errors and define corrective actions;
- Provides a means for reviewing product and process design;
- Helps to identify critical characteristics of the products and processes;
- Improves productivity, quality, safety and cost efficiency;

- Helps to determine the need for selecting alternative materials, parts, devices, components and tasks;
- Assists in documenting the reasons for changes;
- Provides a means of communication between different departments;
- Helps to increase customer satisfaction;
- Improves a company's image and competitiveness.

It is increasingly more essential to focus on challenges which can provide the most value when improved. Task, which can be difficult by itself, let alone while operating in a complex business environment. Development has to happen with as effective use of resources as possible and furthermore provide means for continues improvement. Throughout implementation of FMEA would enable both, solid foundation for development, as well means for continues improvement. Periodical follow-up and an update from the FMEA can allow the effective control of corrective measures.

4.2.2 Functionality of FMEA

The FMEA functions systematically to identify and assess failures which may obstruct the fulfillment of intended result. It can be considered as a methodological tool where reliability is examined and discovered risks are then quantified and calculated to result a decision. The functionality of FMEA can be understood to be ultimately a priority assessment which is contributed from three factors: (Stamatis 2003, 28).

- Severity – Value based on how serious is the effect caused by the failure
- Occurrence – Value based on the probability how often the failure is expected to occur
- Detection – Value based on the probability to detect failure before causing the effect

It is important to understand the difference of these factors to produce valid results. For example, when a certain minor objective does fail frequently, it does not add value to the severity of the failure, only the occurrence. Factors can be evaluated in many ways, either qualitatively or quantitatively (Stamatis 2003, 28). The decision framework requires failures to be viewed from three different perspectives which are; failure mode, failure effect and failure cause. To elaborate more specifically:

- Failure mode is a way in which the objective can fail to deliver the intended functions or requirements. It can be existing, potential or multiple different ones.
- Failure effect refers to the outcome of the failed function. The magnitude of the impact caused by the failed function.
- Failure cause implies to the reason of the failure, an indication to the source of the failure.

In order to identify the previous entities, it is essential to understand the intended use or purpose of the object being assessed. The Identification of the effect provides the means to evaluate the seriousness of the failure, whereas the identification of the cause supports defining occurrence. The detection is defined by the controls available to notice the failure. The values do not have any standard range, although ranking from 1 to 10 is widely recommended, because it provides an ease of interpretation, accuracy, and precision in the quantification of the values. (Stamatis 2003, 30.) The values are multiplied, which establishes the notification of the high-risk priorities and the effective assignment of resources for corrective actions to reduce or eliminate failures (McDermott et al 1996, 13-14).

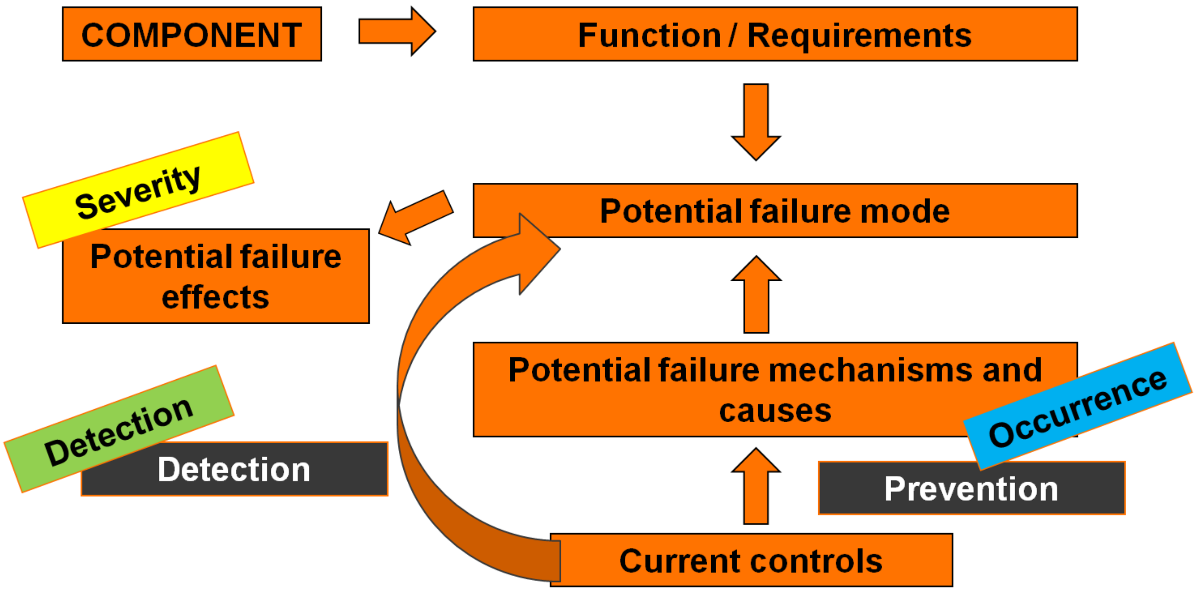

Figure 10. Illustration from the preventive approach FMEA development flow (Wärtsilä Compass 2013)

Although, the FMEA is commonly thought to be utilized for material and equipment failures only, it can be used to assess human failures, performance and software failures just as well (Guidelines for Failure Effect and Analysis 2003: 6-1). This means that there is no single format of FMEA. It can be rather considered to be adopted by the organization according to its needs and requirements. Nevertheless, the following information should be addressed while conducting a FMEA (Wärtsilä Compass 2013).

- Functions, requirements, and deliverables of the product or process being analyzed,
- Failure modes when functional requirements are not met,
- Effects and consequences of the failure mode,
- Potential causes of the failure mode,
- Actions and controls to address the causes of the failure mode, and,
- Actions to prevent occurrence of the failure mode.

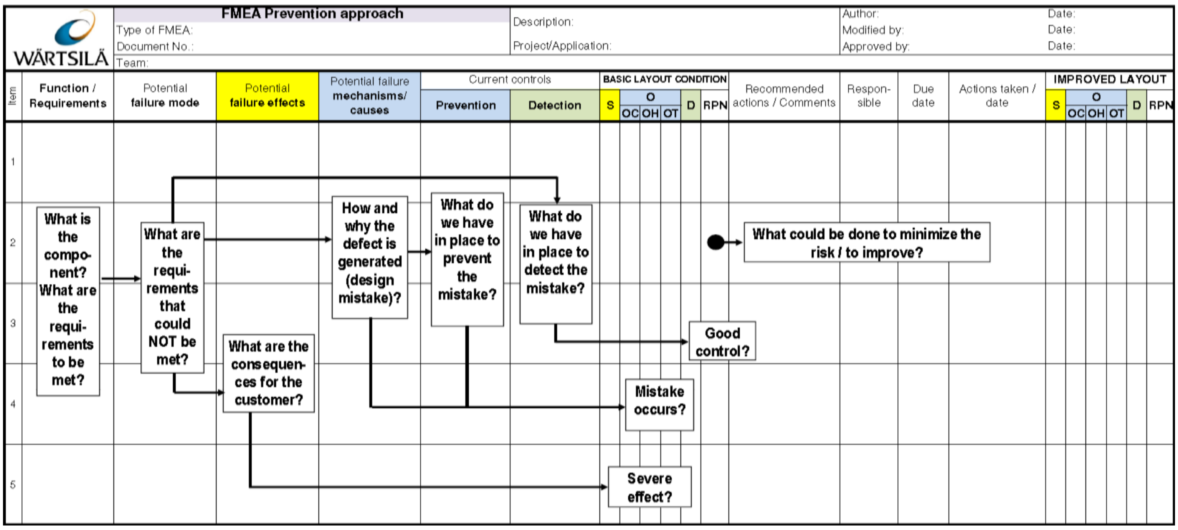

Figure 11. Preventive approach FMEA worksheet (Wärtsilä Compass 2013)

4.2.3 FMEA Team

Considering the immense broadness of the activity involved with the assessment, the FMEA demands preparations, in order to execute a successful analysis. Conducting a comprehensive FMEA in an individual basis can be potentially overwhelming. Execution of the FMEA in a complex environment with many aspects can be time consuming, therefore a target specific team is recommended to be assembled. Team should be cross-functional, multidiscipline and the members of the team should be willing to contribute. (Stamatis 2003, 36.) The FMEA teams are usually group of four to six members, minimum size being the number of different areas affected by the FMEA, for example engineering, manufacturing, technical service and so forth. The customer of the process, whether internal or external can add another unique perspective. The management should select leader for the team who has the responsibility to coordinate the FMEA progress including:

- Arranging and facilitating the meetings
- Providing necessary recourses
- Steering the process to the completion of the FMEA

Person with a background of being a process expert can have a tremendous impact in the FMEA process. In many ways he or she can be a real asset to the team. However, an expert can also influence negatively on the FMEA process if improvements are directed into where the person has invested time and personal integrity. The members with a close contact to the object being assessed can provide valuable insights, but may still potentially overlook some obvious issues. Unbiased perspective and contribution of transparent ideas can be generated by members who have various levels of familiarity to the object. Extensive training about the FMEA is not required, when the member possess problem solving abilities and experience. Still, it is essential for the members to have basic knowledge from the FMEA and as well team work, i.e. consensus-building techniques, brainstorming, etc. Experienced team leader familiar with the FMEA can guide the members through the process. (McDermott et al 1996, 15 – 18.)

4.2.4 Process of FMEA

As an engineering technique, the FMEA is a systematic process to identify potential, and to recognize the causes and impacts of the potential failures so that the residue from the failure can be averted. As stated before, there is no single or unique process for the FMEA, although lack of proper preparations can effect dramatically to the effectiveness of the process. The preliminary preparations should start from when the FMEA is being considered to be utilized. At this stage defining of ground rules can facilitate the FMEA process tremendously. Guidelines for Failure Mode and Effect Analysis (2003, 2;10) explains using following questions to define the boundaries of the study:

- What are the aspects (analysis, recommendations for improvement, implementation of improvement) covered in the FMEA study?
- How much resources are available?
- What is the deadline?
- What is the scope of the FMEA?

The management is usually responsible for defining the boundaries, while team leader determines the scope. The definitions are important to be done before the project starts. This will allow the team to function without problems or conflicts. (McDermott et al 1996, 21.) Every team member should have an opportunity to get fully familiarized with the scope of the study and if necessary brought up-to-speed with further clarifications. Defining the scope can be considered the gateway to the first step of the FMEA analysis process which commonly includes following ten steps. (McDermott et al 1996, 28-44.):

- Step 1: Reviewing the process

The purpose is to ensure the understanding from the situation by utilizing explanatory blueprints from the process or product. Process flow chart, functional blocks, technical drawings, design specification and other related data as complaints, warranty claims, statistical records, etc. can assist the identification of the essential activities from the target environment, as well connections between the departments. Physically experiencing the process or seeing the actual product can further help familiarizing the purpose of the target. Deeper knowledge can be discovered by an expert explaining the function. The system should be broken down into appropriate sizes, which fits for the analysis. Items too small can lose the sense of analysis and cause excessive repetition as where too large items might cause confusion and handling difficulties.

- Step 2: Brainstorming potential failure modes

The purpose is to come up potential failure modes which could affect the product or process. The elements can vary depending on the target for example people, methods, equipment, materials and the environment itself. The data of failures are categorized then accordingly. Data collection and the identified failures are the source of listed failure modes in the FMEA.

- Step 3: Listing of potential failure effects

The identified failures are listed to the FMEA worksheet for the evaluation. Objects and items without any severe concern from risks can be discarded from the scope to facilitate the evaluation process. Team examines the effects of each listed failure based on gathered knowledge and the competence of the team members. Team must be throughout because this step is essential in order to produce valid end result.

- Step 4 & 5 & 6: Rating severity, occurrence and detection value for each effect

The value analysis for each factor must correspond to the descriptions attached to each number. The numbers for each factor can range from one to ten as previously mentioned. Number one reflects to the lowest concern, whereas ten describes the most serious non-conformance. When valuing the detection number, ten can for example mean that there is no detection of any kind for the failure. The failure when occurred will reach the customer with nobody having chance to realize it. In the severity, ten can mean an absolute certainty that failure causes noncompliance with customer requirements. Occurrence can be based on statistical study or estimation from the probability. The value ten can mean a very high chance for the failure to occur. The scale must be clear and concise for each number in every factor in order to avoid confusion among team members. The scale can be defined separately for each target environment to which industries develop suitable criteria’s.

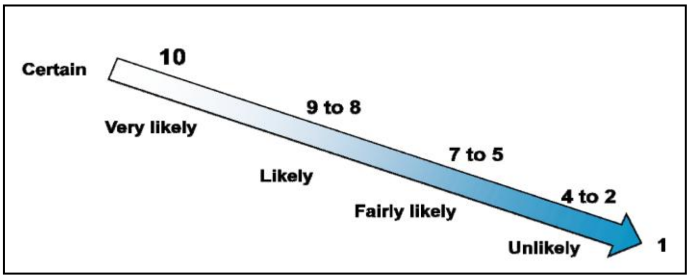

Figure 12. Illustration from the criteria rating for occurence (Wärtsilä Compass 2013)

- Step 7: Calculation of the RPN for each effect

The analyzed values from each factor are multiplied (severity x occurrence x detection), what determines the level of the relative risk number, referred as RPN i.e. priority. The total number itself does not mean anything other than the criticality. The items with a high relative risk number are considered the most urgent to be corrected.

- Step 8: Prioritizing the failure modes for action

In order to avoid overwhelming situations, acknowledged issues should be prioritized based on the RPN value. This helps to focus the efforts to solve the problems which may add the most value. Eventually, the purpose of these steps up to this point is to produce a resolution. The data is used to gain knowledge, which ultimately contributes a decision. The development of this phase can be shown with a following figure:

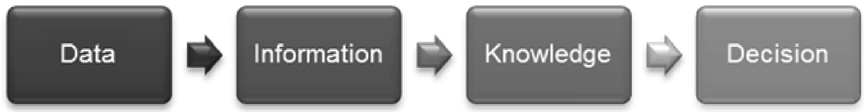

Figure 13. Analysis of data (Stamatis 2003, 37)

- Step 9: Initiating corrective measures

Suggestions can be made for the threshold value for the RPN when to initiate the corrective actions to eliminate or reduce the high risk failure modes. Threshold value can vary depending on the project, available resources and discovered failures and so on.

- Step 10: Calculating the resulting RPN

After completing the corrective actions designated by the successful FMEA execution, another assessment by FMEA is straight forward push for continues improvement. Throughout implementation of the FMEA can provide follow-up for the development and verification, whether corrective action did improve or not. Guideline for Failure Mode and Effect Analysis recommends after conclusion of the FMEA that the members review the objectives and ensure that they are met by asking:

- Is the problem identification specific?

- What was the root cause of the effect or symptom?
- Is the corrective action measurable?
- Is the corrective action proactive?
- Is the use of terminology current and consistent?

Stamatis (2003, 22) summarizes that a good FMEA, identifies known and potential failure modes including the causes and the effects from each of these acknowledged failure modes. Furthermore, FMEA needs to provide the means for specifically designated corrective actions based on calculated risk priority numbers (RPN) and the support for problem follow-up.

5 RESEARCH PROCESS

Within this thesis main focus on the quality was in the transactional environment in the delivery process, nevertheless many aspects were included to the research process to gain proper knowledge to understand how to develop the QA/QC Setup for the Catalyst Deliveries. The research process was attuned around the adopted Failure Mode and Effect Analysis. The main research methods to support the eventual development of the QA/QC Setup were quantitative research in form of the FMEA, which was supported by an extensive qualitative research, referred as the Quality Survey. Purpose of the Quality Survey was to document the quality related feedback to enable the FMEA to take place, and support the later development of the QA/QC Setup. Therefore, the FMEA steers the collected and evaluated information from qualitative research to identify where the risk of failure is most serious. Eventually, the research process forms hierarchy between processes based on identified risks during the Quality Survey. End result of the research process, the FMEA interprets the required quality activity to be developed in form of the QA/QC Setup.

As already pointed, the FMEA is a powerful tool and but can require substantial resources for it to be performed. Therefore, the research process was extended to include more than merely a review from the process. Adequate preparations were enabled by conducting a pre-study, which was to serve effectively to fulfill the needs of this research, which was done individually. The functionality of the FMEA team and the risk identification process was compensated by the knowledge gathered from both the pre-study and the Quality Survey. The Quality Survey focused on collecting the first-hand information from each affecting delivery process area. Also, the personnel involved with NOR delivery projects from business units were interviewed to get the essential customer perspective. The recommended process expert presented in the theory was achieved by authors' experience of modeling process flow chart for the delivery process in question before actual research. Substantial effort was put into collecting as much information in order for the author to perform as a FMEA team efficiently.

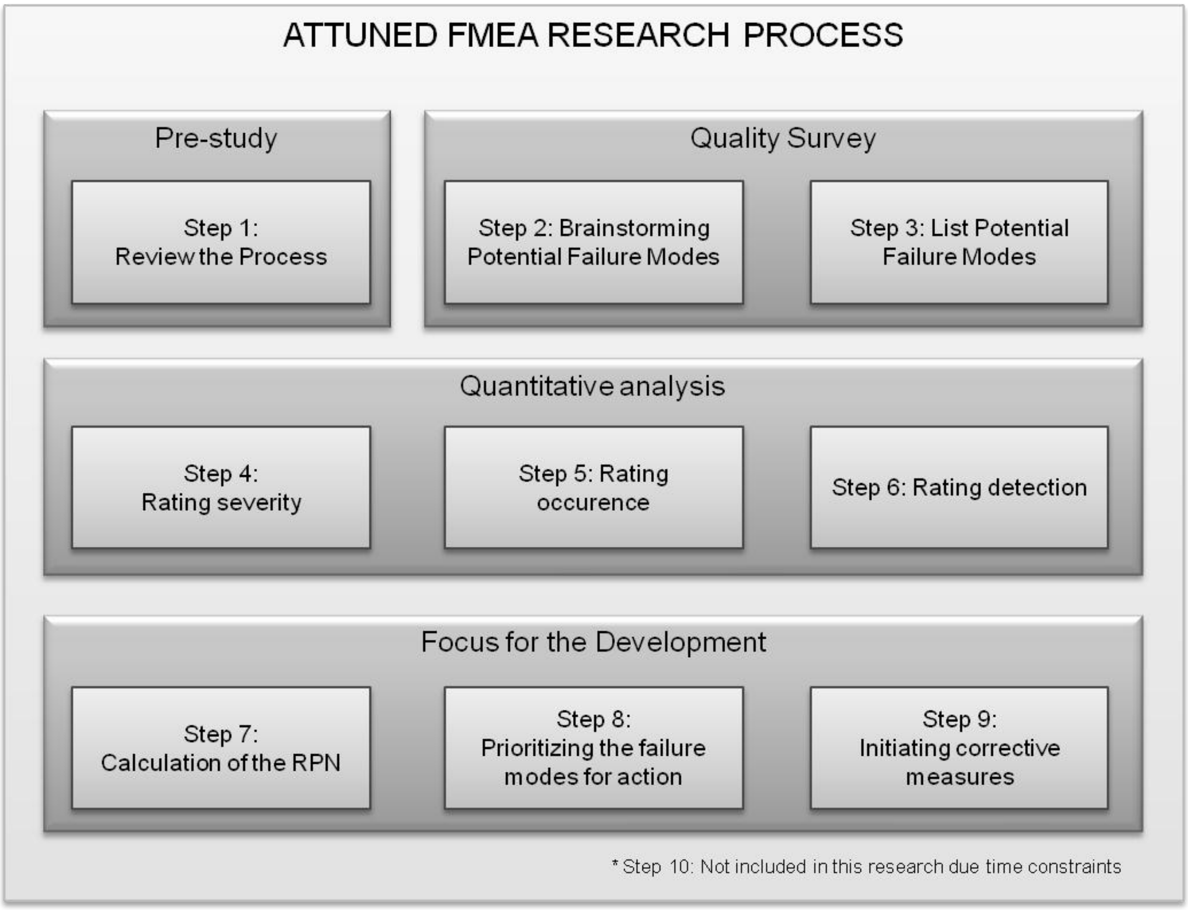

Figure 14. Illustration from the research process according to the FMEA.

5.1 Pre-study

Catalyst Deliveries has been a subject of organizational transition, therefore the starting data relating quality is relatively nonexistent. Noting and monitoring of the quality non-conformities were occasional, thus unreliable source of information to use as a reference. Only comparable data can be considered to be the Customer Relationship On-Line (CROL). The pre-study focused on acquiring more information by interviewing experts and quality personnel as well benchmarking similar activity elsewhere within the corporate.

Benchmarking included comparing methods, performance and documentation in a general level. The objective for the interviews was to gain further knowledge for two particular reasons, firstly to achieve detailed quality know-how from important activities occurring within delivery project, and secondly to form better understanding about relation between specific tasks and areas. Findings from the interviews were documented and utilized in designing the Quality Survey and later when developing the QA/QC Setup. Current situation was evaluated by reviewing mainly organizational but as well corporate documentation and activity related to the topic. This included reviewing the delivery process as well. The customer satisfaction was acknowledged by evaluating results from the Customer Relationship On-Line (CROL).

5.1.1 Customer Relationship On-Line

In order to maintain and develop the customer relationships Wärtsilä has in cooperation with PBI Research Institute developed the CROL® process in order to have a systematic approach to manage both the individual customer relationship as well as customer satisfaction. The purpose of the process is to support Wärtsilä in managing the customer relationship and customer trust as well as monitor the performance of the company at the customer interface. Wärtsilä has been monitoring customer feedback with CROL® since 2003. The process is built for Wärtsilä personnel to focus on customer satisfaction throughout sales, project and service phases. Now it was conducted the first time for stakeholders of Catalyst Deliveries. (Wärtsilä, Catalyst Deliveries 2013.)

CROL functionality is based mainly on pre-thought questions which are rated from scale one to ten. Results are converted into visual figures which can be source of high level information. Although, CROL is efficient measuring raw customer data it does not focus into details. CROL can be considered as a tool which highlight whether issues exist or not. Pre-thought questions may leave quality issues untreated especially, when auditor might have limited knowledge from the situation. Without deeper questioning, opinions might be channeled and therefore leave causes unraveled. Furthermore, a validity of a questionnaire can be questioned, if probability for various people not sharing the same attributes for each value exists. Target for the satisfaction was 85 percent, which was not achieved from the CROL conducted on behalf of Catalyst Deliveries. Results shown in Figure 15 support the need of a corrective action as well.

Figure 15. Catalyst Deliveries - CROL Results 23.09.2013 (Wärtsilä, Catalyst Deliveries)

5.1.2 Interviews

To ensure adequate assets for executing the research and development process, personnel with specific expertise within the corporate were interviewed. Interviewee's relation to the development process varied from relevant quality know-how to comparable operative execution in NOR delivery project. Interviews functioned as a form of consultation and benchmarking to increase knowledge but as well examine way-of-working and to gain another perspective. The feedback was documented from various sources related to the topic among following areas:

- Operational purchasing
- Production Planning
- Project Portfolio Planning

- Quality
- Quality Assurance
- Supply Chain Management
- Supplier Quality Development

5.1.3 Reviewing delivery process

Reviewing the project delivery process was done by examining organizational process flow charts, documentation and way-of-working. This included assessing past events from historical data, as well with open conversation within the department. Also, observation was done to the project environment, for example, by participating in the project weekly meetings.

Author's experience from the project environment supported realizing the potential quality challenges in the delivery, which were deliberately ignored at this stage. Focus was rather placed in the areas not familiar and potentially not recognized as of yet. Process flow chart was reviewed to acknowledge where potential conformance to quality might be endangered. Close attention was put into where function moved from a department to another, and where systematical project execution was not fully presented or was unfamiliar. Especially, the current available procedures and way-of-work for handling these situations were examined. Within a project, functionality of the delivery and collaboration of each stakeholder participating in a delivery can be seen in the Appendix 2.

5.1.4 Operative project environment

The NOR delivery projects are managed by Catalyst Deliveries functioning as an interface between business unit and other stakeholders. Eventual delivery within the project is directed to the business unit, which then on supplies the NOR scope to Wärtsilä's end customer. The main responsibilities and activities during the delivery project from Catalyst Deliveries' perspective consist of order intake, product specification, coordination of design work, subcontracting and final inspection as well delivery hand out.

In a customer delivery project, Catalyst Deliveries is responsible for the project to fulfil the delivery requirements where as in the internal engineering is responsible for the technical conformance and the external design coordination of the NOR product. Therefore, Catalyst Deliveries is not involved with design work itself, only coordination for the design and the documentation.

Major facilitating factor for the project execution is noticeably the level of sales support activity before order intake. Although, not directly included in the scope of the thesis, the particular area has essential effect on the rest of the delivery. Sales support is the beginning, where mutual understanding between each party is being sought from the delivery capacity to the technical conformity, such as space, scope, placement, schedule and terms. Sales support is a diverse and potentially ongoing process, which varies according to the customer and, for example, whether on-site layout is still in design phase or already fully constructed.

Pursuing mutual agreement often continues within the order intake and the technical assessment and may last up to the product specification and further, whether details within sales support were not properly questioned, informed or simply was not available at that time. For example, the fitting of the reactor and mixing unit construction into different layouts of each Ship may require several details to be communicated closely with the customer, which often is not possible solely in the limits of sales support. Communication may last all the way to product specification and beyond to achieve approval for the basic design. This applies especially within marine industry, where space inside of a Ship is limited, therefore creating pressure for the design conformance.

5.1.5 Order intake

Main functions within the order intake are to create resource plan and schedule with relevant tools and execute the kick-off for the project. Order intake is triggered by the Internal Order (IO) which is delivered from the business unit. The project planning is done according to the Notice of Contract (NoC) and the Technical Specification (TS). The NoC provides the figures, terms and dates from the customer contract related the NOR product scope. The TS defines the technical content of the product such as the performance and the preliminary scope among many other design reference data, which is required for the product conformity and functionality.

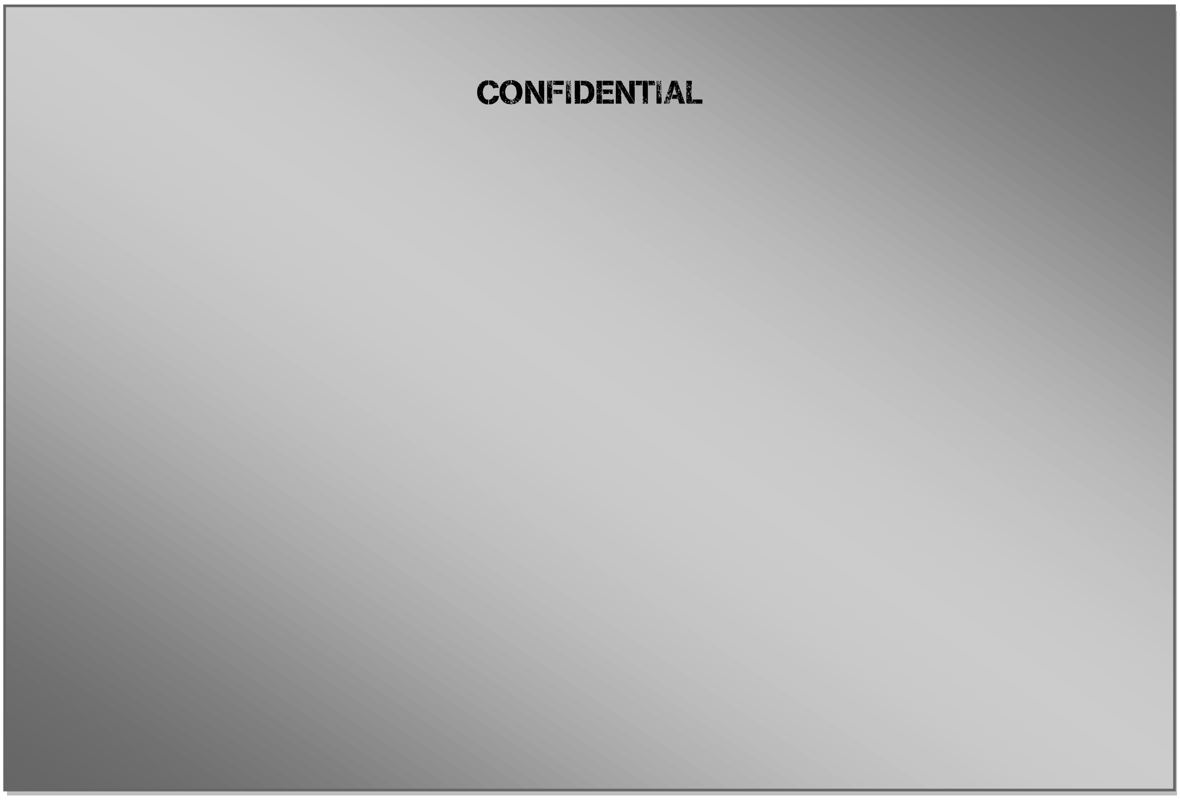

Figure 16. NOR delivery process - Order intake

5.1.6 Product specification

The product specification is where the scope of the delivery is determined as far as possible. Major activity is the creation of the first Bill-Of-Material (BOM) and coding it for the usage in purchasing with requirement dates and so forth. Product specification is done by utilizing the Standard Register according to the given customer input and the Technical Specification. One of the product specification outputs is the identified design needs which consists the project specific design requests not yet existing. This can be anything from special modifications to the reactor or an implementation of an external appliance to the system. Generally it means that previous applicable design is not available or suitable for the project.

The NOR System requires many specifications within each project, although a certain level of standardization exists. Common uncertain details are dimensions and placement of the reactor and the mixing unit within the layout of either the Ship or the Power Plant facility, as mentioned before. Therefore, the sales support before the project and technical assessment done by the internal engineering plays vital role in achieving the functional conformity of the product and as so tremendously facilitating the progress of the project and supporting to ensure the product quality.

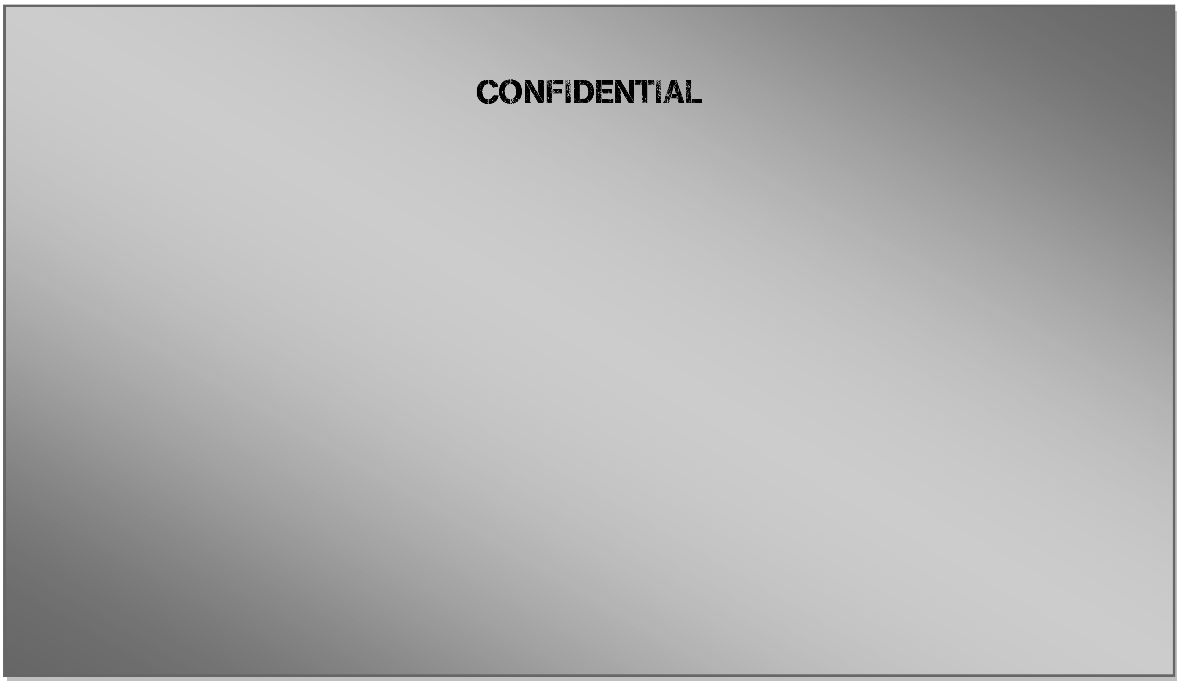

Figure 17. NOR delivery process - Product specification

5.1.7 Project engineering and design documentation

The project specific design activities are managed and overseen by internal engineering. Design documentation relevant to the customer, purchasing and production is coordinated by Catalyst Deliveries. Here, combining and distributing the basic design documentation for the business unit, is one of the major activities. The basic design documentation is referred as Installation Planning Instructions

(IPI) in the marine market which terms of distribution is defined contractually. The basic design documentation is required for the layout design and specification process, but as well, when eventual installation of the NOR scope will take place on-site.

The NOR related design is managed entirely in-house apart from the reactor and the mixing unit, which are done by external engineering, although ownership still remains with Wärtsilä. Design kick-off occurring in a delivery process stands for a meeting held only between Design Manager and external engineering. No other systematical design kick-off activity existed, while the research was being conducted. Considering, whether a validated design exists and no Non-Standard Requests (NSR) are presented for the project, both the reactor and the mixing unit are usually the most time consuming aspects of the project related design work. In most cases, duration depends how confined the space is within the layout. Suboptimal situation leads to a more extensive design alteration, therefore requires more design work to maintain required quality and performance.

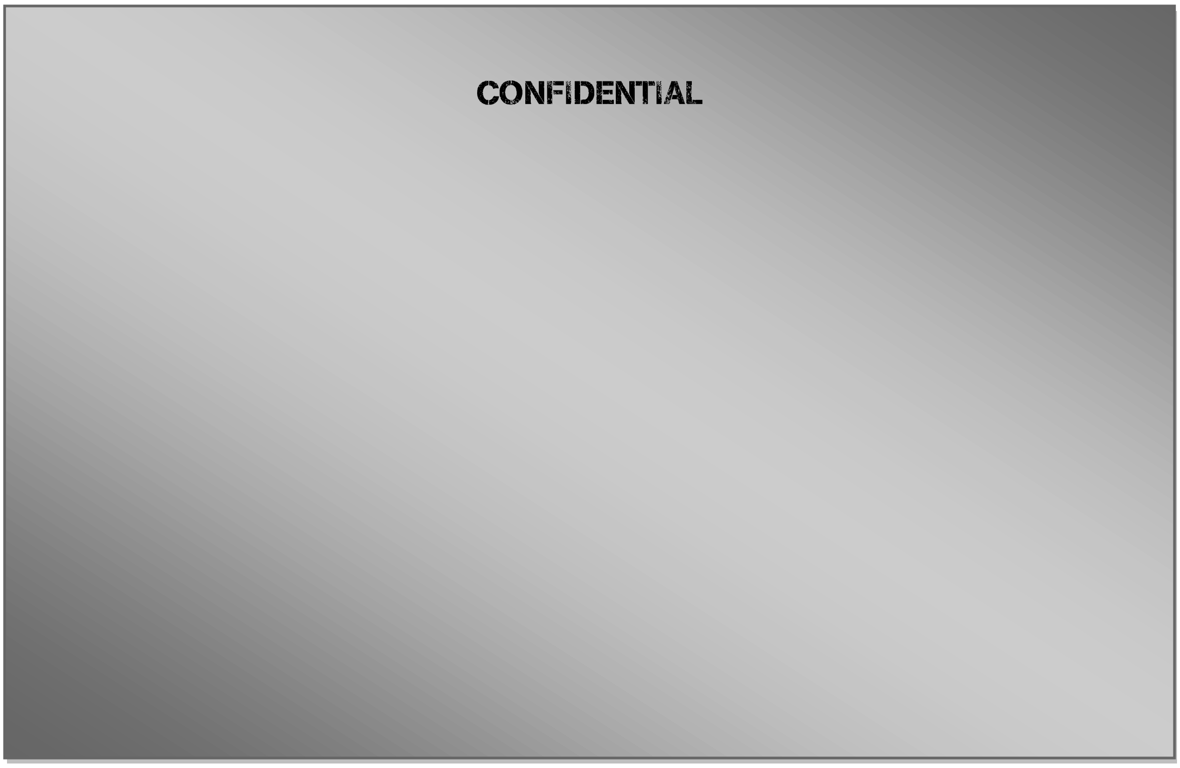

Figure 18. NOR delivery process - IPI Documentation

Another time consuming matter is the level of Non-Standard Request (NSR) done by the customer and especially the inadequate technical evaluation of a certain NSR. Insufficiently determined NSR case may potentially overwhelm with the required duration it may consume. Depending on the content and scale of the Non-Standard Request, the design is produced by external engineering, according to the input given by internal engineering. The arrangement improves the management of internal design resources to focus more into research and development.

The eventual detail design for the project is again coded as the final BOM for purchasing. When all relevant detail designs are updated into the product specification, it forms the actual project specific BOM, which has the documentation and potential special requirement applicable for purchasing. Close cooperation between internal engineering and Catalyst Deliveries is essential for the project conformity.

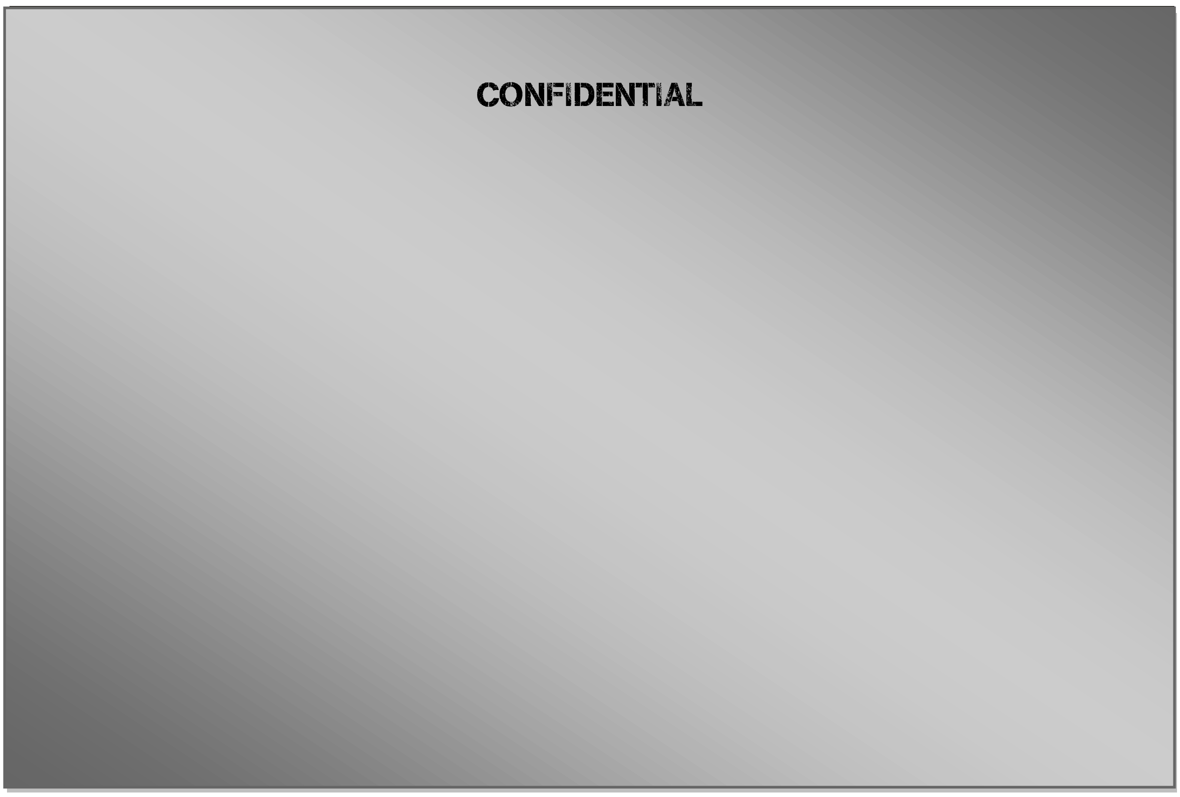

Figure 19. NOR delivery process - Detail design

5.1.8 Project purchasing

The project purchasing is done by Project Purchaser according to the purchase requisitions, which are eventually produced by the Enterprise Recourse Planning (ERP) tool. Supplier sourcing is done by Wärtsilä Supply Management (WSM) for each business area including the NOR. WSM functions to ensure the supplier performance according to the requirements of Wärtsilä. Appointed Strategic Purchasers from WSM are responsible for the components and units in the NOR field. Currently, during a project execution Strategic Purchaser is visible mainly, when designating appropriate supplier for a certain design in case of a nonexistent outline agreement, and when quotation for new design is requested.

Major objective for the project purchasing is to confirm the timely delivery of goods from a supplier to the in-house warehouse. Therefore, changes during the project, whether it is design or schedule, are crucial for the performance of purchasing. Project Purchaser manages and monitors the development of the supplier product progression and documentation deliveries together with Production Engineer. For the needs of research and development, internal engineering may conduct quotation requests when they see fit.

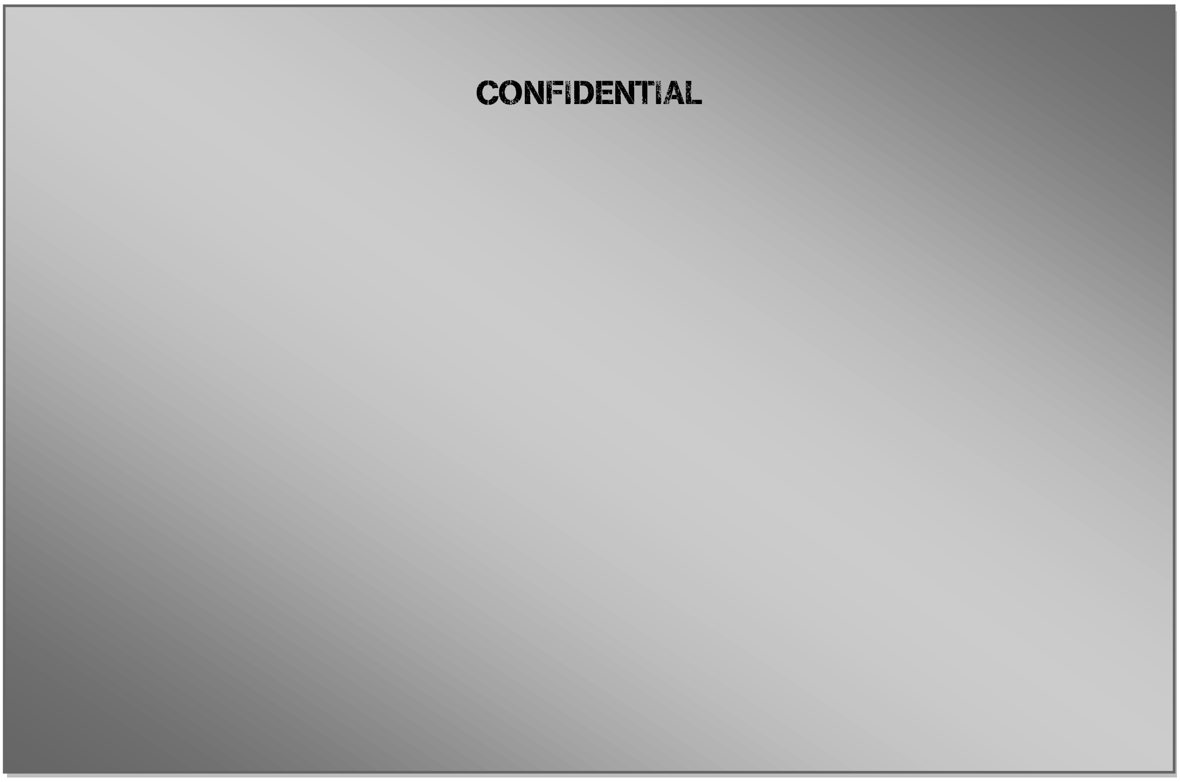

Figure 20. NOR delivery process - Project purchasing

5.1.9 Subcontracting and FAT

During a project, Production Engineer manages the product related development at the supplier, as well the in-house assembly up to the eventual delivery creation and hand out of all NOR units and components. The actual delivery to the on-site destination is done by the business unit in question. Production Engineer functions according to the delivery plan and is directly influenced by the purchaser, data received from the ERP and the engineering. Production Engineer is supported by internal engineering to resolve potential design non-conformances during the sub-contracting and in-house assembly. Important aspect for Production Engineer is to oversee the execution of the Final Assembly Tests (FAT) for the NOR products. Managing the project related logistics up to the delivery hand out is included into the main activity of Production Engineer, where support can be by given by Project Purchaser.

Figure 21. NOR delivery process - Subcontracting and FAT

5.1.10 Project closing

The project closing consists primarily of the delivery notification and the hand out for the business unit, as well the confirmation of the project related documentation, actions and tasks. During the project closing, As-built confirmation stands out as a major importance, as it defines the content of the Spare Part Catalogue (SPC). Therefore, the design documentation within the product specification must correspond to the actual built product, hence the term As-built. Information for the SPC is forwarded from the product specification, so it being up-to-date, is crucial for the conformity of documentation. Another important factor within the project closing is to ensure that all relevant deliverables are acknowledged and noticed by the business unit for later pick up.

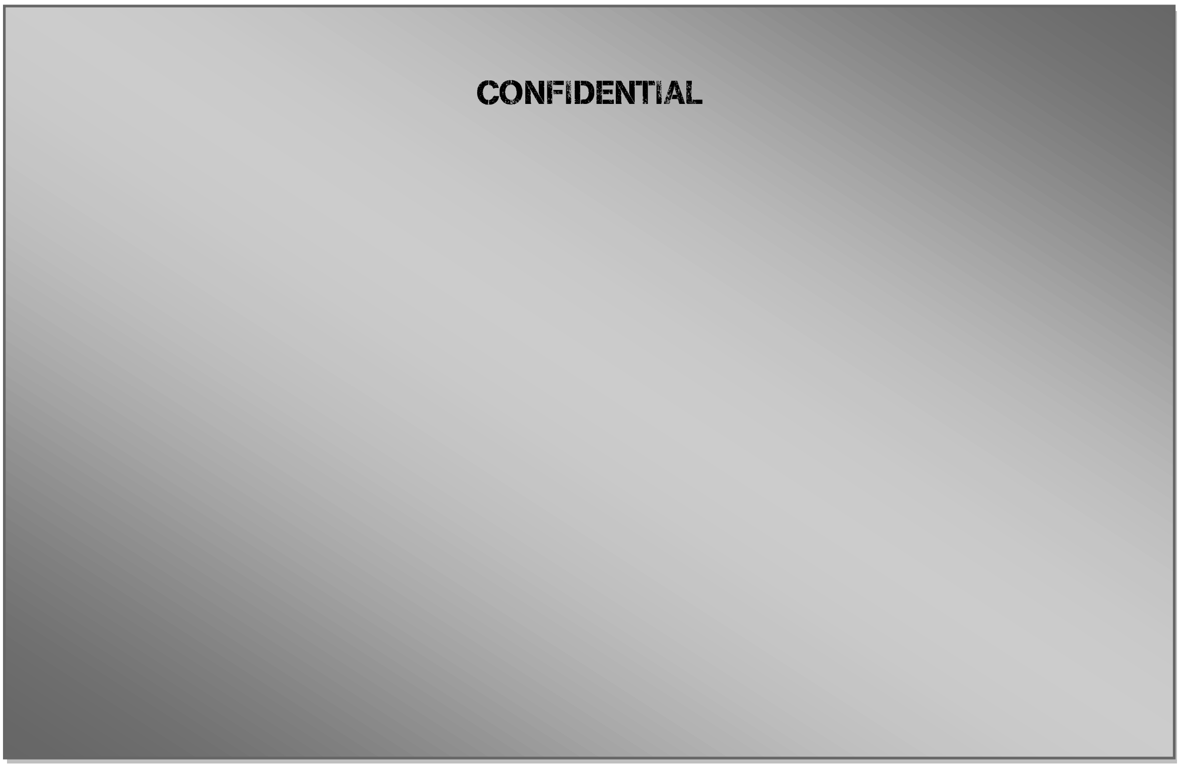

Figure 22. NOR delivery process - Project closing

5.2 Quality Survey

Considering the objective of developing a quality setup, a profound and diverse qualitative research was planned in form of the Quality Survey to explore not only risks but needs and expectations of the target population among other aspects as well. The first-hand information from the operative level was considered as the key part, when developing an improvement. Furthermore, when given a chance to improve one’s performance, it can contribute motivation.

Opportunity was used to raise the quality awareness as well, which would facilitate the future implementation by acknowledging the potential quality concerns. Purpose of the survey therefore was to document:

- Expectations and needs
- Requirements

- Feedback
- Potential risks and causes
- Improvements

The Quality Survey was executed in order to determine the foundation based on the information from the operative level. Gather knowledge of phases which causes challenges maintaining quality but as well as encourage into transparent problem solving atmosphere while conducting the Quality Survey.

5.2.1 Pilot

Pilot interview was held to formulate a better comprehension of the demanded time and the form of questions to use. Idea was to test what kind of an approach would produce the most valuable information. Based on the gathered knowledge and objective, over forty questions and topics were created and ultimately tested during the pilot interview. Separate questions were fashioned to cover each aspect within the delivery from order intake to engineering, and up to commissioning. Most effective questions were chosen to the actual Quality Survey. Questions were further developed to activate interviewees' quality mindset and to lead the conversation in the most productive manner. Specific questions and topics varied depending the on the person being interviewed. Although, variation was included, a common quality theme was intertwined into each question. Questions formed the core guideline for the actual interviews and a support to be used to direct the conversation.

5.2.2 Brainstorming

The agenda for the meetings were to receive valid information about the needs and desires of the personnel involved in the delivery process. My personal agenda was to furthermore document the potential hazards and risks related to the delivery process. For external stakeholders, I emphasized Catalyst Deliveries' target to improve the common performance by aiming to indentify essential requirements regarding delivery performance, and as well the risks that may obstruct the fulfillment of these requirements when occurred. When interviewing Catalyst Deliveries and internal stakeholders, I could incorporate these requirements and concerns from external stakeholders to activate interviewee's quality mindset and awareness. This was to initiate the positive cycle of resolving the potential causes of identified quality concerns.

The interviews itself were planned to focus first on the insights of each person's requirements. Although, potential failure modes were important for the coming risk analysis, brainstorming failure modes were not directly the purpose at the beginning. Interview was rather designed to evolve in such a way that brainstorming occurred during the conversation. Reason for this was to facilitate transparent conversation regarding risks and the process of inspiring solutions. The approach was attuned to prevent the probability for defensive behavior caused by the potential personal infliction to the process.

Interviews were not recorded to avoid intrusiveness. Comments and feedback were rather written down for later evaluation. Each relevant comment was noted and saved during the interview, whether it was an improvement, concern or a failure mode. Documented results from the Quality Survey was planned to be reviewed after the interviews to identify and evaluate unnoticed risks and failures.

5.2.3 Potential failure modes

The Quality Survey produced tremendous amount diverse information. The documented results from the interviews provided evidence from the current situation and important in-sight knowledge from various aspects, including failure modes, which was crucial for the quantitative part of the analysis. Authors' previous experience from the project delivery environment and from the pre-study proved to be beneficial in generating productive conversations.

The interviews lasted from one hour to three hours depending on the person and he/hers relation to the delivery process. The survey sample consisted of personnel participating in the delivery projects with different expertise and accountabilities, therefore governing many quality related perspectives. Survey also achieved redundancy among main challenges, which means quantity of respondents was sufficient (Mariampolski 2001, 58).

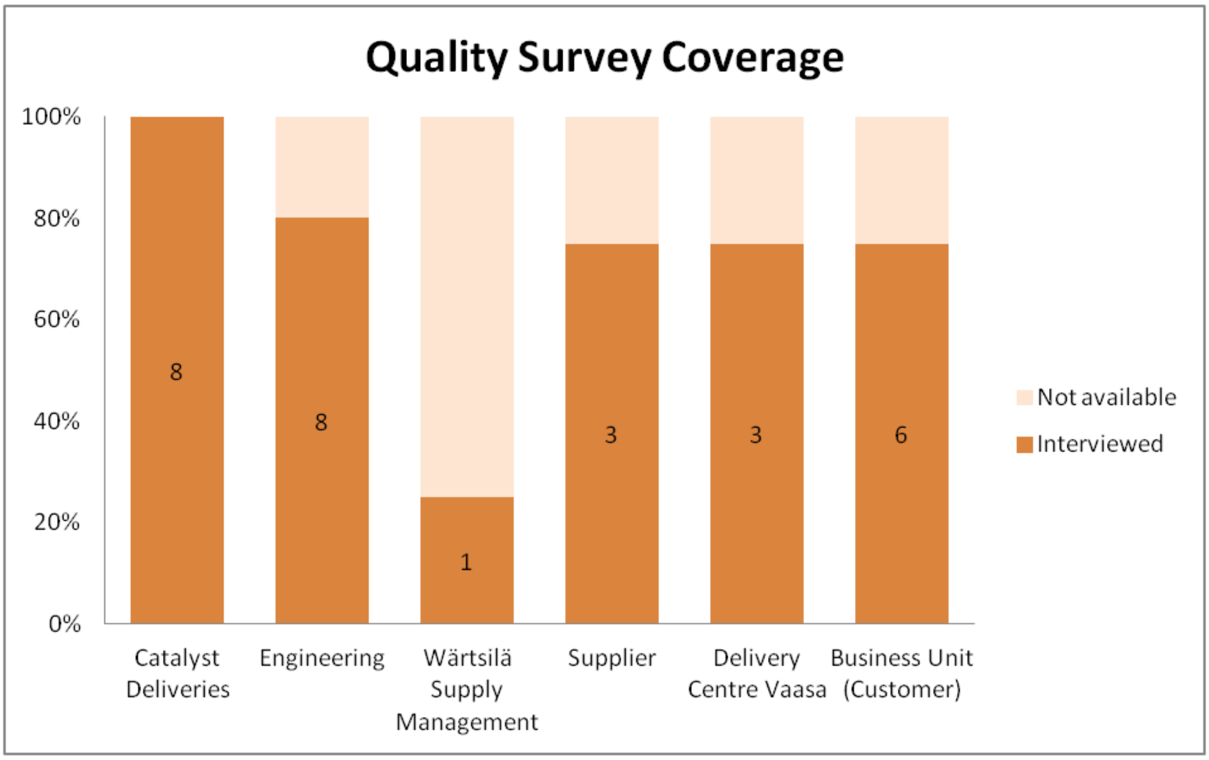

Figure 23. Coverage of the Quality Survey

The Survey assisted the acknowledgement of challenges which led to open improvement and feedback discussion. Although, quality awareness was noticeably, a concern was that support for proper quality execution was not always adequately provided by the system, current way-of-work or present available documentation.

Communication during a project execution was regarded as one the general challenges. Notions ranged from the progress awareness to the inadequate consolidation of required information. It is important to note that, this particular issue includes many form of communication depending on the person and task within the project execution. Furthermore, personnel functioning in a delivery project are divided organizationally, therefore probability for information gaps were thought to be higher. Unawareness were seen to result inefficiency and potentially unnecessary re-work, but was considered often troublesome to prevent without a supportive activity.

Suppliers concern over quality was mainly related to the design validity and quality instructions. Availability and adequacy of quality instructions were at times slightly questionable. The inefficiency was caused by communication breakdown with design and other requirement changes during production. Yet, communication was recognized positively, as being active regarding both delivery and engineering. Communication seemed to be transparent and quick, however minor confusion were related to contacts in a special situation. Some cases implied that information was not distributed between engineering and Catalyst Deliveries. Also, suppliers stressed the importance of short and long term forecasts to ensure minimal lead time with a make-to-order production. This was underlined with the products using special components not included in the normal stock. Fortunately, another project in Catalyst Deliveries is ongoing and implemented to cover this particular aspect.

Warehouse in its current form serves mainly the needs of Wärtsilä Product Company. This means that the purpose of the warehouse is to function with major components and engines, rather than with smaller individual components and units, which are used in the NOR business. Furthermore, available resources within the warehouse proved to be challenging to ensure at high volume phases.

Business unit as a customer perspective highlighted on-time delivery of the qualified product scope and the valid project related documentation. Understanding the end customer and acknowledging their special requirements were seen as matters which need to be emphasized constantly. The NOR products, being relatively unfamiliar in Wärtsilä portfolio, were a potential cause for unawareness with certain details. Lack of understanding the product and the delivery project itself, were seen as a place for improvement. Available data and information for certain personnel in a commercial situation with end customer were at the time limited or not known. Important phase was considered to be the delivery hand out as well. Procedures and documentation regarding packing and shipment were essential. Interfaces and contact points were seen clear, as well positive feedback was given from the transparent communication with whole NOR team, meaning both Catalyst Deliveries and internal engineering.

In order to perform the following quantitative risk analysis, failure modes acknowledged, based on the Survey and pre-study, were reviewed and assessed. Indentified risks were evaluated into failure modes as well. Furthermore, before advancing into risk analysis, further preparations were made to ensure smooth FMEA study by executing following tasks:

- Detailed scope and content of the FMEA study was documented
- Relevant processes were evaluated based on indentified risks to avoid confusion and handling difficulties
- Potential failure modes were listed for specific process
- Supporting documentation were reviewed and made available future evaluation of occurrence and detection with the process owner

5.3 Quantitative analysis

The quantitative analysis conducted in this research can be regarded as process FMEA, where priority derives from the different aspects of a certain risk affecting the process performance as a failure mode. The analysis indicates which process has most concern of causing critical quality non-conformance based on the identified risks directed to it. Therefore, it functions to pinpoint the quality weaknesses in the delivery process by analyzing which steps effect most regarding quality if failed. The FMEA stands as the base for the development of the QA/QC setup. The value criteria for the FMEA were designed based on the target environment by reflecting the objective against related theories. Nevertheless, values are not explained specifically in this thesis to preserve corporate integrity.

5.3.1 Rating severity

The severity of each process was determined based on all previously gathered and documented information regarding potential and existing risks and failures.

Severity was evaluated how identified risks might affect the liability of a particular process steps performance. The focus was on the effects how they influence, not the likeliness or detection. Process step facing the most serious risks and potentially causing indefinite quality non-conformance are ranked the highest. Process step without any severe effects, internal or external, which would have effect for the customer, are ranked the lowest.

5.3.2 Occurrence and Detection

After rating the severity, FMEA was prepared for another interview. This time FMEA specific interview was done in co-operation with the owner of the process step being analyzed. The objective was to gather information to determine the failure occurrence and detection from each process step thus support the author to adequately determine these two factors. Information was exchanged based on accumulated experience gathered from the Quality Survey and pre-study. With this arrangement, purpose was to remain unbiased by communicating transparently and not overlooking obvious aspects.

5.3.3 Risk analysis results and priority assessment

As presented in this thesis, FMEA pinpoints critical process steps within the delivery project by means of risk priority number (RPN). The produced RPN value from each viable process, according to the risk analysis, formed hierarchy of priority among the delivery process steps. This hierarchy supports and directs the required corrective measures.

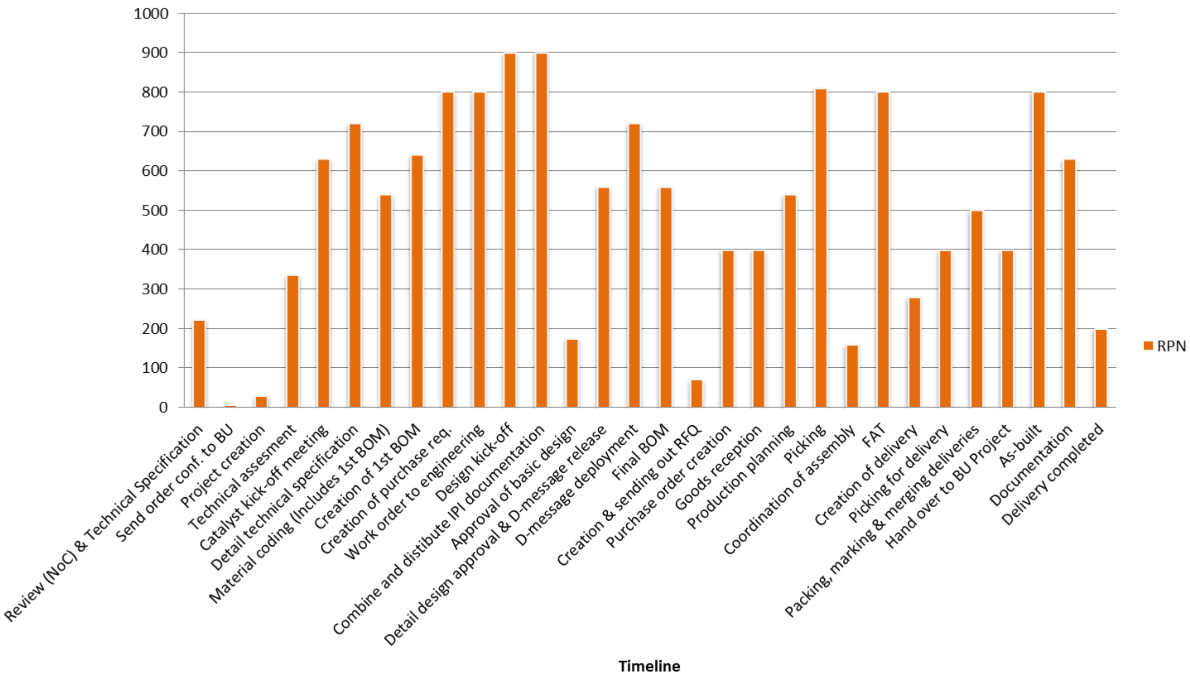

Figure 24. Results from the FMEA priority assessment

The result shows significant variation of priority among different process steps during the delivery project. Process steps, which no not have identifiable risks that might influence the quality performance, are clearly noticeable. In turn, analysis explicitly shows how liable the project environment is during some particular delivery phases. High concentration of serious quality concerns are placed between the technical assessment and the combining and distributing IPI documentation. This shows the importance of acknowledging and understanding of all project requirements regarding product and delivery, right from the start. Design kick-off stands out, as it defines the acknowledgement of project and design requirements to the engineers. Even slightest piece of information insufficiently recognized by the engineers may have a tremendous impact to the project progress and to the quality of the product and documentation. Phenomenon therefore creates pressure for preceding process steps, especially technical assessment and catalyst kick-off, which are interfaces for customer requirements. Potential failures can proceed to the creation of the 1st BOM which includes risks in itself and eventually cause erroneous purchasing.

Currently the design release (D-message) procedure holds risks with high concern. The risks can be eventual continuum of the improper execution in the beginning but includes several risks in its own as well. D-message is the interface between engineering and the project documentation including purchasing. If the process, in this case meaning design review, material creation, D-message content creation, distribution and material coding, are not adequate, it may cause significant non-conformances.

Another highlighted concern lies around the warehouse activity. Identified risks have direct influence to the material management for both purchasing and production coordination. Risks regarding the Final Assembly Tests are diverse. The documentation related to the inspections in itself creates potential risks due to incomplete or insufficient information. The supportive quality documentation for suppliers are an area where there is potential for improvement. Separate aspect is how inspection related documentation is managed with suppliers which is also a risk at the moment.

Risks with serious effects exist in the delivery hand out and the project related documentation as well. As-built documentation faces challenges when design changes are done during production or perhaps within the final inspection. These revision changes, if not accounted for, creates indefinite non-conformance with the documentation. Therefore, successful project execution is highly responsible from the acknowledgement of all project related requirements regarding product, documentation and operational execution within the whole delivery process among each stakeholder.

5.4 The reliability of FMEA results

Although, effective and serves its purpose as delivering usable results, FMEA produces values which can be considered subjective. When conducted as a team, deviating judgment among the values are possible if participants do not share same exact vision. However, this matter did not affect in this research because the analysis was done by one individual, therefore deviating judgment from the values were not possible. Nevertheless, theoretical studies suggest that the FMEA, being as comprehensive as it is, would be more suitable to carry out as a team. To some extent, theoretical statement can be valid, although author would still argue that the FMEA can be executed successfully in an individual basis given certain conditions.

5.4.1 Experience and know-how

First condition is the researchers' adequate experience from the FMEA as well from the situation being assessed. This is vital for managing an effective analysis. Investigator must know various aspects and functions from the objective, whether it is process, product or system. To understand the relation between causes and effects, play a significant role, when figuring out the bigger picture. However, researcher cannot be too well accustomed with the objective, because it may result down-grading of potential issues or even going unnoticed.

5.4.2 Qualitative research or/and statistical data

To compensate the need of a FMEA team, either qualitative research or statistical data is required. Proper qualitative research can perhaps result more, as it can include more perspectives with wider sample than a common FMEA team. Successful utilization of qualitative research is possible, when content and purpose of the qualitative research is adjusted for the needs of compensating a FMEA team. To enable this particular arrangement, commitment and transparent communication is essential among the target environment, as it was in this case.

Considering, if the risks and their effects to the performance are known and evaluated, projections and priorities can be analyzed single handedly, by using valid and applicable statistical data. Liability will be affected, if a probability for discovering new types of failures exists. Therefore, certain requirements exist for objective being investigated individually and solely using statistical data. The source for the data needs to be Statistical Process Control, such as operating time, failure rates or mean time between failures and so on. Simulation or another FMEA even can be used for evaluation as well.

5.4.3 Approach

The capability to perform objectively, without personal investment is important regardless, whether corrective measures would cause more work or not. It is essential to ascertain latest factual information from the situation, to enable a valid risk identification process. When performing the study individually, tendency to explore thoroughly, even when assumptions would be dissenting, is fundamental, as well the commitment from the target environment to the objective.

6 DEVELOPMENT OF QA/QC SETUP

The research can be summarized that a potential risk for the quality non-conformance was mainly related to the aspects which support executing a certain task accordingly, rather than lack of employee's core competence for example. The specific connections between the causes and the effects were successfully indentified as well relating views evaluated. These findings were incorporated into the development process to ensure fitting end result. Research results generated direct improvements propositions and inspiration how to conform quality within the delivery projects. Research was an adequate support and produced justification when developing improvements in form of the QA/QC Setup.

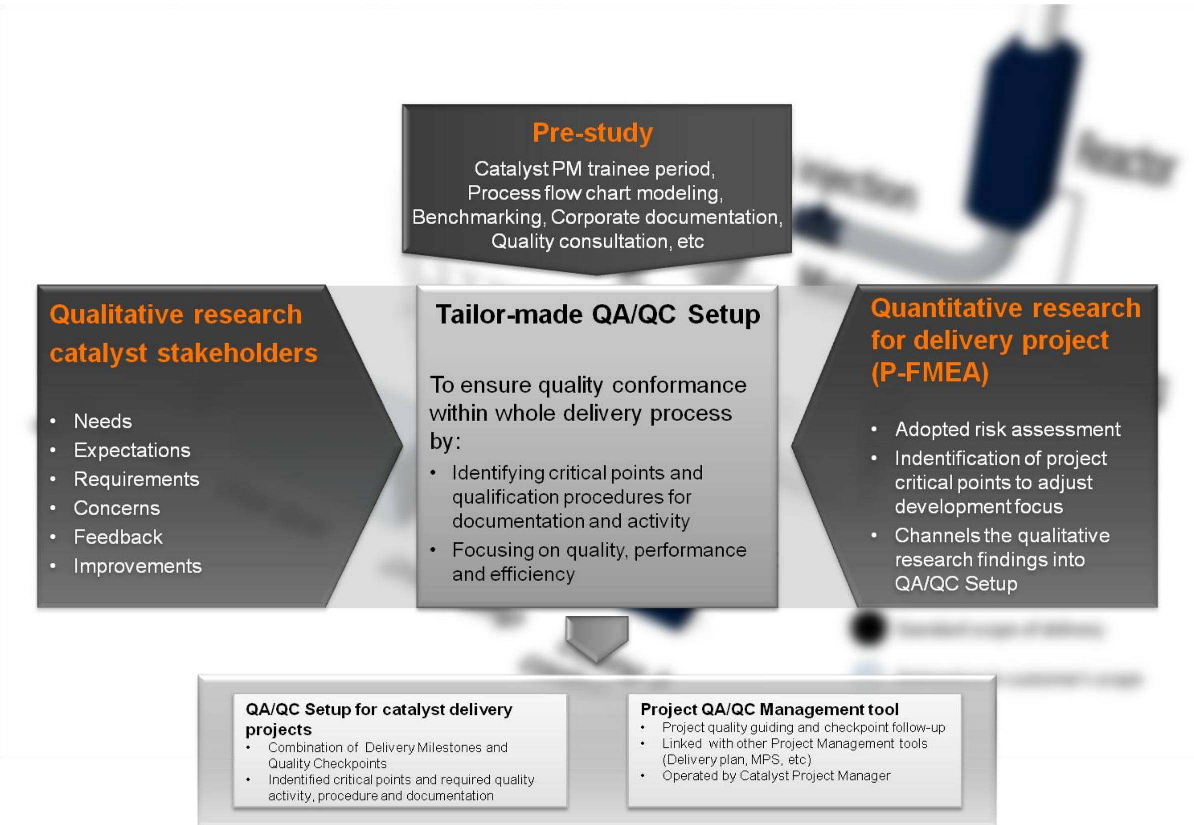

Figure 25. Development of QA/QC Setup

Development of the QA/QC Setup was based mainly on following three pillars. First being the personal experience received from the project delivery environment, as well the extended quality know-how and examination from similar activities during the pre-study. Secondly the documented results gathered from the extensive Quality Survey and lastly the execution of the Failure Mode and Effect Analysis from the delivery process.

Fairly early during the research, a concept from a tool was fabricated which would govern quality assurance and control activity in a delivery project. Concept was immediately figured merely, as an eventual result realizing after the actual research and development process. Therefore, in order to more effectively attain the quality, tailored QA/QC setup was developed first to realize the quality activity. As a concrete quality guidance and follow-up, a tool was seen as a necessity for future implementation. Preliminary concept from the tool was designated for the usage of Catalyst Project Manager, not only as another checking tool, but as a more comprehensive support linked with other project management tools. Reason for choosing Catalyst Project Manager is the nature of his position and the potential assistance it can yield. It has been established that, to be effective, the checking of an activity should be carried out by personnel who are familiar with, yet not directly responsible for, the activity (Stebbing 1989, 53). Within the limit of this thesis, focus was used into the content and functionality of the QA/QC Setup and concentrate into the developing the tool after the thesis.

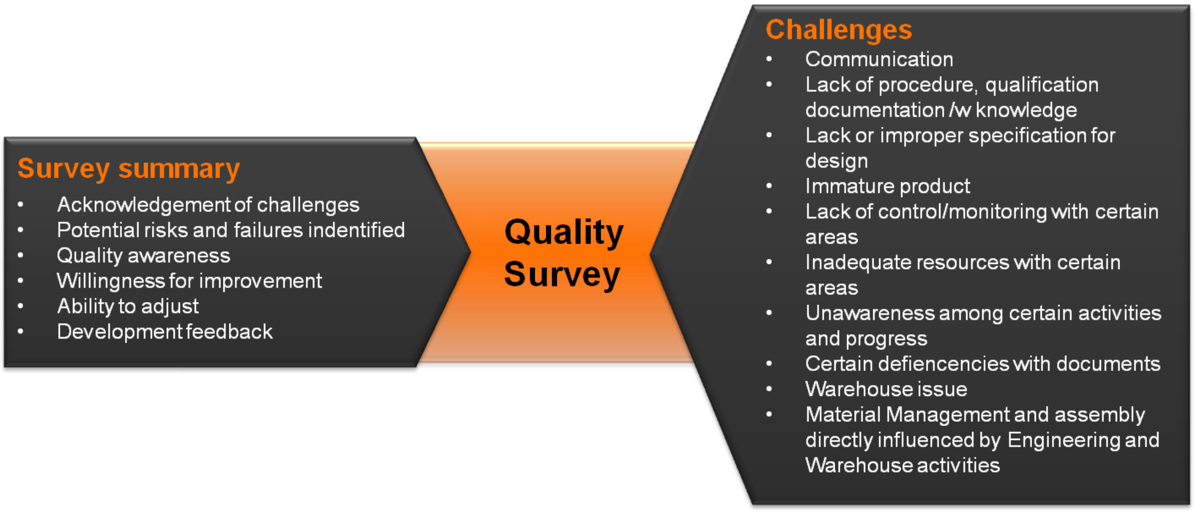

Figure 26. Overview from the Quality Survey

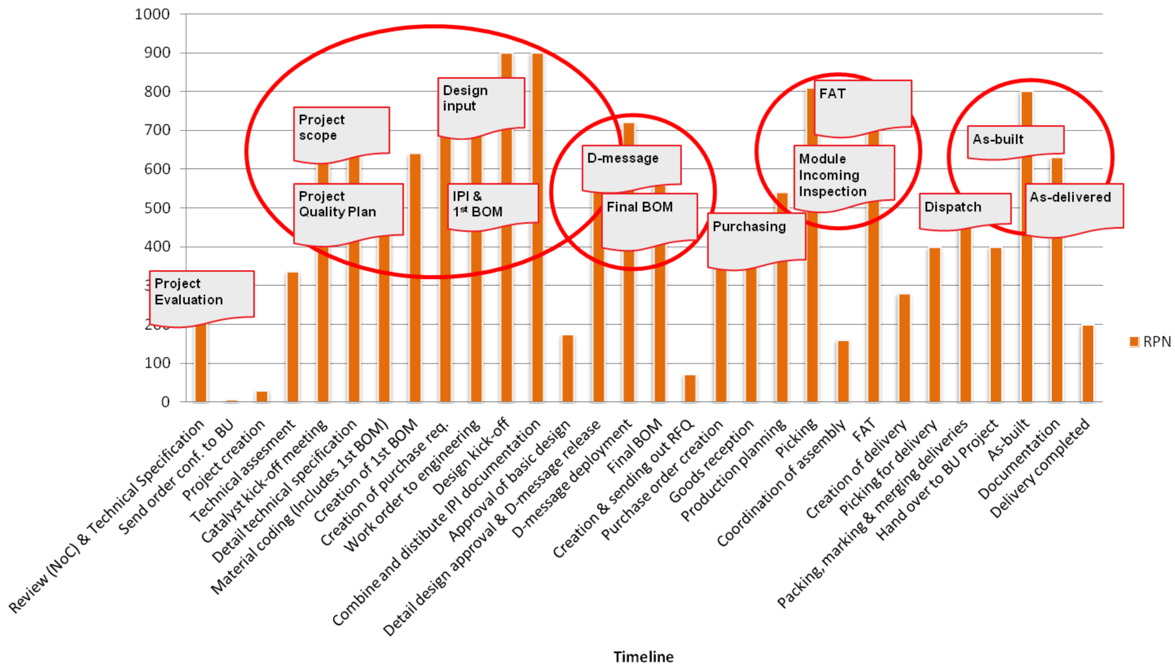

Figure 27. Quality Checkpoints to reflect the highlighted areas

6.1 QA/QC Setup for NOR delivery projects

The actual development process overtook several phases and revisions where different scenarios were evaluated between research results and desired outcome. The setup shows the necessary quality activity, tasks and actions during a delivery project which is required for optimal project execution. Necessity for each activity comes from when reflecting the current performance and research findings with project and delivery requirements derived from the strategy. Setup presents a project delivery process environment where quality activity is defined in form of Project Milestones and Quality Checkpoints. Focus was in developing efficient value adding activity in form of Delivery Milestones which were supported by performance ensuring Quality Checkpoints. Findings from research and development process inspired the solutions now realized and proposed in the Figure 28.

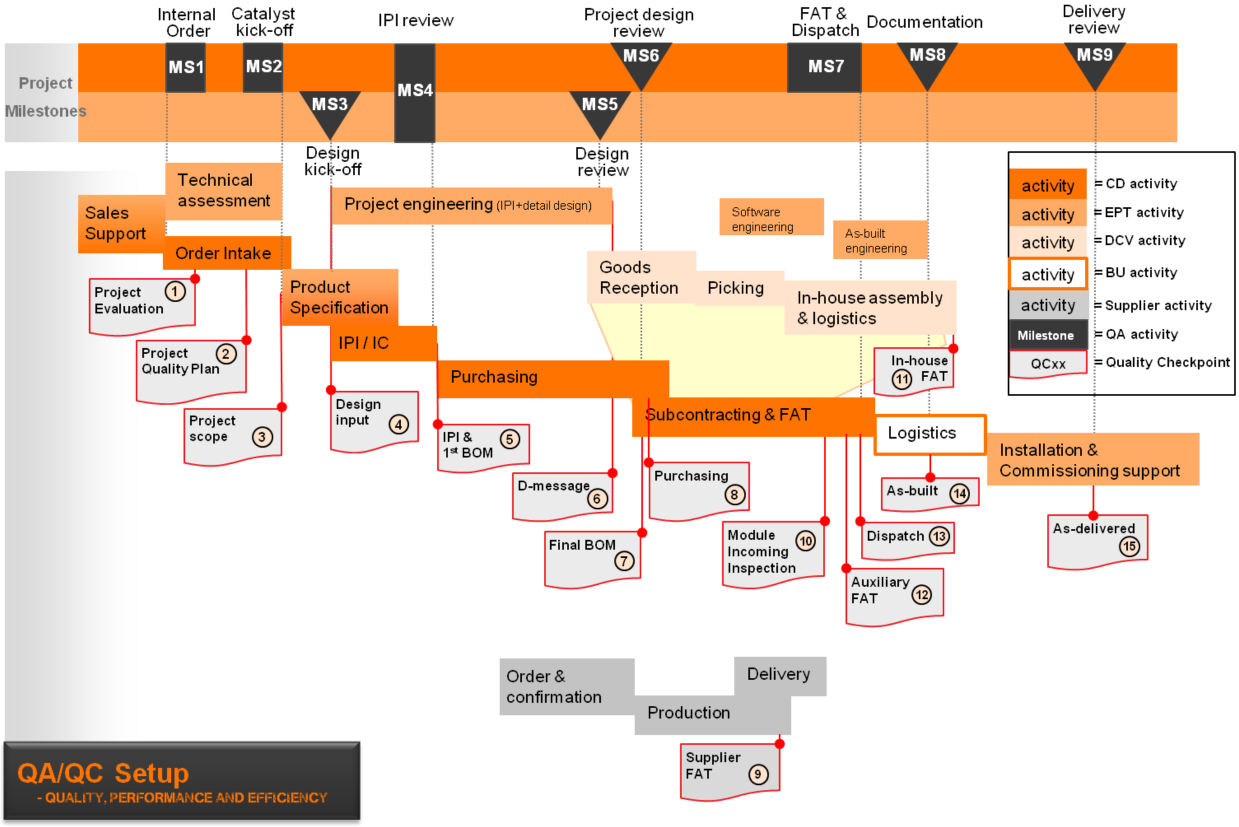

Figure 28. Developed QA/QC setup for NOR delivery projects

Cooperation with Engineering and Supplier Management cannot be stressed enough when attaining quality. Therefore, the QA/QC setup was designed to further deepen the partnership between each of these stakeholders. The objective was to build as efficient setup as possible. Effort was put into indentifying and tuning the existing quality related activity to produce as much value as possible by evaluating content, placement, participants, inputs and outputs, etc. When requirements could not be achieved, new ways and means were developed based on the research findings. The concrete purpose of the setup is to stand as a systematic guideline to conform quality in a NOR delivery project. It is important to acknowledge that assessing other development targets, which are briefly addressed later in this thesis, will further enable the quality attainment during the delivery projects.

Basis for development was to add more value adding substance into critical project phases in form of way-of work, documentation, instructions and information consolidation. By this approach developed setup seeks to achieve transparency among activities and requirements to relevant personnel. Improve specification and proper recognition of requirements which would ultimately lead to better workload management by pointing out explicitly what is needed to secure operational and product quality and ultimately the customer satisfaction.

6.2 Functionality of QA/QC Setup

The functionality of the developed QA/QC Setup is based on a combination of Project Milestones and Quality Checkpoints. In the setup, delivery process and activity during project is modeled and responsibility color coded. Milestones stands for quality activity where main purpose is to communicate and consolidate information into facts, therefore avoid any misconceptions otherwise generated. The setup defines separately which Project Milestones should be in form of a meeting with specific descriptions. In general, a milestone means an interface where information is communicated, exchanged and distributed with specific agreed terms. Therefore, a milestone ultimately seeks assurance by providing confidence that each relevant customer requirement is accounted for. Descriptions of the content were created and developed for each Project Milestone and Quality Checkpoint, which explains and suggests all relevant information regarding that particular activity or event (Appendices 5-28).

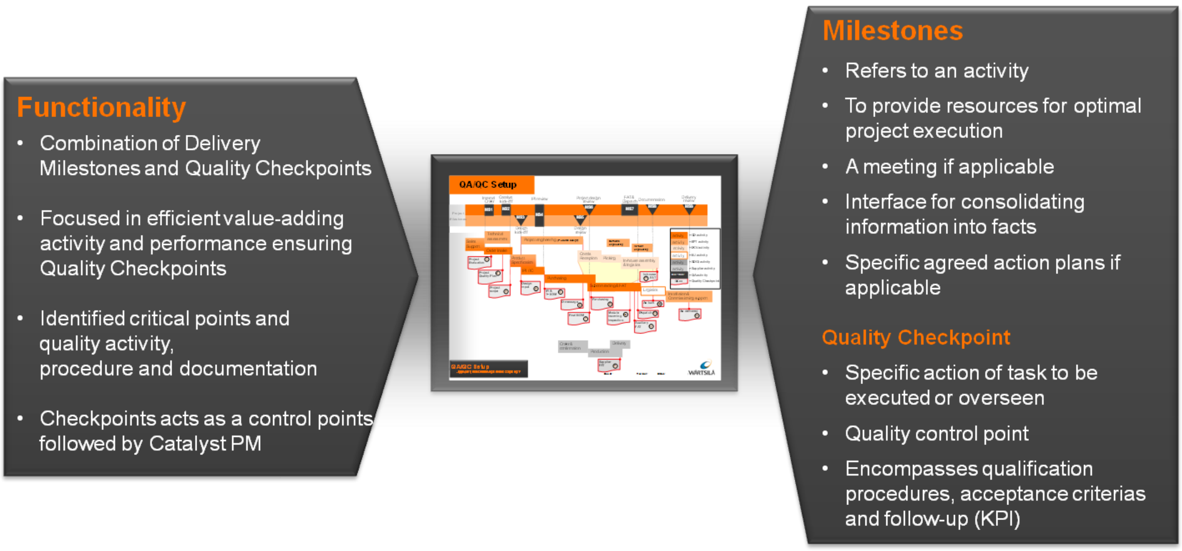

Figure 29. Functionality of the QA/QC Setup

6.3 Project Milestones

Milestones are a significant point or an event during the NOR delivery project. It refers to an activity which provides resources for optimal project execution. Milestone differs from a Gate-model, where progression will happen only, if it is separately decided. This would lead to severe failing of flexibility which is essential for the customer NOR deliveries. Gate-concept would be more suitable in product development projects or substantially bigger projects entities than the NOR deliveries. Milestone includes the necessary descriptions and information regarding that particular phase of the delivery process to ensure quality, from which an example can be seen in the Figure 30.

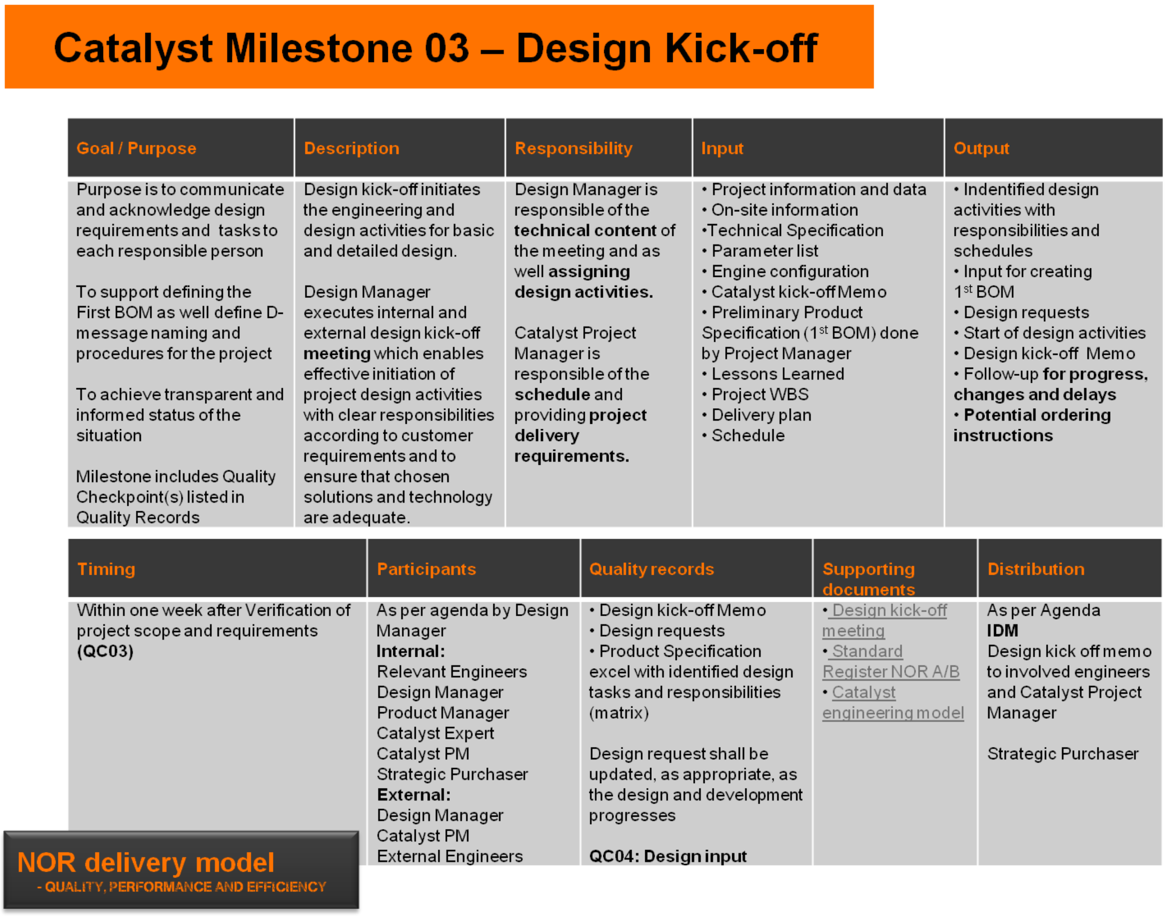

Figure 30. QA/QC Setup - Project Milestone 03 - Design Kick-off

The figure shows the reasons of the milestones in form of goals and purposes. It can be a specific state or an end result. It also explains, whether the milestone includes Quality Checkpoints or not. Description informs how these goals are being pursued and additional details from the milestone itself. Responsibility delegates significant matters to clarify the quality obligations. Each important input affecting the content is also listed to ensure the proper outcome of the milestone. Detailed outputs for the milestone have been set as well. When each milestone should be happen during the delivery process is also stated. It can be tied into another milestone or more specific outcome, as for example, Quality Checkpoint 03 – Verification of project scope and requirements. The participants relevant for the successful execution of the milestone are included too. The quality records show more specifically which important quality related documents should be related to the milestone. To assist the execution and comprehension of the milestone, adequate documents for support has been created or added as well. For example, more detailed document to describe the execution of the Design kick-off was created during this thesis. Finally, milestone suggests distribution list and place to be used as repository for relevant documents.

6.4 Quality Checkpoints

The Quality Checkpoints are junctions were the project can proceed into a non-optimal direction. In this case, it means potential re-work and deviations with the requirements without proper execution. The purpose for the Quality Checkpoints is to prevent any misaligned efforts by checking that the most critical tasks are executed correctly. The action or task may be included in a Project Milestone, as it contains the factors essential for the project outcome to be checked. They act as control points with specific qualification procedures. Catalyst Project Manager is responsible for overseeing that the content of the checkpoint is executed, to which Project QA/QC management tool will be eventually developed. One of these Quality Checkpoints can be seen in the figure 31, as the rest of them are shown in the appendices. Status of checkpoints interprets the level of quality performance regarding that particular project. When each checkpoint is completed on schedule and accordingly, it will provide assurance that the customer expectations regarding quality will be fulfilled.

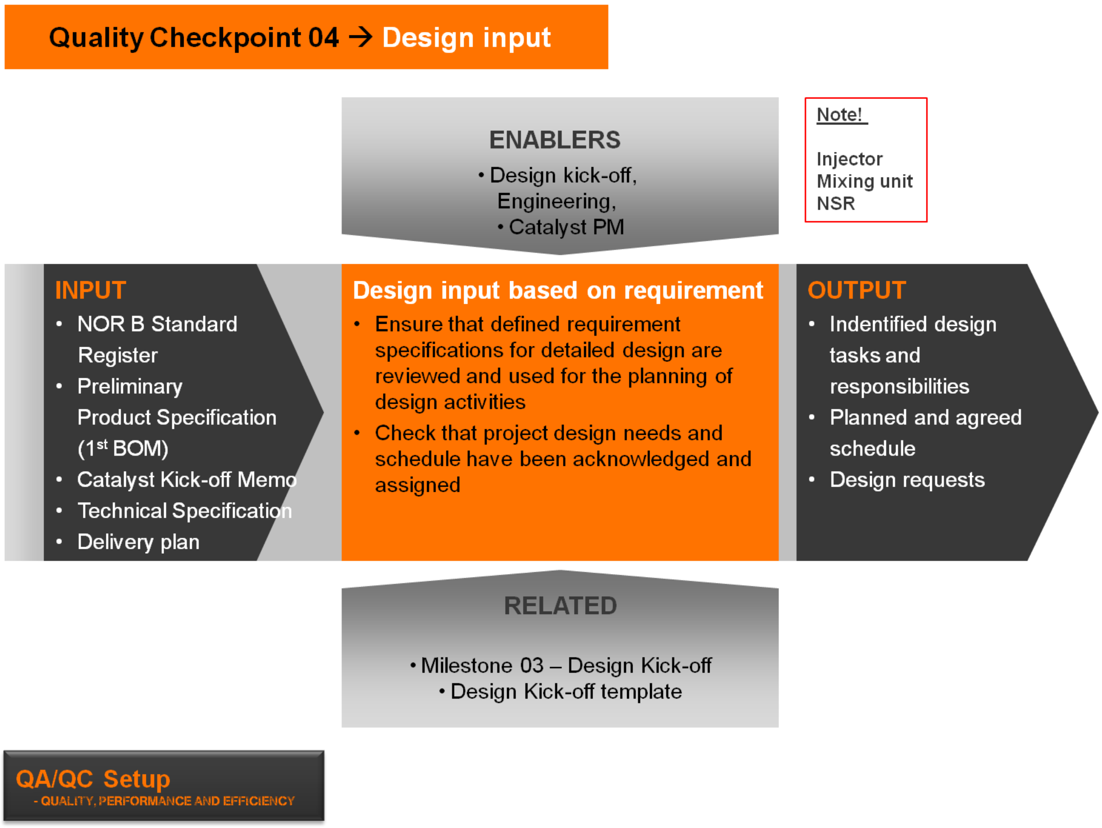

Figure 31. QA/QC Setup - Quality Checkpoint 04 - Design input

As an example, the Quality Checkpoint 04 – Design input, ensures that all relevant engineers to the project have clear recognition from the requirements and responsibilities. Furthermore, to ensure that project schedule have been acknowledged, thus increasing the level of project progress awareness. In this case, these are enabled by the Design kick-off.

6.5 Concept from Project QA/QC Management tool

The research generated an idea for a quality tool for delivery project but was discarded as being too complex to develop in the limits of the thesis. Nevertheless, basic idea for the tool would be that the operative actions critical concerning quality would be logged and monitored in a server based program. It is essential that the program would be light, easily accessible and visually understandable. The person conducting the critical quality task is accountable for registering its completion. Checking of an activity would be done by the person familiar with the task, in most cases the Catalyst Project Manager. Bigger entities can be checked by the project owner and so forth. Purpose is to empower each key person who participates in a delivery project. The system would be modular and formed for each project separately based on the level of quality requirements and how challenging the project is. Definition would be done at the beginning of a project by Catalyst Project Manager and agreed by management of delivery and design organizations. Managing critical change conditions within the system would be agreed by key superior and executed by Catalyst Project Manager. Critical factors, as FAT would be signed with a confirmation done by the person responsible for it. Contacts of each relevant personnel would be saved for each project. Personnel would be automatically notified when change occurs in their domain or when project progresses. This offers clear and latest vision from the status of quality related activities.

Limited access for non-key personal and externals would be suitable. Each check contains instructions, requirement and acceptance criteria, and also required, used and produced documents, named and linked. If confirmation is later opened, reason must be written. The system would operate dynamically by valuing each action and effect on to the whole delivery. For example, inadequate quality activity in the beginning would cause early warning for later effected process steps in the delivery and possible more quality activity is then required. In the other hand, if more resources are put into something specific, it might require less quality activity in somewhere else.

The system can be extended to cover more than operative processes inside Catalyst Deliveries. Suppliers, subcontractors and logistics for example can be empowered to notify the completion of a certain activity. It would not only be thought as an extra weight, because it can be also function as an instructional tool for a person not familiar or remembering the specific action. It can shorten the lead time significantly by eliminating the time spent between questions and responses. After executing a certain task, an email is sent automatically to Catalyst Project Manager containing all relative information about the execution such as person involved, time, which documentation used or/and produced and for which project.

This kind of dynamic system for delivery project builds comprehensive evidence that all internal and external requirements are guaranteed to be fulfilled, thus ensure the customer satisfaction. Records from each project execution logs can be used to pinpoint exactly want went well and but most importantly, what did not, therefore deliver precise input for continues improvement.

6.6 Additional development targets

To ensure seamless functionality of the QA/QC Setup, more detailed approach to certain areas can be suggested. These development targets are diverse, concerning many essential aspects, which can facilitate the implementation of the QA/QC Setup and the quality attainment. As an example, the confusion around D-message procedure is imminent. Design change and how it effects to the receiving end should be clearly indicated in the D-message. Also, a critical factor is to ensure that the requirements will be passed into the Purchase Order. Issue is complex, as the initial data may be insufficient or delayed, and the required design review may be affected due to limited resources. Although, the QA/QC Setup already addresses this challenge, implications can be made, in form of adding an applicable resource to both creation of D-message and approval of design content. Fortunately, during the research process training regarding D-message was held which will, at least, mitigate risks involved with D-message procedure.

Research suggests that the documentation that transfers requirements should be defined further for both supplier and for internal purposes as well. Quality instructions and FAT documentation requires urgent improvements regarding content and management. Critical updates for FAT documents would be; changing the approval method, correcting the referenced standards and addition of serial numbers from the essential components to ensure traceability. This includes adding software version into the FAT documents which are installed during the inspection procedures. This can improve commissioning phase by pointing out, whether unit have the latest software or not. Supplier related documents should be defined more clearly as well.

Important factor is to focusing on the essential meetings to be as productive as possible. Suggestion can be made to review the content of the meeting templates with engineering and other relevant experts annually or, if necessary, before each meeting. Effort should be focused as well on evaluating unfamiliar requirements and finding out what have not have been questioned earlier, in order to be efficiently prepared for each meeting including technical assessment. Feedback from the Quality Survey indicated that some personnel participating in the delivery were lacking progression awareness. Especially personnel, who are not directly involved with the projects on a daily basis, but are still needed in some essential process steps. These people do not need much, only topics covering deadlines and progression of each project. Further transparency on top of the QA/QC Setup would be achieved by focused training and instructions mutually from both delivery and engineering, applicable for either stakeholder.

Warehouse in its current form causes indefinite liabilities for the performance of Material Management and lead time. Warehouse has difficulties functioning with the NOR related business, as it functions mainly to serve Wärtsilä Product Company. During the research, possibilities for alternative ways to cover Warehouse activities were initiated. Further assurance for minimal lead time would provide a definition of safety stocks for critical components with a long delivery time.

Suggestion to ensure conformance of the As-built documentation, is to use suppliers cloud server, where inspection reports would be stored right away. Storage would be for the use of Engineering, Production Engineer and Project Manager at least. Reports should include requests for design revisions as well, which would be direct instruction to properly confirm the As-built documentation.

Creation of the Delivery Risk Register would enable continues risk identification process. The register would be a place to record relevant risks affecting the delivery. Recording of the risks should be made easily accessible. Obligations and responsibilities are not required during the listing. Nevertheless, risk cannot be discarded, although listing is made. The Delivery Risk Register would be eventually assessed in the developed Milestone 09 - Delivery review, where its content would be used to reflect into the actual delivery. One of the outcomes of the delivery review would be the initiation of systematical corrective measures, according to the Delivery Risk Register. Improvement could be directed to anything from a single process to the QA/QC Setup. Based on the status of the Delivery Risk Register, evaluating challenges can also be facilitated at the beginning of a project.

7 CONCLUSION

Conclusion of the research can be reflected to the theory, where indications to quality related challenges are presented. Communication, the effects of improper process, documents and resources cannot be discarded when aiming to attain quality. In some cases, personal accountability may compensate a certain degree of insufficient support, although probability for human error still exists. Therefore, quality must be embedded entirely in all levels and seen as an opportunity for profit – not effort.

Research showed the importance of passing relevant requirements to each operating individual as efficiently as possible throughout the project delivery. Performing the required task accordingly creates demand for way-of-work, sub-processes and documents which act as interface for requirements between two operators and organizations. Insufficient or incomplete information caused by any of these may result in a potential chain reaction. This was occurring in several occasions, which the developed QA/QC Setup focuses to address. The QA/QC Setup therefore pursues to self-generate quality by strengthening value-adding communication and driving efficient collaboration while providing confidence from the quality performance with the created Quality Checkpoints.

Witnessing the capability of Failure Mode and Effect Analysis was an interesting experience. FMEA proved to be an adequate tool to be exploited as a main research process. Performing the analysis individually with the support of qualitative research was expected to be a major task, but nevertheless completely manageable with the proper preparations and approach. This included most importantly, the diverse Quality Survey, which produced applicable information for the risk analysis and inspiring solutions in the form of QA/QC Setup.

Noticing the level of quality awareness and development already during the research was welcoming. Strong commitment regarding the objective was a tremendous support while carrying out the research process. Still, challenges are faced in certain situations and conditions. However, I am optimistic that future implementation of QA/QC setup, together with additional development targets will ensure the ability to achieve quality conformance during NOR delivery projects.

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APPENDICES

Appendix 1. NOR QA Setup – NOR A Today

Appendix 2. NOR delivery process – High level

Appendix 3. Failure Mode and Effect Analysis (1/2)

Appendix 4. Failure Mode and Effect Analysis (2/2)

Appendix 5. Catalyst Milestone 01 – Internal Order

Appendix 6. Catalyst Milestone 02 – Catalyst kick-off

Appendix 7. Catalyst Milestone 03 – Design kick-off

Appendix 8. Catalyst Milestone 04 – IPI review

Appendix 9. Catalyst Milestone 05 – Design review

Appendix 10. Catalyst Milestone 06 – Project design review

Appendix 11. Catalyst Milestone 07 – FAT & Dispatch

Appendix 12. Catalyst Milestone 08 – Documentation

Appendix 13. Catalyst Milestone 09 – As-delivered

Appendix 14. Quality Checkpoint 01 – Project Evaluation

Appendix 15. Quality Checkpoint 02 – Project Quality Plan

Appendix 16. Quality Checkpoint 03 – Project scope

Appendix 17. Quality Checkpoint 04 – Design input

Appendix 18. Quality Checkpoint 05 – IPI & 1st BOM

Appendix 19. Quality Checkpoint 06 – D-message

Appendix 20. Quality Checkpoint 07 – Final BOM

Appendix 21. Quality Checkpoint 08 – Purchasing

Appendix 22. Quality Checkpoint 09 – Supplier FAT

Appendix 23. Quality Checkpoint 10 – Module Incoming Inspection

Appendix 24. Quality Checkpoint 11 – In-house FAT

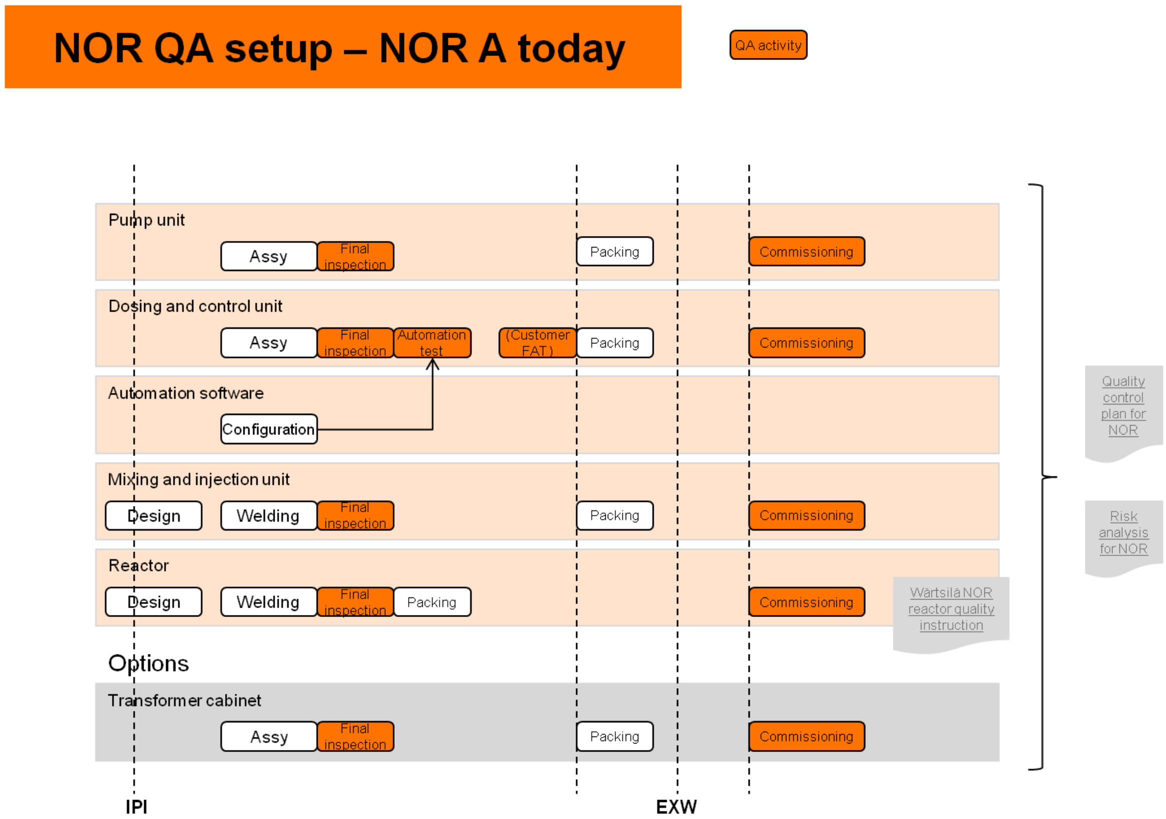
Appendix 25. Quality Checkpoint 12 – Auxiliary FAT

Appendix 26. Quality Checkpoint 13 – Dispatch

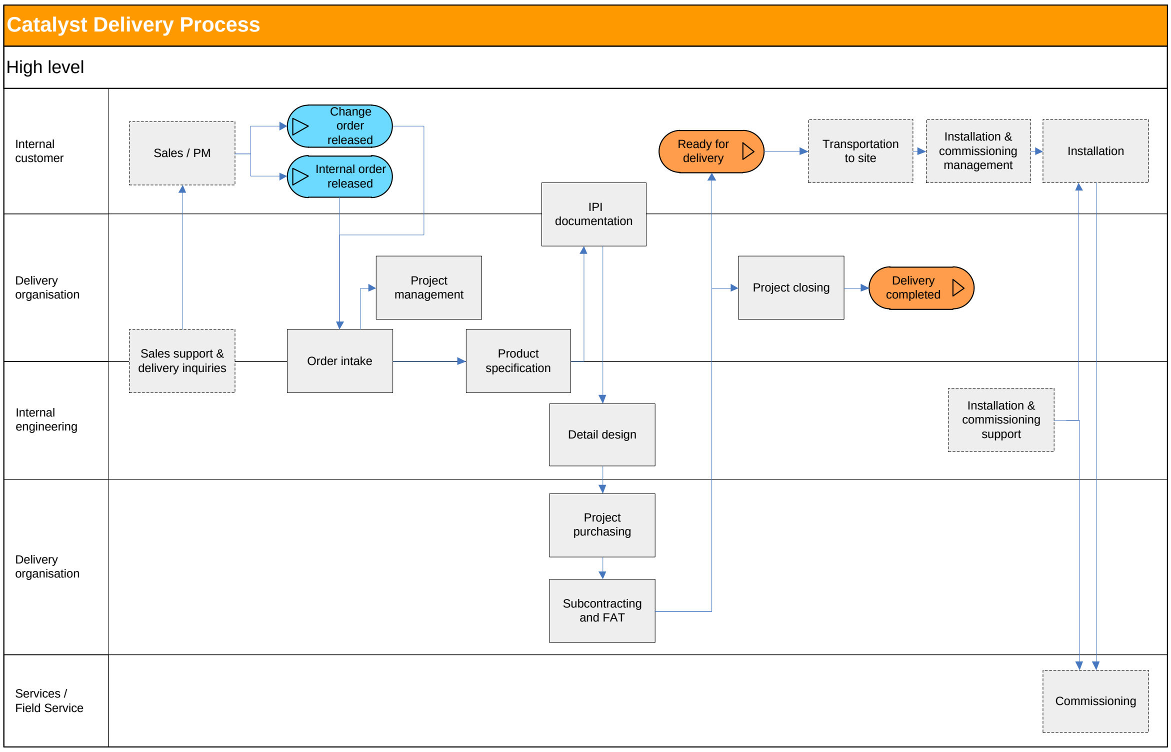
Appendix 27. Quality Checkpoint 14 – As-built

Appendix 28. Quality Checkpoint 15 – As-delivered

APPENDIX 1. NOR QA Setup – NOR A Today



APPENDIX 2. Catalyst Delivery Process – High level



APPENDIX 3. Failure Mode and Effect Analysis (1/2)

Failure modes and effects analysis (FMEA)

Project:	**Risk assessment for catalyst delivery process**	Date:	**31.10.2013**
FMEA Team:	Joona Piirto	Prepared by:	Joona Piirto

SEV = How severe is effect on the customer?
OCC = How frequent is the cause likely to occur?
DET = How probable is detection of cause?
RPN = Risk priority number in order to rank concerns; calculated as SEV x OCC x DET

Add Row

Function	Responsibility	Process Function Recuirement	Potential failure mode	Potential failure effects (internal/end customer perspective)	SEV	Potential causes	OCC	Current process controls	DET	RPN
		What is the step?	In what ways can the step go wrong?	What is the impact on the customer if the failure mode is not prevented or corrected?		What causes the step to go wrong? (i.e., How could the failure mode occur?)		What are the existing controls that either prevent the failure mode from occurring or detect it should it occur?		**0**
Order intake	Catalyst Deliveries - Delivery projects	Review (NoC) & Technical Specification	Inadequate level of information, mutual understanding, requirements	Delayed design work, quality non-conformancies	7	Specification & design requirements unsureness, unaware quality problems, TS defined inadequatly before, Mixing pipe not defined, problem may not be discovered until IPI, How complete is the scope definition, size and amount, content varies, managing changes along the way	4	Catalyst kick-off	8	**224**
		Send order conf. to BU	Forgetting	Information breakdown, no real effect	2	Human error	1	Email cc to GM	4	**8**
		Project creation	Incorrect MPS update, WDMS serial number + metadata, Project schedule, SAP Project (E&FL)	Insufficient information, unrealistic project delivery schedule, deviations from agreed schedules, ei aiheuta niin ongelmia	5	Late project start, doing everything in a hurry	2	Noticed when needed	3	**30**
	[illegible]		Non-conformance of	[illegible]				[illegible]		

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APPENDIX 4. Failure Mode and Effect Analysis (2/2)

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APPENDIX 5. Catalyst Milestone 01 – Internal Order

Catalyst Milestone 01 – Internal Order

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QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

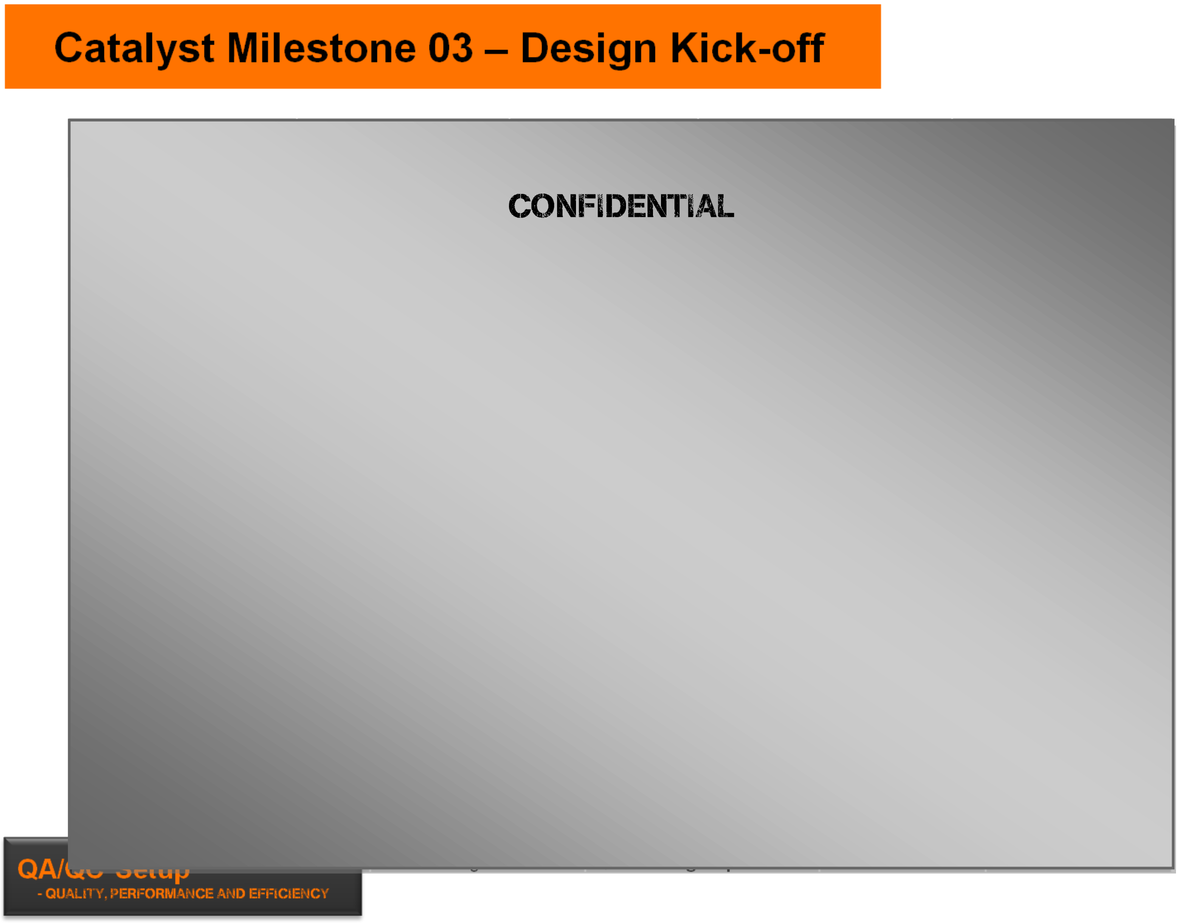
*if applicable

APPENDIX 6. Catalyst Milestone 02 – Catalyst Kick-off

Catalyst Milestone 02 – Catalyst Kick-off

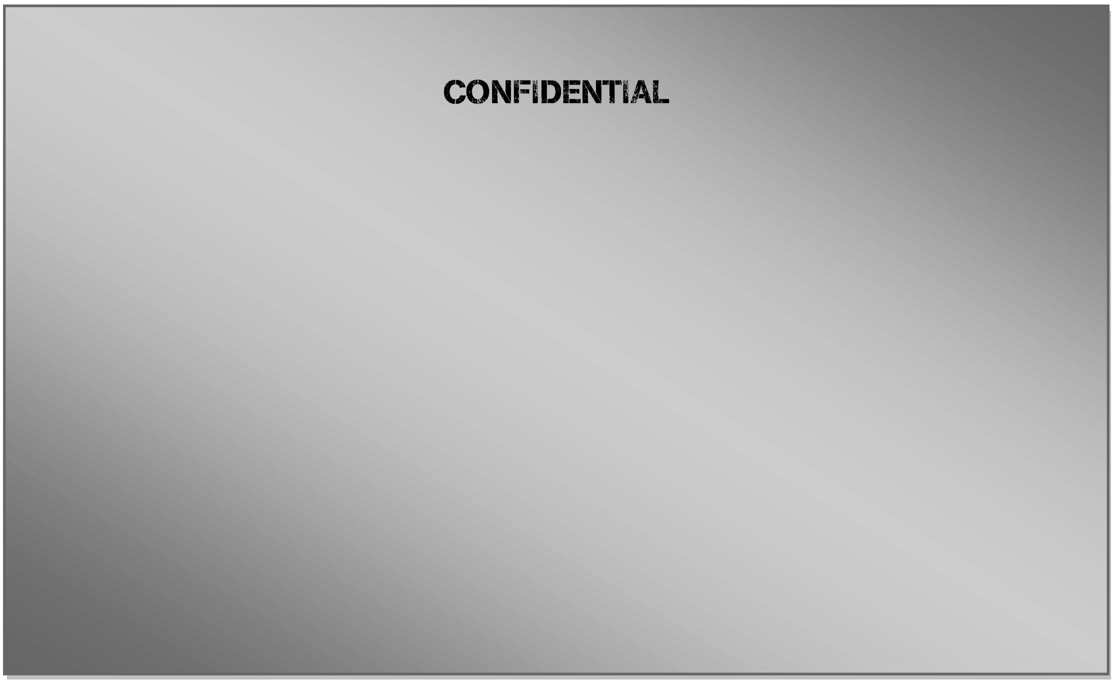
QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

APPENDIX 7. Catalyst Milestone 03 – Design Kick-off



APPENDIX 8. Catalyst Milestone 04 – IPI Review

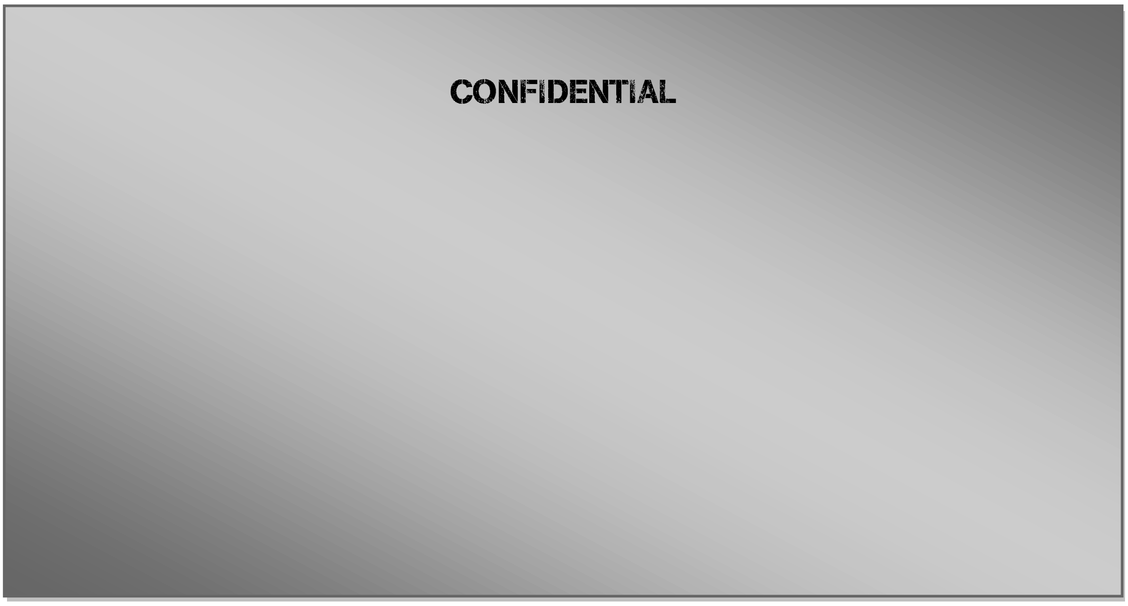
Catalyst Milestone 04 – IPI Review



QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

APPENDIX 9. Catalyst Milestone 05 – Design review

Catalyst Milestone 05 – Design review



QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

*if applicable

APPENDIX 10. Catalyst Milestone 06 – Project design review

Catalyst Milestone 06 – Project design review

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QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

**if applicable*

APPENDIX 11. Catalyst Milestone 07 – FAT & Dispatch

Catalyst Milestone 07 – FAT & Dispatch

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QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

APPENDIX 12. Catalyst Milestone 08 – Documentation

Catalyst Milestone 08 – Documentation

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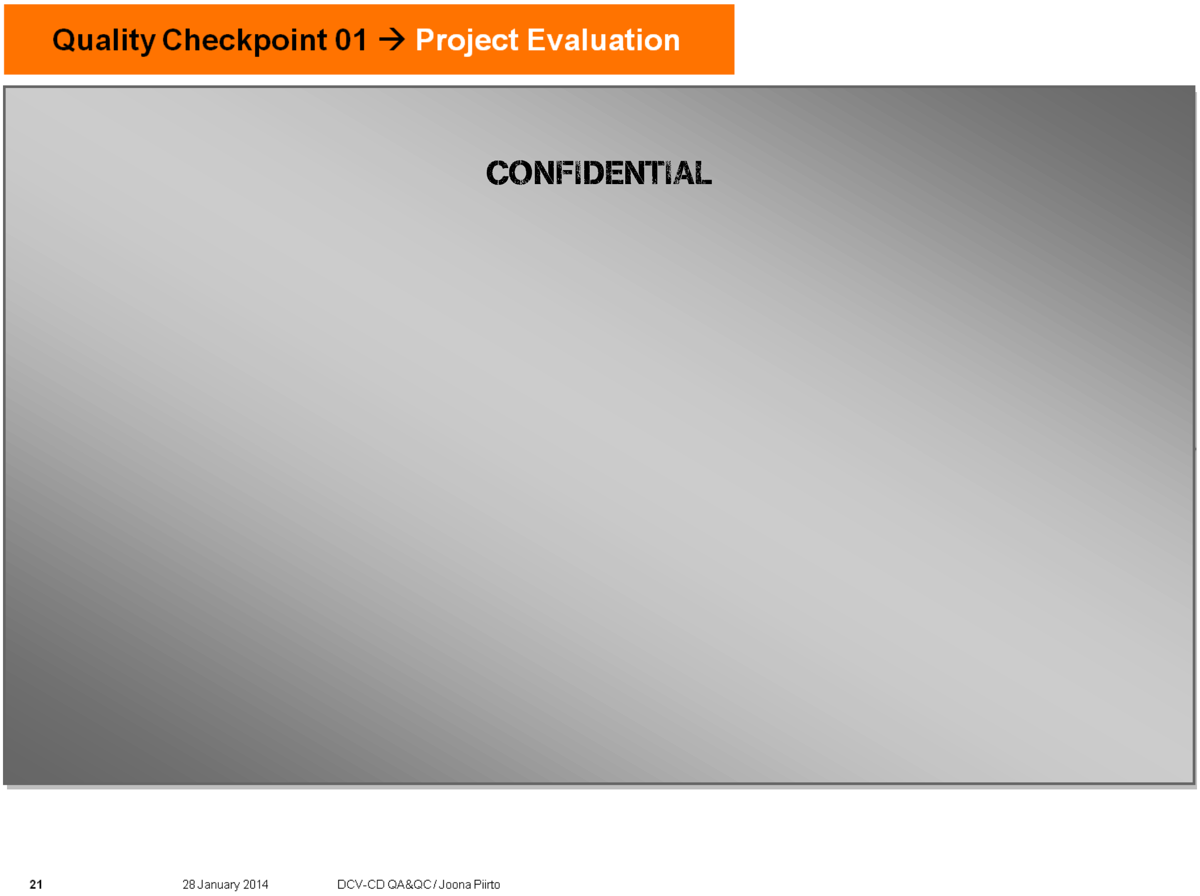
QA/QC Setup
- QUALITY, PERFORMANCE AND EFFICIENCY

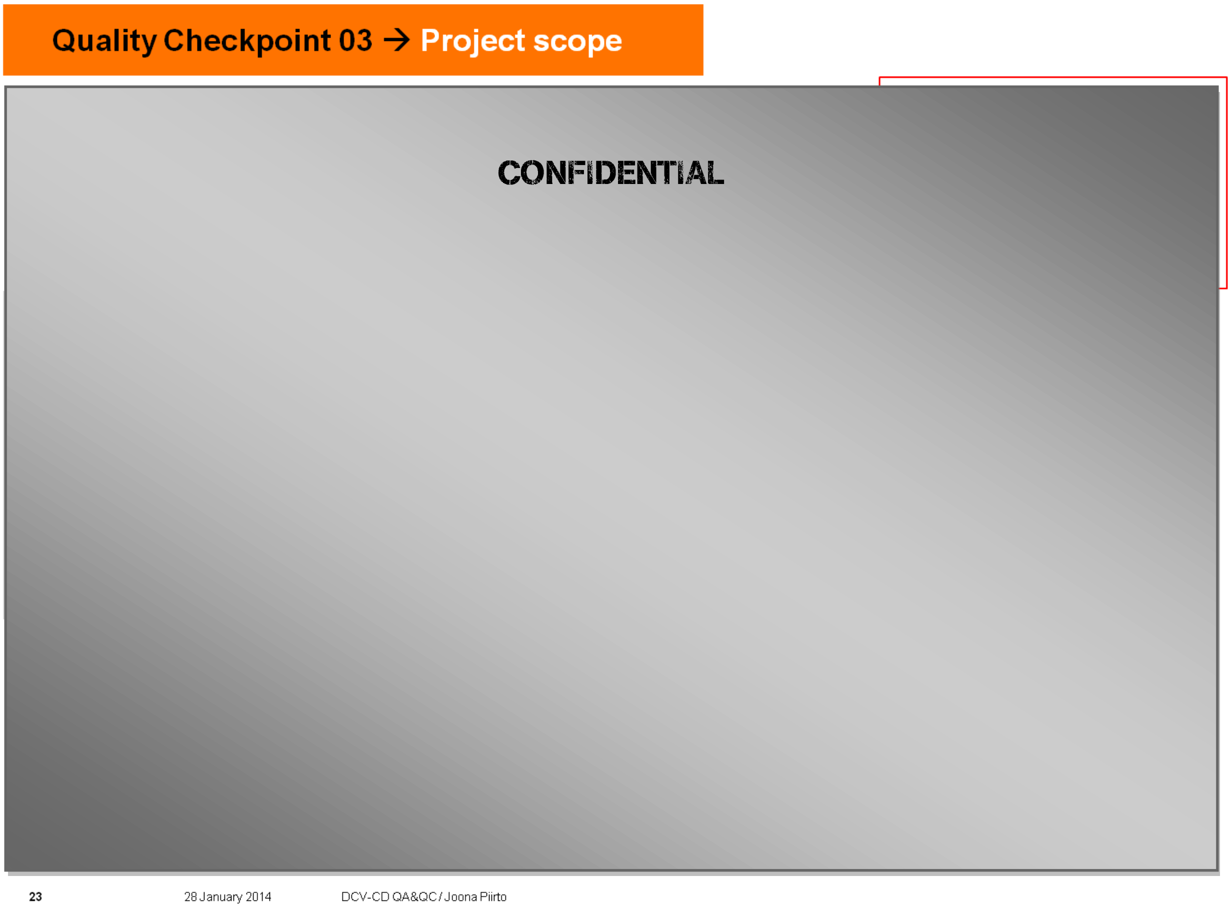
APPENDIX 13. Catalyst Milestone 09 – Delivery review

APPENDIX 14. Quality Checkpoint 01 – Project Evaluation

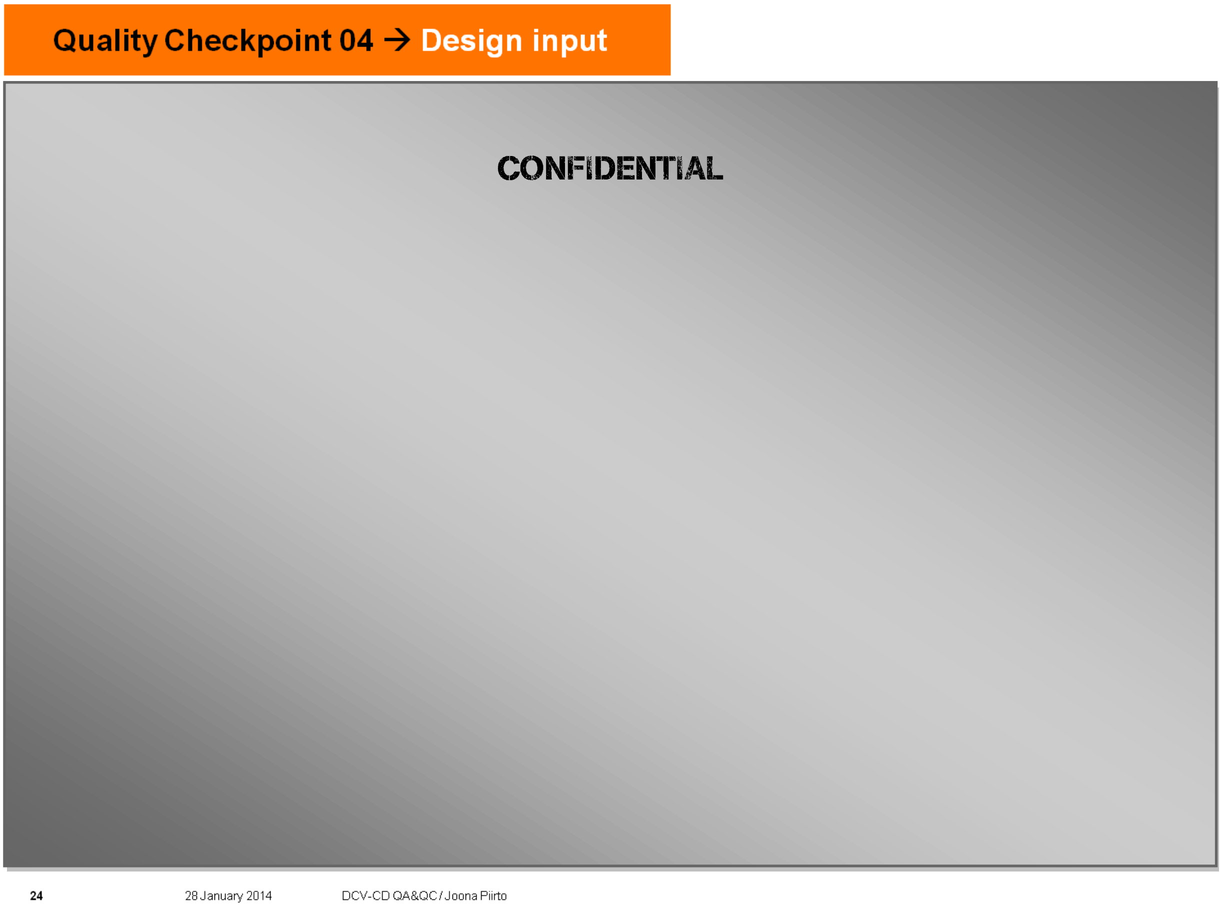


APPENDIX 15. Quality Checkpoint 02 – Project Quality Plan

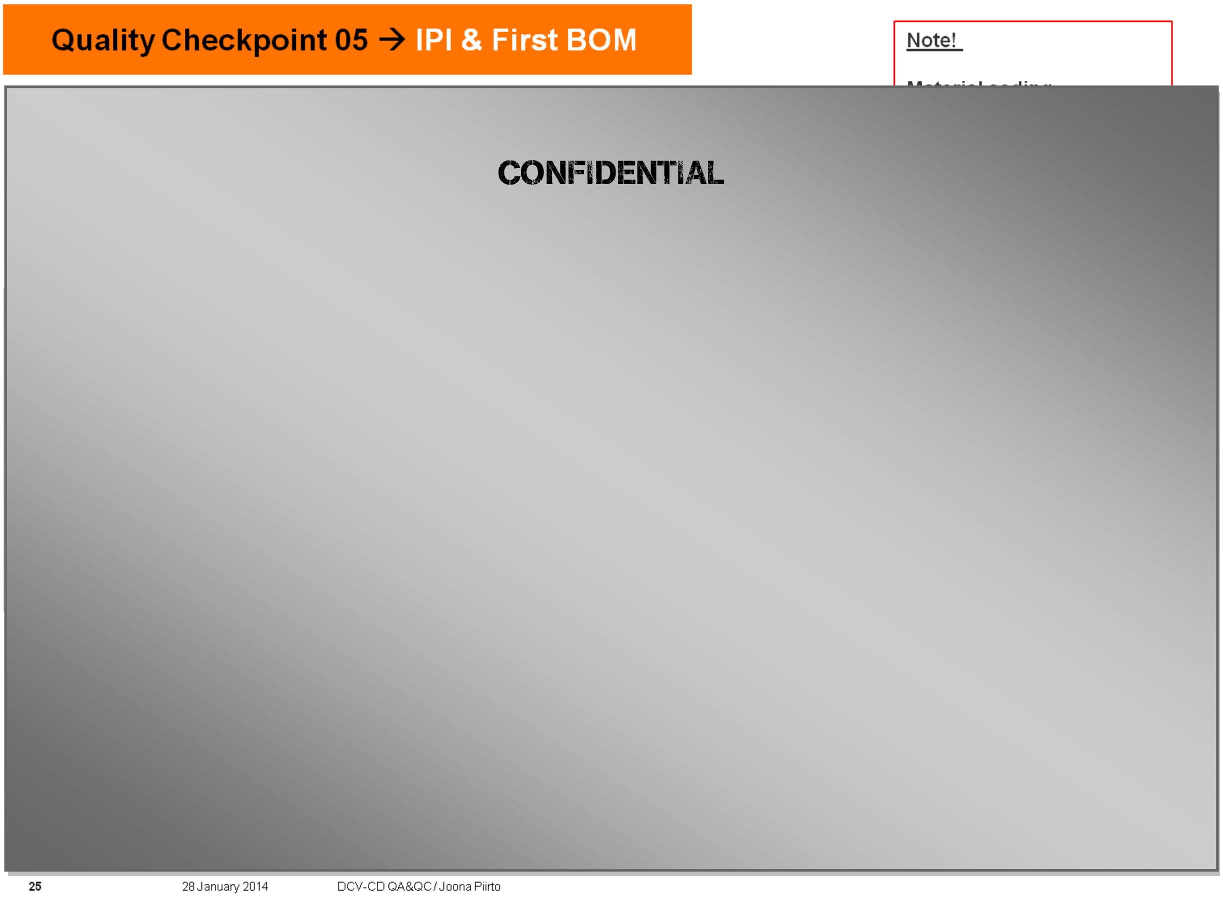
APPENDIX 16. Quality Checkpoint 03 – Project scope



APPENDIX 17. Quality Checkpoint 04 – Design input



APPENDIX 18. Quality Checkpoint 05 – IPI & First BOM



APPENDIX 19. Quality Checkpoint 06 – D-message

Quality Checkpoint 06 → D-message

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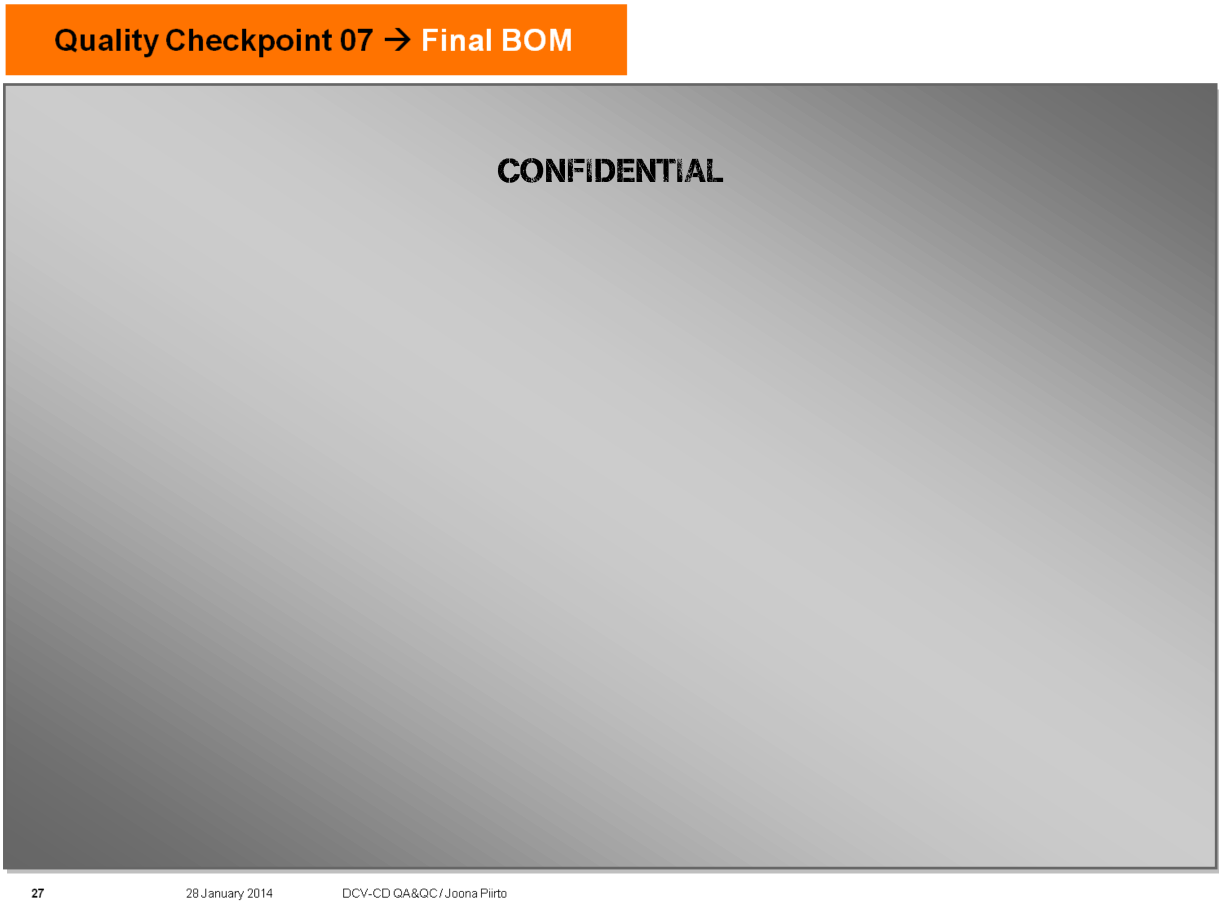
APPENDIX 20. Quality Checkpoint 07 – Final BOM



APPENDIX 21. Quality Checkpoint 08 – Purchasing

Quality Checkpoint 08 → Purchasing

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APPENDIX 22. Quality Checkpoint 09 – Supplier FAT

Quality Checkpoint 09 → Supplier FAT

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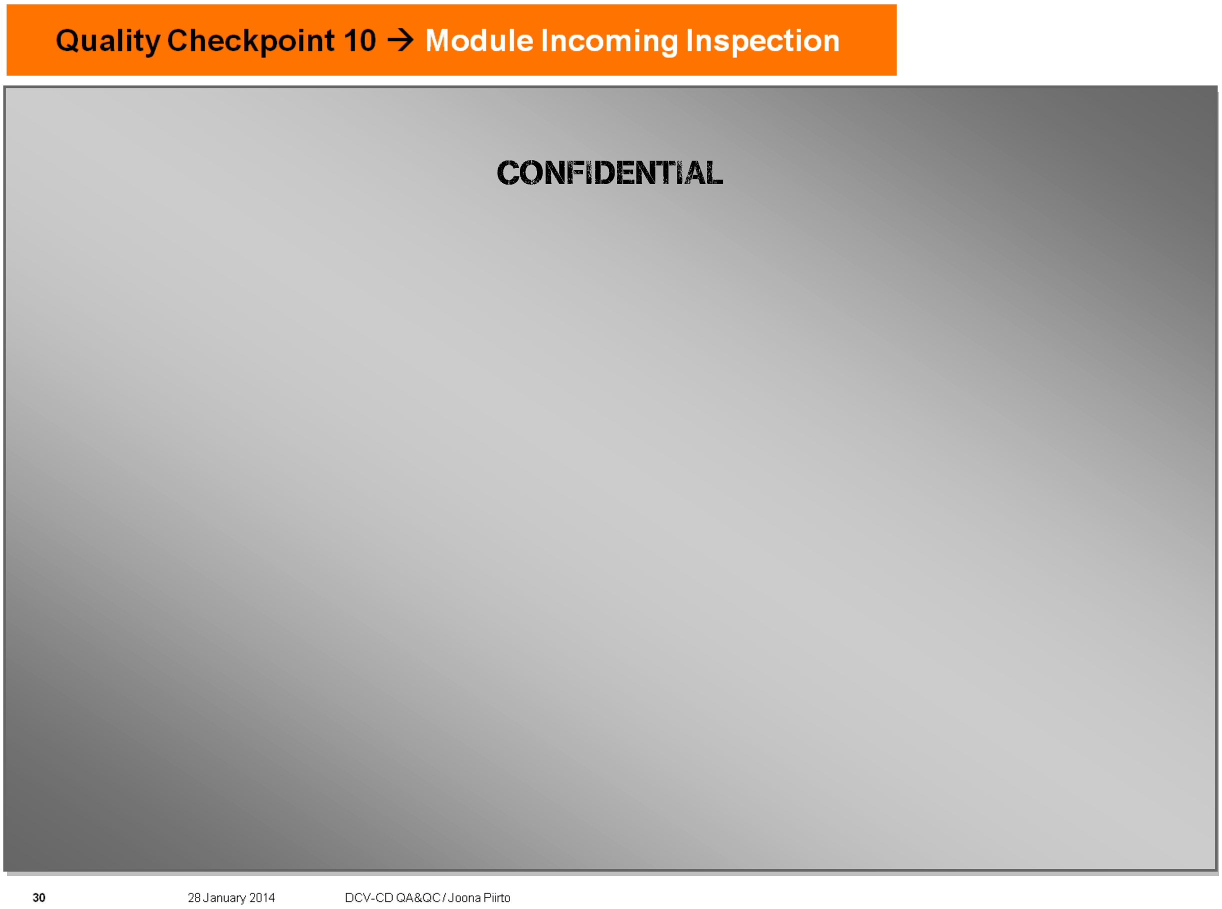
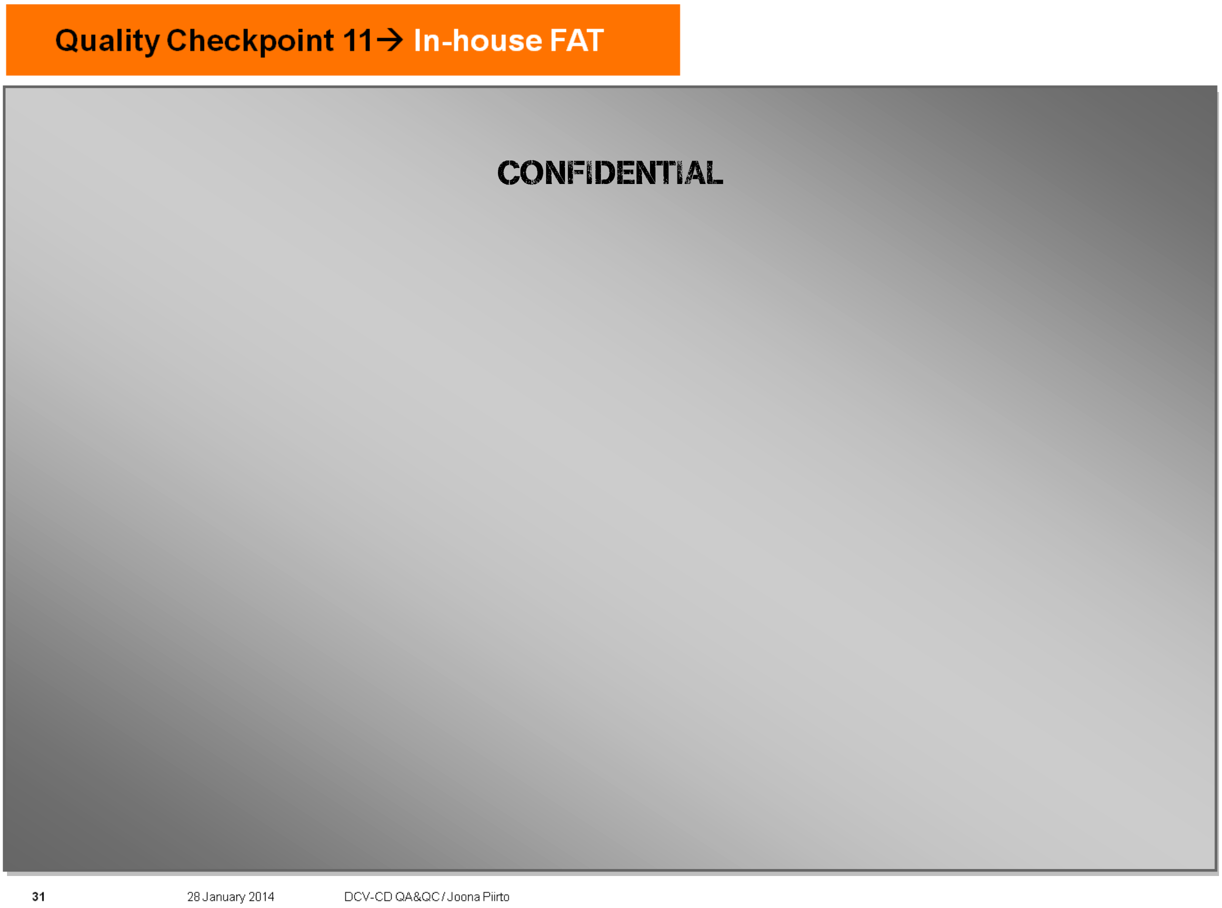
APPENDIX 23. Quality Checkpoint 10 – Module Incoming Inspection



APPENDIX 24. Quality Checkpoint 1 – In-house FAT



APPENDIX 25. Quality Checkpoint 12 – Auxiliary FAT

Quality Checkpoint 12→ Auxiliary FAT

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APPENDIX 26. Quality Checkpoint 13 – Dispatch

Quality Checkpoint 13→ Dispatch

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APPENDIX 27. Quality Checkpoint 14 – As-built

Quality Checkpoint 14→ As-built

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APPENDIX 28. Quality Checkpoint 15 – As-delivered

Quality Checkpoint 15→ As-delivered

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