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Developing Quality Assurance Dashboard for ETO Manufacturing in an SME

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Global Manufacturing Management
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Summary

Purpose: the purpose of this research is to develop quality assurance dashboard for Engineer To Order manufacturing based Small to Medium Enterprises. Based on this research, quality-related indicators for dashboard content were identified for engineer-to-order SMEs, and a dashboard was developed for a case company confirming SMEs' capabilities.

Design: The research is based on literature study and case study. Following research questions are answered with literature study to identify dashboard content for ETO based SMEs and to establish step by step guideline to develop the dashboard. Case study is carried out with the development of a quality assurance dashboard for the case company to understand complete phenomenon with practical implementation.

Findings:

RQ1: What are the critical factors need to be considered for identification of quality assurance indicators for manufacturing of ETO based SMEs?

Critical quality factors that can be considered for identification of the quality assurance dashboard for ETO bases SMEs are a) customer satisfaction, b) Process Quality metrics, c) Supplier Quality Metrics d) Process Improvement e) Employee involvement

RQ2: What are the dashboard indicators for quality assurance for manufacturing for ETO based SMEs?

Based on critical factors, from literature study, most significant indicators identified for ETO based SMEs are on time deliver, Rework cost, Defect Cost, Top performer, top supplier indicators

RQ3: How to develop QA dashboard for manufacturing for ETO based SMEs

To develop a dashboard, ten specific steps are identified that considered capabilities and challenges of ETO based SMEs

The case study illustrates how the guidelines are simple to follow for an SME with challenges. Moreover, the developed dashboard with dummy data shows how it would be beneficial for SMEs, as well as laying the groundwork for developing a dashboard with actual data.

Contribution: The research filled the gap in identifying quality assurance dashboard content and developing such a dashboard while considering the characteristics and capabilities of SMEs. Further, this research was able to contribute to the practical field since ETO based SMEs can use it to develop a quality assurance dashboard that is specifically tailored to their needs and takes advantage of modern tools.

Limitation: Due to data security concerns, this research uses dummy data to develop the dashboard. As a result, the entire phenomenon and challenges of the actual data collection strategy cannot be uncovered.

Abbreviations

ETO: Engineer to order

MTO: Make to order

ATO: Assembly to order

MTS: Make to stock

CODP: Customer order decoupling point

QMS: Quality management system

QA: Quality assurance

QC: Quality control

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1. Introduction

1.1. Background

The fundamental principle of quality has become an essential element in many manufacturing processes around the world. In the beginning of 1990s research into quality in manufacturing was in rise and researchers focused on how quality should be implemented and the kind of results it brought back to the company. (Eriksson, 2016)Deming (1982) demonstrated that to dominate the market, an emphasis on quality is vital that result is reduction of cost due to improved quality, fewer mistakes in process, less rework, and delays, as well as better utilization of resources(Daryl Powell, 2022). The stages of quality evolution in organizational work can be categorized into four categories: inspection, quality control, quality assurance, and total quality management(Dale, 2007).

Quality assurance is critical to the growth of any business. The American society of quality defines Quality assurance as ‘’all the planned and systematic activities implemented within the quality system that can be demonstrated to provide confidence that a product or service will fulfill requirements for quality."(Coleman, 2020). It includes an organized system of managing processes, items, and services in such a way as to ensure that they meet the needs and expectations of customers(EPA, 2002). A good quality assurance process leads to cost savings for an SME, thereby enabling the SME to offer lower prices to its customers and win more market share(Mutingi & Chakraborty, 2021). In recent decades, economies across the world have significantly benefited from the growth, innovation, and success of SMEs. The EU Commission defines a medium-sized company as having less than 250 employees or a turnover of less than 50 million Euro (and/or an annual balance sheet total of less than s43 million); a small-sized company as having less than 50 employees or a turnover of less than 10 million Euro (and/or an annual balance sheet total of less than 10 million Euro) ("User guide to the SME Definition," 2020). In the European Union, SMEs employ almost 84 million people in 2021(Clark, 2021). Moreover, small and medium-sized companies generate innovative ideas and foster entrepreneurship throughout the EU, this enables competitiveness and job creation.

Enterprise	Max. People Employed	Max. Annual Turnover	Max. Annual Balance Sheet Total
Small	< 50	≤ € 10 million	≤ € 10 million
Medium	< 250	≤ € 50 million	≤ € 43 million

Table 1.1: Classification of SMEs ("User guide to the SME Definition," 2020)

Thus, SME involvement in scientific research is of utmost importance due to its contribution to the economy. SMEs face stiff competition and various kind of challenges to survive in this uncertain global market. The small manufacturer experiences challenges about quality in manufacturing like lack of people and skills, non-existent quality system etc(Norton, 2007). SMEs play an increasingly important role in subcontracting for organizations competing in an increasingly global market, regardless of their size or sector. Larger organization tends to depend on suppliers mostly which are SMEs. To improve their product quality and being competitive in the market, larger organization need quality products from SMEs. Therefore, SMEs need to assure quality for manufacturing and their products(Ghobadian & Gallear, 1996). With the recent advancement of technology, different types of dashboards have become extremely popular over the past few years concerning quality assurance. In the academic literature, this development has not been reflected, resulting in scientific gaps. Dashboard is a graphical visualization tool that provide insight with representation of information and data in systematic way to facilitate monitoring, analyzing and taking rapid decisions (Pauwels et al., 2009). Only consulting farms and software companies are making this type of dashboard based on their own skills. (J. v. Soest,2013). Moreover, as of now, most of the existing dashboard development procedures are usually geared toward large organizations with advanced information system which are too complex for SME. Characteristics and challenges of SMEs should be considered for developing dashboard for SME. There is lack of research that addressed element of dashboard for quality assurance dashboard and provide overall guideline to develop a dashboard for QA in SME. Therefore, the fundamental objective of this project is to develop a QA dashboard with identification dashboard content for SMEs considering capabilities of SME. This project presented a case-based approach to develop a prototype QA dashboard for the case company based on findings in the literature study. The case method allows researchers to answer why, what, and how with a reasonable understanding of the complete phenomenon. In this project, Probad AB, an innovative manufacturing industry that is characterized as an SME, is the case for this single case-based research. With a focus on quality, functionality, and flexibility at the heart

of everything Probad AB does, the company manufacture and deliver prefabricated bathroom cabinets made from steel fiber reinforced concrete.

1.2. Research gap:

With the advancement of technology and industry 4.0 revolution, Information plays crucial role to get competitive advantages for companies. Dashboard is a digital tool that is capable to display most important information based on user need. For example, in manufacturing industry, if any manager wants to know about vital information of a manufacturing plant like production volume, Customer delivery etc. than the manager can monitor these from a dashboard. And dashboard display vital information with simple graphical representation that facilitate decision making. Dashboard can be categorized as I4.0 toolkit.

Nowadays, MNEs are highly utilizing this tool in their business compared to SMEs. Researchers, software companies and consulting farm are more focused with implementation of digital tools like this for MNEs. According to recent researches, most established digital tools like dashboard are developed for or by larger MNEs(Mittal, Romero, et al., 2018),(Horváth & Szabó, 2019),(Soest, 2013). On the other hand, SMEs priorities and capabilities are largely different from MNEs. Moreover, due to limitation of knowledge, experience and resources SMEs must face various challenges to implement any digital tool. In addition, SMEs are struggling with awareness to know about recent technologies that are constantly developing in this era. This led to a research gap for SMEs to develop dashboard considering SMEs need. The research gap is more prominent for quality assurance dashboard for SMEs. There is different type of dashboard available in manufacturing industry in various level from shop floor to management level. Some research is found for developing dashboard for sales and production floor(Eckerson, 2010; Soest, 2013; Vilarinho et al., 2018). There is clear lack of research for dashboard content for quality assurance dashboard that consider capabilities and characteristics of an SMEs company.

1.3. Research objectives

As discussed in background and research gap that quality system used is inadequate in small manufacturing companies with less or no idea of quality assurance dashboard. The objective of this research to develop a dashboard focusing on dashboard content for quality assurance and considering characteristics and capabilities of SMEs. The key components of a dashboard are presenting a summary of metrics and integrating underlying drivers to communicate performance throughout the organization (Pauwels et al., 2009). Metrics of dashboard is also known as performance metrics, performance indicators and/or as performance measure. For identification

of indicators organization must identify factors based on overall objective of the dashboard. Therefore, it is crucial to investigate the critical factors and performance indicators based on the critical factors to develop QA dashboard for SMEs.

However, for dashboard content regarding quality of manufacturing industry, CODP is an important consideration. The position of CODP influences the process of operation hence quality. The more CODP is placed towards the downstream of the supply chain the higher the variation of the products. When every product manufactured is unique, metrics of quality change compared to repetitive manufacturing. Moreover, with the complexity of manufacturing processes and increased variety of products the fields of improvement and quality assurance of processes varies.(B. Illés, 2017). In this project, case company is identified as ETO company. Therefore, this research is further narrowed down to ETO based SMEs. Therefore, redefined overall objectives for this project is: **''To develop a quality assurance dashboard for ETO based SMEs''** To achieve the overall objective, following research questions are formulated:

1. What are the critical factors need to be considered for identification of quality assurance indicators for manufacturing of ETO based SMEs?

Use of dashboards promotes visual management of information which facilitates decision making for performance management. Indicators are key to constructing an effective dashboard that facilitates decision making. Identification of metrics for measuring quality assurance requires identifying number of critical factors that influence overall quality assurance in an organization. The critical factors are the principles that are fundamentally associated with the objective of a quality management system, so they enable a systematic method of identifying quality assurance indicators. Considering the objective of this research, it discusses the identification of these critical factors for ETO-based SMEs.

2. What are the dashboard indicators for quality assurance for manufacturing for ETO based SMEs?

One of the most significant part of developing dashboard is to having indicators that can be presented in the dashboard. After identification of critical factors, indicators of quality assurance dashboard need to be identified based on critical factors. Dashboard is built mainly based on effective indicators. Indicators, varies with the CODP of the company. Considering objective of the thesis, indicators related to the quality assurance for ETO based SMEs will be identified-

3. How to develop QA dashboard for manufacturing for ETO based SMEs?

A step-by-step procedure for developing a dashboard considering quality assurance content and capabilities of ETO based SMEs will be established in this project. To get full understanding of nature and complexity of the phenomenon with benefits and challenges for SMEs, a prototype dashboard will be developed for a case company following the established steps.

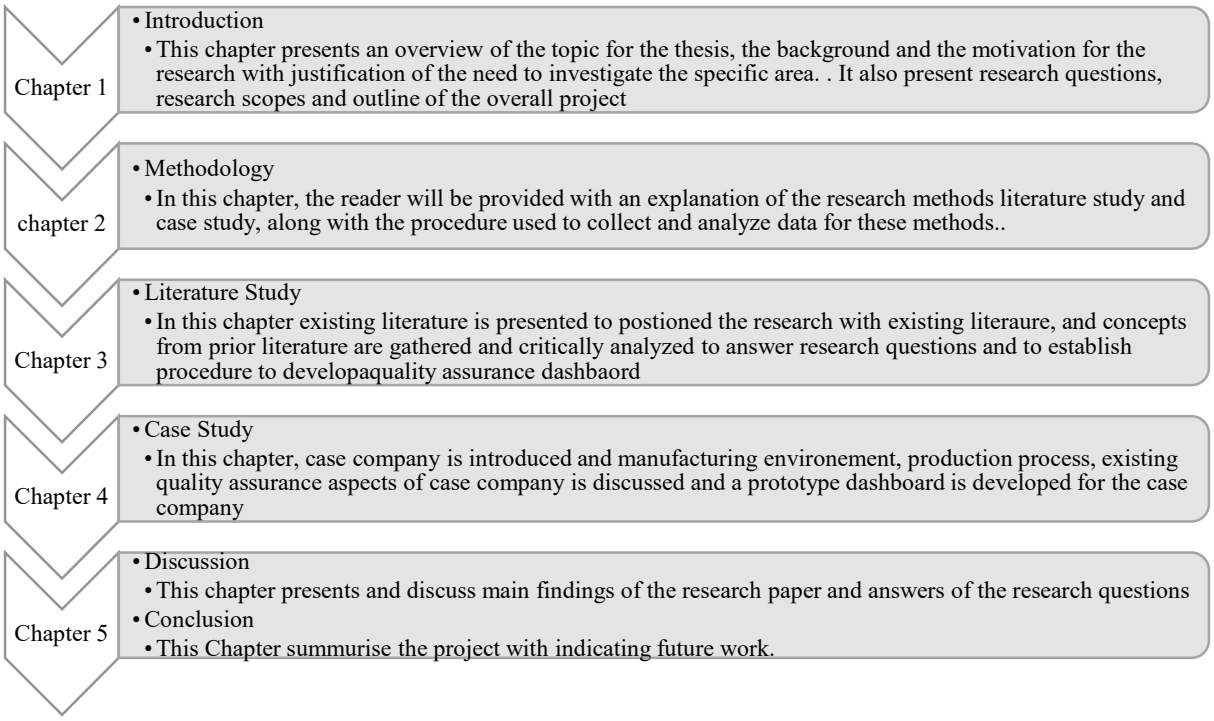
However, before formulation the research question, in this project CODP of the case company was identified. Therefore, the research includes understanding of different CODP and identified CODP of the case company based on literature study. Moreover, this project needs to access the existing system of the case company. Therefore, below tasks were carried out to support the overall thesis.

1. Identification of different manufacturing environment from literature review
2. Identification of manufacturing environment of case company based on literature study
3. To assess the quality assurance system of case company

1.4. Research scope:

Quality and Quality assurance is a broad topic that covers many areas in research. This project is narrowed down to quality assurance of production process. The case company of the master's thesis is an SME and according to the research objective, this thesis will focus on quality assurance of ETO based SMEs. For designing dashboard which is fundamental objective of the thesis , the project will mainly focus on elements related to quality assurance. Visual design management related to interface, and it issues of dashboard will not be covered by this project.

1.5. Research Structure



2. Methodology

The purpose of this chapter is to introduce the methodology used in this thesis. How data is collected and how it is interpreted depends on the methodology used. The first part examines how the literature study was conducted and how data is collected for this thesis. The objective of the literature study is to borrow existing concept and filling the gap in research with answering the research question. The final part describes how the empirical study was conducted and data for empirical study is collected. According to (Karlsson, 2016), with case study an understanding of the phenomenon can be gained by observing actual practice, and meaningful, relevant theory can be generated from it. As the overall objective of the thesis is to develop a dashboard, after establishing procedure to develop a dashboard with literature study, case method will enable developing the dashboard in actual practice which will provide better understanding of the phenomenon and theory developed in literature study.

2.1. Literature Study

Literature study of this thesis is focusing on two parts. In first part, the objective of the literature study is related to the research task to identify characteristics of different CODP. By identifying characteristics from literature, CODP of the case company can be identified that narrowed down the research questions and overall research objective. There are several research on CODP and characteristics of different CODP with similar and different opinion to differentiate the characteristic of CODP. From literature study, characteristics of different CODP will be identified and based on that survey questionaries will be developed to investigate the CODP of the case company. Below key words related to CODP will be used for this part of literature study. In second part, literature study will strive to answer the research questions and will facilitate developing procedure to develop a quality assurance dashboard for ETO based SMEs.

Sources: Scopus, Science Direct, Google Scholar, NTNU BIBSYS, ProQuest

Research Question and task	Key Words set 1	Key Words Set 2
For research task for CODP	CODP, Engineer to order, make to order, Assembly to order, Make to Stock,	Definition, Manufacturing environment,

	Customization, standardization	Characteristics, Types, production environment
Understanding of QA	Quality Assurance, Quality System, QA, QMS, QC,	Definition, Manufacturing, Process, Tools, Customized production, SME, Small Companies, ETO,MTO
Research questions related to factors and indicators	Principles, criteria, factors, Performance management, Performance measurement, KPI, metrics, Indicators	Quality, quality assurance, QA, ETO,SMEs, SME
Research questions related to dashboard development	Dashboard	Definition, development, design, purpose, SMEs, ETO, manufacturing

Table 2.1: Data collection method for literature study

2.2. Case Study:

The result of literature study will be utilized in case study for empirical evaluation to define quality metrics for SME and based on CODP. For research task to identify CODP of the company, interview will be carried out. To develop QA dashboard content and to develop dashboard observation and document study is carried out to collect practical data.

Research Question and task	Data Collection methodology	Description
CODP,	Observation, Interview	Observation of production process, Interview of professional to get deeper understanding of production characteristics

Existing QA system	Observation, Document Study	Understand existing QA system, Studying existing QA documents
QA Dashboard	Observation and discussion with supervisor	Finding out benefits and challenges and observation for idea generation

Table 2.2 Data collection for case study

2.3. Research design based on methodology:

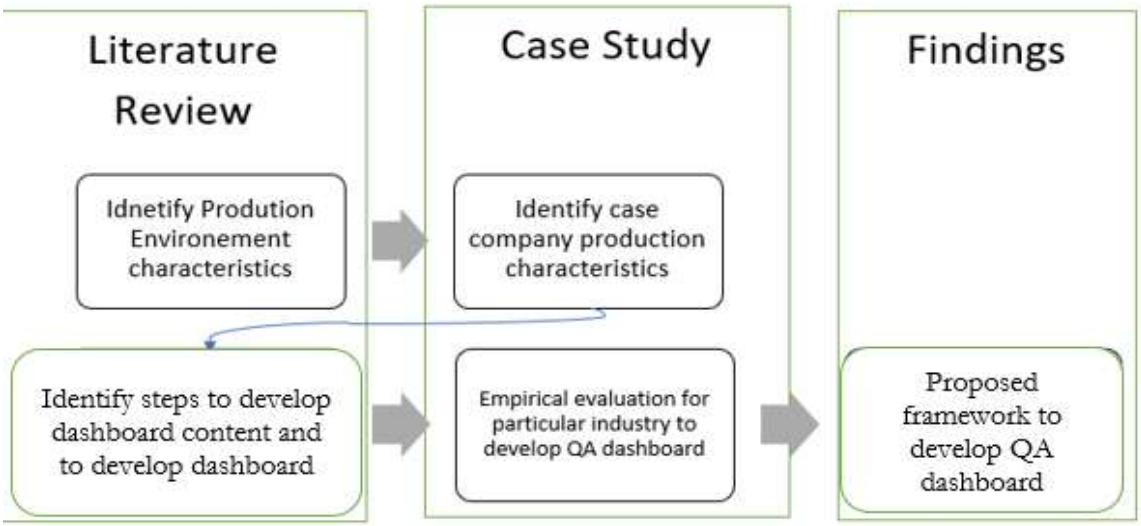


Figure 2.1: Research design

3. Literature Study

The purpose of this chapter to gather existing concepts to achieve research objective and to fulfil the scientific gap with established procedure to develop the quality assurance dashboard. With the help of the literature study, research questions will be answered to identify dashboard contents and to establish the procedure to develop QA dashboard for e ETO based SME. Before gathering existing concepts and findings, the literature study identified characteristics of different CODP. This is due to fulfill the task related to identify CODP of the case company and to understand characteristics of the case company. Therefore, first part of he literature study is dedicated to the mentioned thesis task to understand different CODP and to identify the case company CODP.

3.1. Characteristics of Company:

For many companies to achieve customer satisfaction, they must align their operations with the needs of their customers on the continuum between standardization and customization. Alternatively, there is a risk of mismatch, which can ultimately lead to processes being inefficient or simply failing to meet customer expectations. To deliver total value to the customer, it is critical to consider the customer order decupling point (CODP) when structuring and configuring supply chains.(Manuel Schoenwitz, 2017). Customer order decoupling points (CODPS) are aimed at addressing the point from where customer is engaged in the manufacturing process.(J. Gosling, 2017) According to Soest, it is the point in the manufacturing process flow that differentiates the standardized production flow from the customized production flows(Soest 2013) It provides a framework in manufacturing operation for choosing between upstream versus downstream approach to operations. Moreover, the CODP includes key properties of a manufacturing system and performance improvement priorities.(Hallgren & Olhager, 2006)

A literature review from (Wikner and Rudberg) reveals that there are four CODPs which are most frequently used: engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS). The further downstream the CODP is positioned the more standardized is product and the further upstream the CODP is positioned the more activities can be based on customer order commitment See figure 1 and 2. (Wikner, 2004)CODP reveals the ability and strategy of an industry to manufacture customized or wide range of products

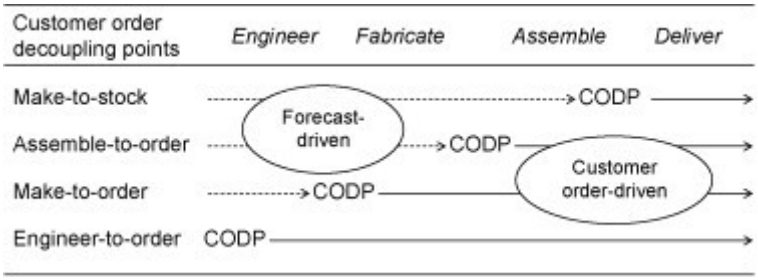


Figure 3.1: Different customer order decoupling points (based on Sharman, 1984)

3.2. Characteristics of different Customer Order Decoupling Point:

For investigating the characteristics of different CODP, researchers divided and discussed important factors in three categories (Olhager, 2003). These are Market related factors, product related factors and manufacturing process related factors.

Market related factors:

In market related factors, lead time is one of the most important factors that influence position of CODP.(Buer et al., 2018) There are two kind of lead time. One is production lead time, and another is delivery lead time. Production lead time refers to the time required to produce the product and delivery lead time refers to the time to produce and deliver the product. If the product lead time has ability to meet customer requirement or if there is need of stock or finished good inventory to meet customer requirement regarding lead time affect the placement of CODP. Delivery lead time is a benchmark to make delivery speed a true competitive advantage, this benchmark is used to improve production lead time(Olhager, 2003).So delivery lead time is market related factor that affects CODP position. Another factor that affects CODP placement that is product demand volatility. If the demand for products can be forecasted than the product demand is low volatility. For low volatily product demands, products can be produced and keep in stock based on forecast. On the other hand, product with high volatility demand cannot be forecasted easily so production starts after order. Therefore, demand is an important factor for CODP placement (Olhager, 2003) Another important factors are product volume/frequency. Volume/frequency refers to The amount of products manufactured per year and the number of times they are manufactured.(Jonsson & Mattsson, 2003). This factor is related to product demand volatility(Olhager, 2003). High volume products are generally with low product demand volatily. Higher the product volume, CODP placement is placed towards the upstream.

Product related factor:

In product related factors, level of customization plays a crucial role for CODP positioning. Another important factor is product variation. Level of customization refers to the amount of control a customer has over the properties of the finished product. According to the developed matrix by buer, if customers are allowed for full specification, it is highly customized order and CODP is placed generally towards downstream like MTO and ETO and on the other hand if customer is not allowed for specification, it is generally standard product with MTS and uppstream CODP. Another important factor is product variety. With large variety of products it became almost impossible to stock product based on demand.(Olhager, 2003). Buer also discussed that if company is able to produce large number of variant than the CODP is generally towards downstream. Buer also mentioned about bill of material and level of process planning factors.(Buer et al., 2018) If the bill of material is complex and has uncountable stage than it is more ETO and MTO production environment. Author mentioned that the dept of product structure indicated the product complexity.

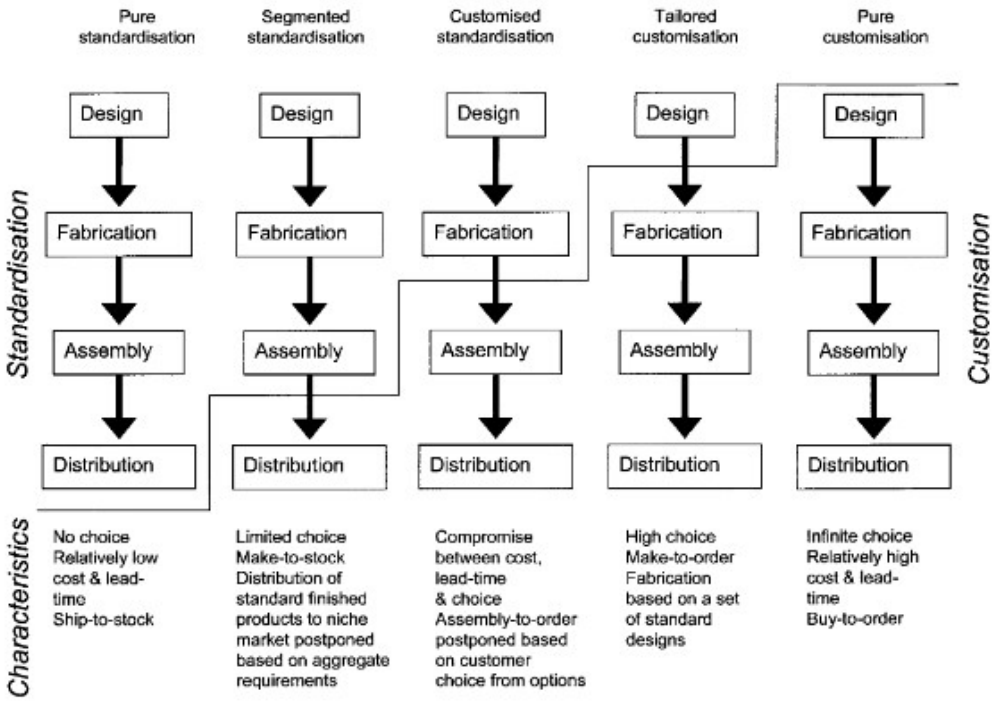


Figure 3.2: Customization versus standardization ((Manuel Schoenwitz, 2017)

Manufacturing related factors:

According Olhager, production lead time is related to manufacturing related factors that should be considered with respect to delivery lead time requirement set by markets. (Olhager, 2003) Production process is also an important factor for CODP. High volume production for high volume demand generally need CODP is placed towards downstream. For high volume production, layout of manufacturing is generally line production. On the other hand, for low volume and customized production CODP is generally Fixed position or job shop production. Quality is generally focused in process for high volume production and product quality focus for low volume and downstream operation. Production planning is based on forecast for upstream and for downstream it is capacity, material availability and S&OP planning. (Olhager, 2003)

Based on factors, below characteristics are found for different CODP.

Category	Market Related	Product Related	Production /Process Related	Ref
ETO	• Uncertainity in Demand • Development of new suppliers • Low volume • High product volatility demand	• Pure customization. • Complex product structure • HighVarety • Customer's involvement throughout the development process.	• Focus on Felxibility. • Fixed Position Layout. • Lot size of one	(Oldebråten, 2017) (Olhager, 2003)
MTO	• Uncertain Market • Low Volume • Pre-defined set of suppliers • High Volatility demand	• Tailored customization • Static Configuration of existing design	• Linear process • Job shop • Small lot size	(Aslan et al., 2012)

		• Customer involvement after design or design within predefined solution		
ATO	• Medium uncertainity • Medium volume of production • Medium lead time for delivery	• Customized standardization to create variety of choice with shorter lead time • Customization enters at late period of production	• Combination of invenotry and capacity to be able to produce based on demand •	(Wemmerlöv, 1984; William et al., 2009)
MTS	Predictable demand of finished goods High Volume low variety demand	Pure Standardization	Focused on efficency Line production	(Wemmerlöv, 1984)

Table 3.1: Characteristics of different CODP

Characteristics of ETO manufacturing:

In engineer to order manufacturing, companies start design of products after customer order. This kind of company generally knows very little about what to produce before the customer involvement(Bertrand & Muntslag, 1993). Customer is involved in design phase of production. So, the products are purely customized based on customer choice. Market demand of ETO based companies are highly uncertain. Production situation is also dynamic as production specification is also uncertain along with market demand. Without involvement of customers, it is hard to predict required parts. This leads to uncertainty in lead time, capacity, and price. Therefore, flexible manufacturing is considered for this ETO manufacturing companies. (Bertrand & Muntslag, 1993) In ETO production, design activities are also part of production and lead time

includes design activities. Production is carried out in fixed layout position as in ETO manufacturing, generally products are large for example ship, airplane.

Characteristics of MTO manufacturing:

The MTO strategy involves production after the customer order has been received(Willner et al., 2014). In this type of company, design is generally completed before the customer order is arrived or design is supplied by the customer. (Kingsman et al., 1996; Saniuk & Waszkowski, 2016). According to Willner, in this type of company, the customer still selects desired design of the products within a pre-defined solution space. Sainul and Waszkowski summarized MTO characteristics as high variety, customized to customer specifications, small lot sizes, long lead times and production is not regular as the order and demand is not regular. Regarding market characteristics, demand of product is uncertain. Strike rates indicate the volatility of the MTO market. Strike rate refers to the percentage of tenders which become firm orders. For MTO company strike rate can be very low as 15%)(Aslan et al., 2012). Product characteristics is tailored customization based on customer specification and high variety. (Saniuk & Waszkowski, 2016) and production is generally job shop with small lot sizes and linear process(Aslan et al., 2012; Willner et al., 2014). Many of the MTO companies are small to medium enterprise companies (Aslan et al., 2012)

Both ETO and MTO is initiated by customer specification. So, it might be confusing between these two CODP characteristics. Degree of uniqueness of the product is an indication to differentiate ETO and MTO.(Oldebråten, 2017) Most of the researchers agreed that ETO manufacturing strategy is driven by customer order and order decoupling point is at design stage. However, there is different opinion in the degree of modification of design. Some researchers argue that ETO companies can modify existing orders while others argue that to be an engineer to order company a completely new design is developed based on customer order. Engineering to order manufacturing involves two different stages. One is nonphysical stage, and another is physical stage. Nonphysical stage is the stage that sets engineer to order manufacturing apart from others CODP strategy. This stage includes tendering, engineering, design, and process planning activities with different possible configurations for new product design or for modification of existing project. (Adrodegari et al., 2015). Product development and engineering processes exists in MTO manufacturing too but there is difference in the process design in PD and engineering process of MTO and ETO production. In MTO, process design is linear for product development and engineering process. Responsibilities to develop or modifying the product is well developed in MTO organization. On the other hand, in ETO manufacturing

engineering process are not highly formalized. There interaction between sales, engineering and production team is high to define product specifications correctly based on customer requirement. (Willner et al., 2014). Another difference is that ETO companies processes are highly knowledge intensive and are often built on tacit knowledge. It is harder to exchange tacit knowledge that is why lot of informal exchange of information sharing is common in ETO companies. On the other hand MTO companies strength lies on skills and competency to perform certain type of operation rather than the actual product. (Kingsman et al., 1996)As MTO companies get order after the design stage, these companies are mainly focused into how to produce with machines and skills they have. (Kingsman et al., 1996)

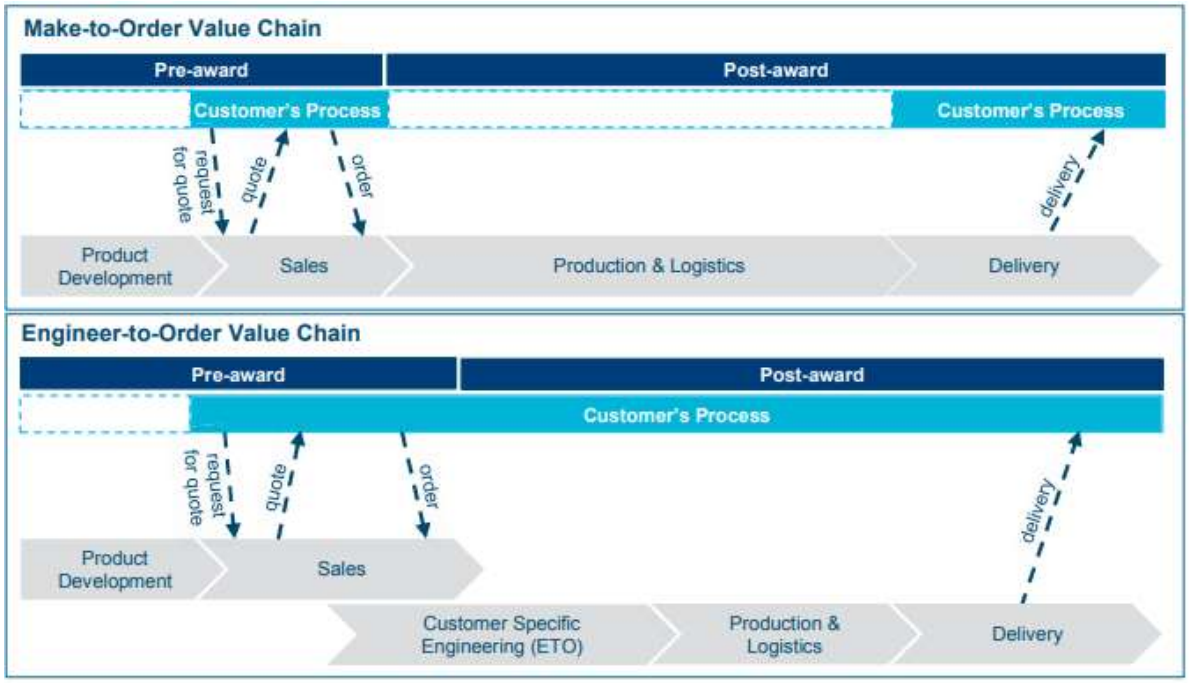


Figure 3.3: ETO and MTO value chain (Willner et al., 2014)

Factors	MTO	ETO	Ref
Product Development (PD) and Engineering process Design	Linear process	Many iterations and loops	(Willner et al., 2014)
Product Structure	static (are initially defined and later only long-term changes are executed)	dynamic (customer-order specific requirement	(Willner et al., 2014),

Strength	Skill and operation based	Design and tacit knowledge based	(Aslan et al., 2012; Willner et al., 2014)
Customer involvement	Customer involvement after design or design within predefined solution	From design stage to throughout the production	(Aslan et al., 2012; Willner et al., 2014)

Table 3.2: Difference between ETO and MTO

3.3. Quality in Manufacturing Industry:

Quality is not a modern concept to consider rather it is considered throughout the ages. This simply can be described with the concept to decide whether any food is in enough good condition to consume or not. However, though this concept is known in many ways, manufacturing industry started nurturing this concept from the early 20th century. During this time, for improving quality in manufacturing industry, best known pioneers are W. Edwards Deming, Joseph Juran, Walter Shewhart and Armand Feigenbaum.

The term quality is described by Juran with two important criteria to grab full understanding of quality for the manufacturing industry. Firstly, it refers to the features of the products that meet customer need. Therefore, quality is related to customer satisfaction and product features. In this sense, better the quality, higher the cost for investment to develop features. The second criteria is freedom from deficiency. It refers to the freedom from error in production, reducing rework, reducing waste, reducing customer dissatisfaction and so on. These criteria reduce overall cost if quality is better.

Product features that meet customer needs	Freedom from deficiencies
Higher quality enables companies to: Increase customer satisfaction Make products salable Meet competition Increase market share Provide sales income Secure premium prices The major effect is on sales. Usually, higher quality costs more.	Higher quality enables companies to: Reduce error rates Reduce rework, waste Reduce field failures, warranty charges Reduce customer dissatisfaction Reduce inspection, test Shorten time to put new products on the market Increase yields, capacity Improve delivery performance Major effect is on costs. Usually, higher quality costs less.

Table 3.3: Definition of quality (Juran, 1998)

In 1920s, the goal of quality was to ensure that engineering requirements were met in the final product. Therefore, it became crucial to better define and control quality after the Industrial Revolution and the rise of mass production. The concept of quality control emerged during that time with developing statistical methods and advanced measuring and testing technologies with increasing degrees of automation. In 1950s

The importance of quality is growing rapidly due to growth in the complexity of product and system. Quality plays a critical role to get competitive edge for the business hence importance of quality is realized even more by the companies and quality assurance concept emerged. ASQ and ISO 9000, both organizations define Quality control and Quality assurance as part of quality management.

Figure 3.4 Components: Relation between quality (Coleman, 2020)

Definition of QA according to ASQ "part of quality management focused on providing confidence that quality requirements will be fulfilled." And Definition of QC according to "part of quality management focused on fulfilling quality requirements."
In most cases, QA activities and responsibilities cover all aspects of the quality system in one way or another, while QC is a subset of QA

Coming back to the history, after the second World War II Japan achieved remarkable success in quality improvement. After that, Quality in manufacturing industry got more attention. Companies started to worry about manufacturing quality in the late 1970s as they realized they were falling behind Japanese manufacturers. Therefore, American consultants came up with several models or systems of which total quality management, or TQM, is the most successful. During this time, for improving quality, W. Edwards Deming, Joseph Juran made remarkable contribution in quality for manufacturing industry. According to Deming, one of reason for success in Japan for quality improvement was engagement of employee from all levels whereas American managers used to barely speak to workforce. This lacking is covered by TQM method as an essential TQM precept is that quality is not just the responsibility of the quality department within an organization, but rather should be a guiding philosophy shared by everyone within the organization

Deming quality management principles covers employee engagement and continuous improvement concept. According to Deming, customer demands, technology, and competitors

were constantly and rapidly changing and to be ahead of these, companies had to continuously improve their products and services (Deming, 1986)

In 1980s many companies also fail to implement quality initiatives. Juran Josheph another pioneer also mentioned in her book that successful companies had common quality initiatives though companies were different. One of the initiatives were that ‘’Measurements were developed to enable upper managers to follow progress toward providing customer satisfaction, meeting competition, improving quality, and so on’’ According to Juran, below responsibility should be for upper management to maintain quality.

These responsibilities included(Juran, 1998):

- Serve on the quality council
- Establish the quality goals
- Provide the needed resources
- Provide quality-oriented training
- Stimulate quality improvement
- Review progress
- Give recognition
- Revise the reward system

On top of that, as discussed Deming emphasized on the importance of involvement of workers. According to Deming, involvement of worker is as important as involvement of managers for ideas and continuous improvement. Further, Deming recommended that companies listen more to their customers to reduce natural variability in their products' quality. Additionally, from monitoring internal processes, it is critical to assess variability and ensure customer satisfaction. (Ebel, 1991, p 18)

Deming was prominent for process quality management. According to TaguchiŽ.1987, quality non-conformity costs rise with the magnitude of the non-conformity. Poor quality manufacturing processes consumes more resources due to scrap and rework for both the work-in-process and for the end products. Defect rates and rejections are also high at the final inspection stage because of this. As a result, identifying and improving processes is crucial in terms of reducing costs and enhancing quality,

A four-step process can be used to describe process quality management(Ahire & Dreyfus, 2000):

- Identifying key processes based on prioritization
- Using quality tools and the identification of improvement strategies, identify the root causes of issues in selected processes
- Implementing corrective actions ranging from error-proofing techniques to resetting local parameters to complete process redesign
- Measurement of process improvements

Overall, Quality management covers continuous improvement, quality improvement, customer satisfaction, organizational learning adaption and goals, performance measurement, quantitative measurement of process and employee engagement. (Juran, 1998). QA and QC are part of quality management where QA is the extension of QC that means QC is part of QA(Peris, 1998). However, Juran described that quality control purpose is to serve people who is directly responsible for conducting operation and quality assurance purpose is to serve people who need to know that all is well with information and assurance(Juran, 1998)

3.4. Critical factors in Quality Management System:

In order to achieve quality for production process and product, most companies crate a management system that focus on quality goals, quality assurance, quality control and quality improvements. There are different quality models developed for systematic approach in quality. The most popular quality models are EFQM, MBNQA and ISO 9000. Brief discussion of some QMS is followed

International Organization for Standardization (ISO)

ISO standards are generally used as the most common standards for a QMS. International experts of ISO/TC 176 developed principles that can be used as basis for quality management.

The seven quality management principles are:

1. Customer focus

The most important principle of QM is to focus on customer. Meeting customer requirement and exceeding expectation can bring sustainable success in business. Suggested action by ISO to be customer focus includes understanding customers need and expectation. keeping the entire organization informed about customer needs and expectations, Measuring and monitoring customer satisfaction.

and taking appropriate actions. A dashboard can facilitate monitoring customer satisfaction effectively.

2. Leadership:

Leadership is another significant principle of QM principles. To create a productive and progressive business climate, leaders must take responsibility. Suggested action y ISO includes ensuring everyone in the organization is aware of the mission, vision, strategy, policies, and processes of the organization and making sure people have the necessary resources, training, and authority to take responsibility.

3. Engagement of people:

The ability to create and deliver value within an organization depends on skilled, empowered and engaged employees at all levels. According to ISO, Engagement of people in achieving quality goals is enhanced by the recognition, empowerment, and enhancement of competence. Action includes to facilitate fostering culture of sharing knowledge and experience, recognizing and acknowledging people contribution and promoting collaboration throughout the organization.

4. Process approach:

The best means of achieving consistent results and predictability is when activities are understood and managed as interrelated processes that work well together. Action includes the management of processes and their interrelationships as a system for achieving, Making sure the information needed to operate and improve is available to monitor, analyse, and evaluate the processes etc,

5. Improvement:

Improvement is a continuous process in successful organizations. An organization needs to improve itself to maintain performance levels, to adapt to changes in its internal and external environment, and to create new opportunities.

Figure 3.5 QMS principles (ISO 9001:2015)

6. Evidence-based decision making:

If decisions are taken after evaluating and analyzing data and information, companies will have a better chance of success. Objectivity and confidence in decision making are enhanced with facts, evidence, and data analysis. According to ISO, suggestion for action includes determining, measuring and monitoring key indicators to demonstrate the organization's performance and analyzing and evaluating data and information using suitable methods

7. Relationship management

The purpose of the principle is to ensure that relationships between the company and partners like suppliers are mutually beneficial in order to add value to both parties. According to ISO Organizations that manage relationships with all of their interested parties to maximize their impact on performance are more likely to achieve sustained success. Action includes measuring performance and providing performance feedback to interested parties, as appropriate, to enhance improvement initiatives.

EFQM

The European Foundation for Quality Model (EFQM) is the next step following the adoption of QMSs, such as ISO 9000, towards achieving TQM. The European Foundation for Quality Model provides a framework for a comprehensive quality management system. This model is developed

to increase competitiveness of European industry and closing the gap of competitiveness with USA and Japan.

EFQM is the business excellence model tools that measure organizational performance to drive organizational improvement. This tool also emphasized data driven assessment related to standard criteria of organization to find out opportunities to improvement. Many research papers have tried to demonstrate that the EFQM model is one of the best methods for measuring and improving organizational performance. Figure 3.6 shows the criteria that EFQM emphasized.

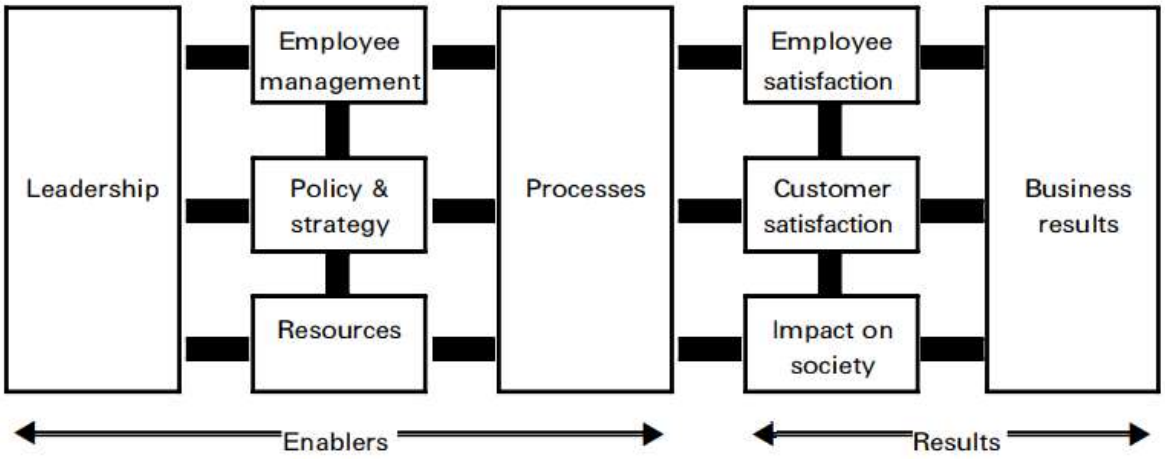


Figure 3.6: EFQM framework (European foundation for quality, 2012)

Other than EFQM, ISO9001 there are some others models like MBNQA frameworks, King Abdullah II Award -Jordanian quality award etc. The award models that are the most recognized around the world have been summarized by researchers and which includes the Deming Prize, EFQM Award, MBNQA frameworks, ISO, & King Abdullah II Award -Jordanian quality award(Jaafreh, 2013).

Some researchers investigated and compared all these quality management systems to identify critical factors to consider for total quality management or quality management system. However, there are some areas that are common to all model, even though each has its own categories and emphasis. Customer satisfaction, leadership, employee involvement, process improvement are some common criteria which are emphasized by most of the models.

3.5. Quality critical factors for SMEs and ETO

Customer Satisfaction:

Now if we investigate characteristics of SMEs and Characteristics of ETO company then customer satisfaction comes first. As according to Rantakyro there is “no business without the customers”’ (Rantakyro¨,2004,). SMEs strongly believe that as most of the SMEs are customer focused for their survival in the market. SMEs strength lies in customer satisfaction as they get the opportunity to work closely with customer. Even, SMEs owner work closely with customer to bring high satisfaction for customers(O'Donnell et al., 2002; Reeves & Hoy, 1993). For ETO companies, customer satisfaction is crucial factor as most of the ETO companies competitive advantages are closely related to the customer satisfaction like high quality tailored product, responsiveness to the market, faster delivery(Siong & Chong, 2018). Scholars and all the quality model agreed on the importance for considering customer satisfaction as critical factors of quality that should be considered in quality assurance dashboard.

Leadership and employee involvement:

Researchers also agreed about the importance of leadership and employee involvement factors for SME. However, there is conflicts in the way to dealing the factors. For having insufficient resources and talent in SMEs employee development with wide training is challenging. Moreover, in SMEs employees generally have different job responsibility. Therefore, motivated employees are crucial assets of the SMEs. Thus, employee involvement factor is also crucial for SMEs and for employee involvement motivating the employee is significant. According to Hobadian and Gallear (1997), the management visibility of SMEs is a strong characteristic of their organization. Management generally have more control in SMEs compared to large organization. Thus, leadership is also important for SMEs. According to Marcus Assarlind & Ida Gremyr, customer satisfaction, leadership, employee involvement and process follow-up are the most critical factors for SMEs based on SMEs characteristics. On the other hand, ETO companies working process is project based. According to scholars, for project-based processes leadership and involvement of employees plays a significant role as the success factors of project highly depends on the people of the company(Macomber & Howell, 2003)

Process improvement:

Management of operations relies heavily on process improvement(Anand et al., 2010). Smaller firms may benefit from process improvement as they can help overcome some of the limiting aspects that are associated with them(Wolff & Pett, 2006). Sustaining process improvement and continuous improvement have been identified as important methods for improving the

productivity of small and medium businesses(Terziovski, 2010). Therefore, PI has an imperative role to play for small and medium businesses. On the other hand, the manufacturing process for ETO companies is more complex when compared to other manufacturing. Because of this, some scholars emphasize process improvement for ETO companies(Matt & Rauch, 2014).

Supplier Quality:

However, based on characteristics of ETO company, besides, customer satisfaction and other factors, supplier quality also plays a crucial role. To guarantee the timely delivery, the ETO firms must manage their suppliers to ensure they comply with the specified(Gosling & Naim, 2009; Sousa et al., 2017).

Below are the description for the critical factors for quality management in an organization

Criteria	Description	Reference
Customer satisfaction	Many scholars and model emphasized on customer satisfaction as success of business is greatly impacted by customer satisfaction. Deming mentioned ‘’The consumer is the most important part of the production line, Quality should be aimed at the needs of the consumer, present and future	European foundation for quality, 2012, ISO9001:2015, Deming prize, (Juran, 1998), Black & Porter (1995), Anderson (1995), (Kaynak, 2003; Flynn et al., 1994)
Leadership	According to the scholars and experts, leadership is important because that build the foundation of the organization with critical goals and objective for successful business operation	
Employee involvement	Employee involvement is another critical criterion for QMS as organizational performance depends on involvement and performance of employee from all levels.	
Process improvement	In production, processes consist of the combination of machines, methods, materials, tools, and people. Quality of process directly or indirectly impact the competitiveness of the business and quality of the product. There are several tools	
Supplier Quality Management	Supplier quality is a critical factor in quality management because materials and purchased parts are the major sources of quality problems in the organization	

Table 3.4: Critical factors in QMS

3.6. Quality assurance Method:

To achieve quality for production process and product, most companies crate a management system that focus on quality goals, quality assurance, quality control and quality improvements. Organization generally develops a systematic approach to quality including whole team that strive to achieve organizational goals. According to Collins, QA provides systematic approach for the pursuit of quality and Peris described it as that QA is concerned with conformance of goods and services to established standards(Peris, 1998).

QA methods are aimed at providing a framework to enable best practice for critical factors of QMS and quality improvement, process improvement, and cost avoidance activities, and the allocation of Quality Assurance responsibilities(Summers, 2019)

For process management and improvement, Deming has promoted the use of statistical process control for tracking process performance during in-production quality assurance. To fulfill that mandate, authors (Ahire & Dreyfus, 2000) implemented the following process measures :

1 Monitoring of scrap rework,
2 Application of SPC tools,
3 Use of corrective and prevention tools
4 Focus on key processes

Another author proposed following outline for QA(Jabnoun, 2002) that facilitate process management, leadership and employee engagement :

1. Setting the standard
2. Training employee to enable them to conform with standard
3. Measuring performance
4. Analysis of measured performance data
5. Taking corrective action

Deming and Jabnoun described, Quality assurance is empowered by number of methods and quality control tools. For example, 7-quality control tools are part of SPC tools and which facilitate measuring performance with different visualization graph, analysis of measured data, monitoring key process etc**.** Some of the seven tools used in process identification and process analysis. The figure 2.4 below shows the use of 7 QC tools in process identification and analysis.

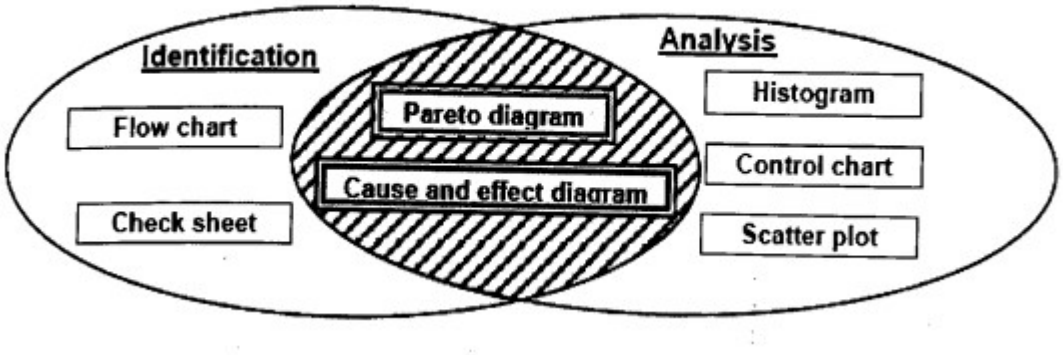


Figure 3.7: 7 QC tool(Barraza, 2007)

Following are 7 quality control described:

Since there are multiple quality improvement paradigms for organizations to use to improve their products or services, there is wide variety of Quality Tools (QTs). Even a similar organization may have different needs, which, in turn, may use different QTs (Sousa et al., 2005) As SMEs lack of expertise and skilled talent, 7QC tool can be used for quality improvement (SHUANG, 2012), (Magar & Shinde, 2014). These QC tools are basic engineering quality tool that are easy to learn and use. The purpose of QC tools is to collect data, analyse data, identify root causes, and measure results. The use of these tools with dashboard can aid quality improvement by providing great process tracking and analysis with visualization. Some QC tools are described below(Magar & Shinde, 2014; SHUANG, 2012):

Pareto Diagram:

This diagram is originated by an Italian economist Vilfredo pareto. He observed that large portion of total wealth is in few hands and this pattern in common in many field. In manufacturing industry, it is also common to observe this pattern. For example, 20% of item a company purchased could value 80%. So, this 20% item is vital few. This role is also known as 80/20 role. With this diagram, it is possible that manufacturing industry can focus on vital few instead of trivial many. Using this on dashboard, company will be able to identify those vital few to prioritise or take decision

Cause and effect Diagram:

This diagram is a problem analysis diagram that systematically generate investigate causes of a particular problem and visualize this with the diagram. This quality tool is originated by Dr. Kouro Ishikawa and it was also known as Ishikawa diagram. With this diagram, causes of a

problem is categorised and effect is analysed and visualised thorugh the diagram.

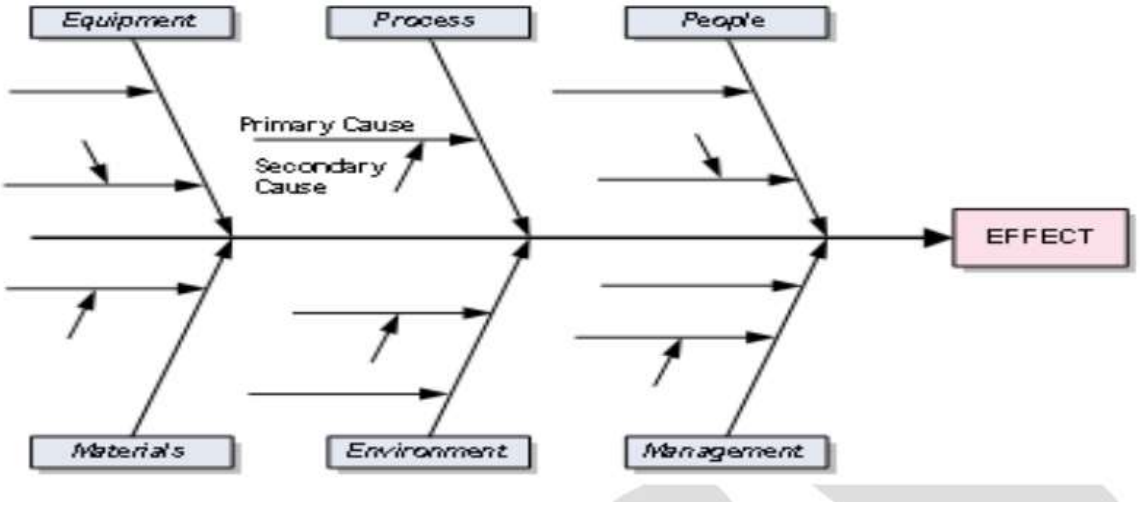


Figure 3.8: Cause and Effect/ diagram(Magar & Shinde, 2014)

The 7 QC tools are engineering quality tools. These tools are easy to learn and handle. Moreover, they are used to analyse the solution to an existing problem. They defined the 7 QC tools are the basic for all other tools.

3.7. Quality assurance method for Engineer to order company

For production that produce higher variety of products need flexible quality management methods. The supply chain of this kind of production is affected by various customer needs. (Zhao et al., 2008) According to B. Illes, the complexity of quality assurance increases with the type of manufacturing product increases (B. Illés, 2017). That requires focus in this field to simplify the quality assurance process and improvement of the process. New technology like big data and internet of things can significantly improve the current methods.(B. Illés, 2017; Galindo-Salcedo et al., 2022)

Moreover, because of recent uncertainties and competitiveness in the market along with emergence of new technologies challenges related to technology equipment, human resources, and machines are prominent now. To mitigate these challenges, upgrading current method and using new technology and ideas are required. Author described, in the field of quality and to combat the challenges utilization qualitative and quantitative data can improve quality assurance process and improve overall product and process quality. However, in that case, identification of how data or information should be collected and utilized should be explored. Despite the importance of information in quality assurance Nookabadi and middle found out there is lack of effective model regarding this and proposed a model for quality assurance information system

with addressing the issues. (Nookabadi & Middle, 2006). Due to complexity of engineer to order production, authors divided quality assurance methods from preproduction to postproduction criteria. In Engineer to order or design to order manufacturing, Quality starts from pre-production stages. Nookabadi mentioned three stage like pre-production stage, production stage and post-production stage. Selma basic also defined ETO in three phase which are

There are three major phases that require coordination in ETO are:

- Tendering (sales/marketing)
- Product development (engineering)
- Product realization (production)

Nokhabadi discussed that during tendering or preproduction stage below information need to be processed to support quality assurance.

- Requirements that satisfy customer needs
- Translating need into technical specification (Can be utilized QFD tool)
- Exploring capability to achieve customer satisfaction
- Identification of Quality characteristics of products (Ex. Tools: FMEA, FTA etc)

And in Production stage according to Nookabadi, following matters should be considered

Task	Objective	Method
Process verification	to produce product according to specification	Inspection, test
Analysing process performance	• To detect special causes of out-of-control conditions in a process and for avoiding recurrence of the problem • to identify trends in process performance and to initiate preventive control measures.	by analysing historical or current data
Carrying out final inspection accordance to the quality plan	to complete the evidence of conformance of the finished product to specified requirements	By increasing inspections and tests made during processing

Identify and report any non-conformity	To segregate the non-confirming product and take decision	Identification with inspection or test. Repaired product also should be reinspected
Reject analysis	To take appropriate corrective actions and steps to eliminate them.	
documented procedures shall be established and maintained	to control, calibrate and maintain inspection, measuring and test equipment	
Program of preventive maintenance should be introduced	To ensure continued process capability	all equipment should be proved for accuracy prior to use
Analyzing the result of process and product audits	to identify specific areas that call for investigation of design, processing, control methods or procedures.	

Table 3.5: Method for QA in production stage (Nookabadi & Middle, 2006)

The time required to implement discussed method and model varies with the organization capability. In this methods of QA, one thing is prominent that use of data. In task like analyzing process performance, reject analyzing requires historic analysis of data to identify any trend or process performance. Moreover, in previous discussion about quality management and quality assurance, measure and analysis are emphasized by scholar and experts for quality in manufacturing industry. To quality assurance with prevention of nonconformance, the company conducts both quantitative and qualitative analyses of the causes. For systematic approach and evidence-based decision making, performance analysis and for performance monitoring in ETO is critical. Therefore dashboard with quality indicators for ETO can play significant role in QA. Performance measures can be used as a tool for translating strategies into desired behavior and results, communicating each employee's responsibilities, monitoring progress, and providing feedback (Muchiri & Pintelon, 2008).

3.8. Quality Performance measure for ETO:

According to Sjøball and Båkas, performance measure which is also known as metrics or indicators depends on its production situation. Metrics of ETO differs from metrics of MTS because of their different competitive priorities. Authors also identified that there is rare literature that explicitly focused on metrics of ETO companies(Sjøbakk & Bakås, 2014). For example, Quality-based measures of performance focus on issues like number of reworked units, the number of material inspections, the number of customer complaints etc. And in for ETO company performance measure of rework units is emphasized and analysed in different level compared to MTS company. Because the cost of correcting an error increase exponentially in every phase in ETO as presented in figure X and in worst case scenario if error is detected in last phase that the product must be reproduced that is highly expensive, time consuming for ETO companies. Moreover, there is also threat for loosing sale and loyal customer. Juran and Garrad explained cost of quality in three categories which describe that

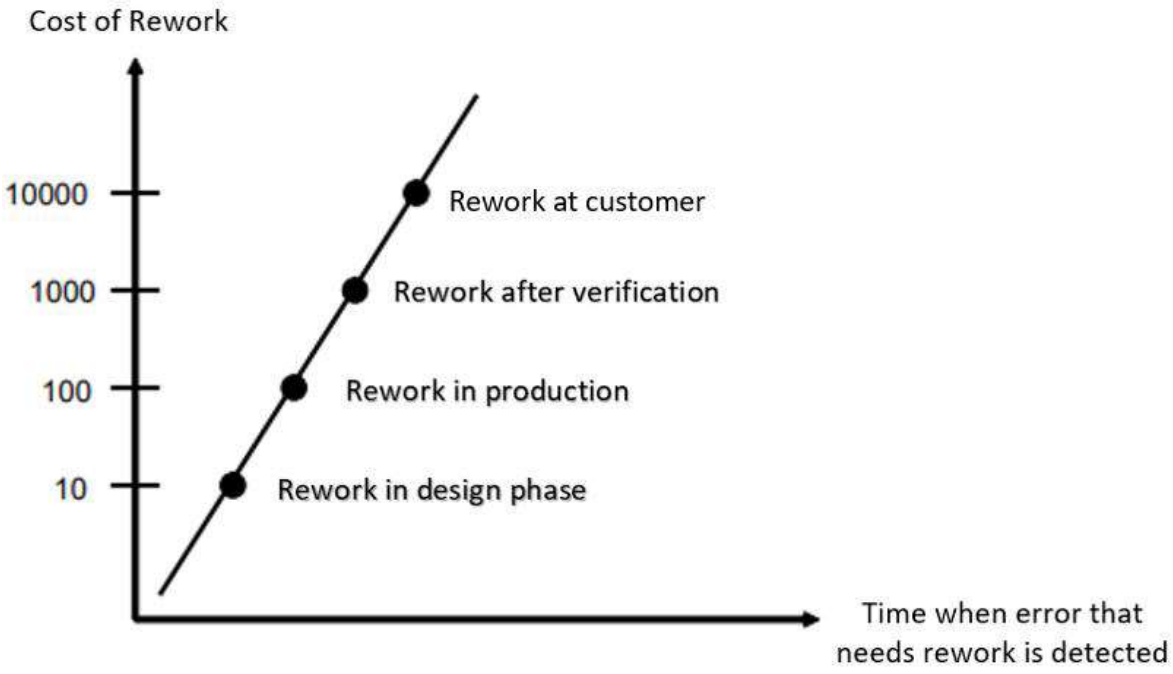


Figure 3.9; Cost of Rework based on project stage (Sjøbakk & Bakås, 2014)

when any non-conformity or defect is detected, companies have to consider cost of non-conformities as well as cost of inefficient process and cost of lost opportunities and sales.

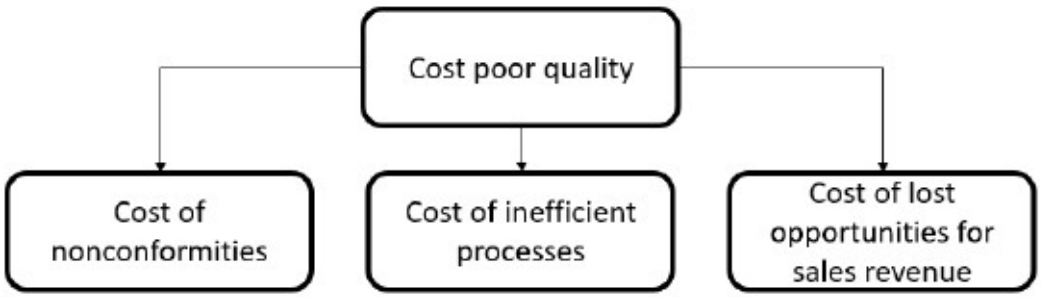


Figure 3.10: Cost of poor quality (Sjøbakk & Bakås, 2014)

Therefore, metrics related rework is crucial for ETO companies. The phase, in which stage rework is detected resemble the severity and cost associated with the rework. Another significant measure of ETO company is on time delivery. In large engineering projects, there are usually delays and reworks because these projects need several revisions during their implementation, as explained by Mello, Strandhagen & Alfnes (2015). Therefore, on time delivery resembles performance and competitiveness of this kind of company. On time delivery is associated with customer satisfaction. Besides on time delivery, customer complaints rate measure is also crucial for ETO performance indicators,

In below table, based on quality factors, indicators for ETO company is mentioned:

Critical Factors	**Dashboard indicators**	**Reference**
Customer Satisfaction	On-time delivery, Customer compliant rate, Net Promoter Score, Avg time to resolve issue	(Sjøbakk & Bakås, 2014),(Dhafr et al., 2006; Fisher, 2021; Rao et al., 2011; Siong & Chong, 2018; Sousa et al., 2005)
Process **Quality metrics**	Rework rate, Defect rate, Cost of Defect, Scrap Rate	
Supplier Quality Metrics	Supplier defect rate, Raw Material defect rate, Percentage of defect from individual Supplier, Supplier on time delivery rate	
Process **Improvement**	Improvement action	

	Ishiwka Diagram	
	5 Why	
	CAPA process	
Employee involvement	Top Performer bonus	

Table 3.6: Dashboard indicators based on quality critical factors

Below are some descriptions for the indicators:

On-time delivery(Rao et al., 2011): Delivering products on time is one of the key factors that customers evaluate the delivery experience, and therefore is crucial for customer satisfaction and customer retention. A low rate of on-time delivery leads to more customer complaints. On time delivery also can be measured as delay rate. This resembles percentage of on time delivery to customers. Therefore, production must be finished in scheduled time. On time delivery can be calculated periodically. Organization need to collect data of on time and late deliveries to calculate the on time delivery rate. Data can be collected based on frequency of the delivery from daily, weekly, or monthly. The formula of on time delivery is

On time Deliver = No.of customer orders delivered on time& in full/Total no planned to be delivered per period

Net Promoter score (Fisher, 2021):

This indicator directly resembles the satisfaction of customer regarding product, service or overall impression for the brand. Data collection strategy for this indicator is generally from survey. Large number of customers get the survey and customers response is collected from survey. With the survey, customer can rate their satisfaction level from 0-10. Once survey data is collected, response is divided into categories like promoters, passives, and detractors. Promoter's rating is counted from 9 to 10. They are the loyal customer and satisfied customer. Passive rating is from 7 to 8. Passive customers are neutral customers. And detractors' ratings is 0 to 6. They are mostly unsatisfied customer and difficult to retain. Below is the formula to calculate overall NPS.

NPS Calculation Formula: NPS = % Promoters – % Detractors

Defect Rate(Dhafr et al., 2006):

Defects are a result of several factors including equipment malfunctions, process variation, and incorrect process operation etc. Standardizing the process of recording and analyzing defects

is of utmost importance. Data of defects can be collected and should be analyzed periodically. Defect rate can be calculated with below formula

% Defect Rate= (no of bad production in period/Total production in period) X 100

However, for ETO companies this approach is not effective as all defects are rated the same, regardless of their severity. Therefore, measuring the cost of defect is more appropriate compared to no of defects(Jonsson & Rudberg, 2017).

Cost of defect(Jonsson & Rudberg, 2017):

Defect cost rate is the cost for rectifying defects in relation to the total project cost.

% Defect cost rate=

(Cost for rectifying defects in project i /Total production cost for project i)× 100;

Where i=1,2,3….n

Supplier on time delivery(Rao et al., 2011):

It is the ratio of the number of purchase orders that were delivered by suppliers on-time (according to the purchase order and invoice) to the total number of purchase orders.

Supplier on time delivery = No.of purchased orders received on time& in full/Total no planned to be received per period

Top Performer(Leva et al., 2016):

Performance indicators for human related to quality, measure number of error generated by human in workstation. In this indicator, the top least error generating operator per period are recognized as top performer and motivated with bonus or reward.

CAPA(Biswas, 2008):

CAPA is not quantitative indicator for dashboard. It is more qualitative dashboard content for monitoring and progress of actions. CAPA includes corrective action of an identified problem, root cause analysis to determine the cause of the deviation and prevent the recurrence of a similar issue, and preventive action involves eliminating the causes of potential non-conformities or other problems as part of the Quality Assurance system. CAPA involve several steps like identification of problem, monitoring of action and progress with graphical visualization etc. For monitoring progress and overall CAPA actions status, dashboard can be utilized.

3.9. Quality Assurance Dashboard development:

3.9.1. Dashboard

Dashboard is originally inspired by dashboard of aircrafts and automobile. The concept of digital dashboard outgrows in 1970 as decision support system. In 1990s with the surge of web, business related dashboard appeared for monitoring business related activities(Kerzner, 2011). With the development of business intelligence and technological advancement, digital dashboard now gain popularity among manufacturing industries. Dashboard refers to a graphical visualization tool for monitoring, analyzing critical business activities and facilitate fact based easy decision making for users. Dashboard in business is generally originated from business intelligence field. Business intelligence is the key technology that extract information from different source and process and analyze data with BI system and then present it on dashboard. (Noonpakdee et al., 2018) According to Stephan Few, Dashboards serve as a centralized display of all necessary information on a single screen, clearly and without distraction, in a way that can be easily understood by users(Few, 2005)

Below is the example of typical dashboard for manufacturing industry.

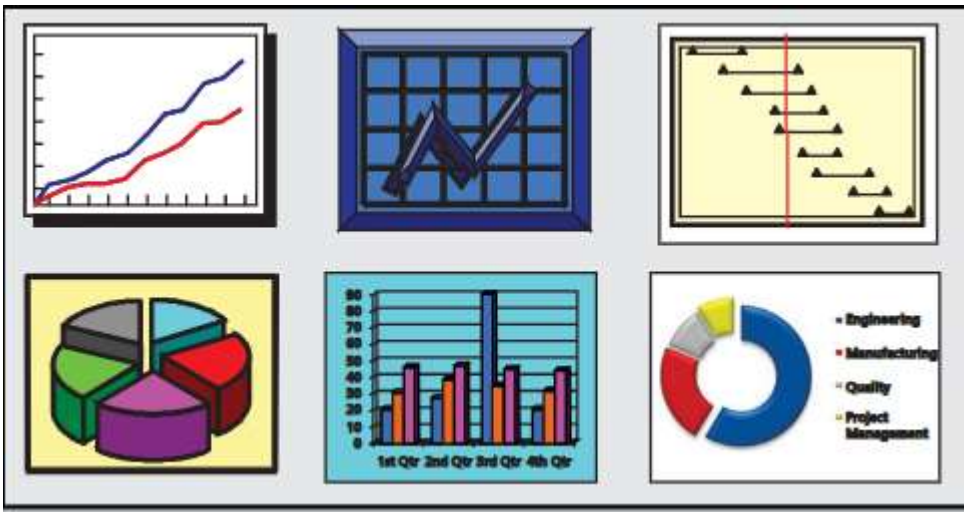


Figure 3.11 Typical dashboard framework (Kerzner, 2011)

Eckerson, categorized dashboard use in three set of functionalities(Eckerson, 2010). These are:

- **Monitor:** Monitoring critical business activities with indicators (Example: revenue, sales, production volume etc.) In case of any indicator fails to be within predefined target it triggers an alert.
- **Analyse:** Analysing root cause of problem by enabling user to explore information from different dimension

- **Manage:** Dashboard enable collaboration and decision making with providing information in understandable manner. Thus, it assist in managing people and process with fact based decision making

Based on user need and functionality Eckerson categorized dashboard in three types. This is illustrated in Figure 1. Monitoring the company's status is important for executives. Information related to performance is analyzed by management, while shop floor staff looks for details. Each user needs different content to be added into dashboard based on their need.

Figure 3.12 Dashboard category (Eckerson, 2010)

Therefore, Eckerson categorized dashboard as Strategic, Tactical and Operational dashboard.

Operational dashboards: According to Eckerson, operational dashboard display detailed data for front line worker or supervisor to monitor if everything is going accordingly. Therefore operational dashboard emphasized monitoring.

	OPERATIONAL	TACTICAL	STRATEGIC
PURPOSE	Monitor operations	Measure progress	Execute strategy
USERS	Supervisors, specialists	Managers, analysts	Executives, managers, staff
SCOPE	Operational	Departmental	Enterprise
INFORMATION	Detailed	Detailed/summary	Detailed/summary
UPDATES	Intraday	Daily/weekly	Monthly/quarterly
EMPHASIS	Monitoring	Analysis	Management

Figure 3.13 Comparison in type of dashboard (Kerzner, 2011)

Tactical dashboard:

Tactical dashboard emphasis on analysis more compared to monitoring or management. Different departments and managers use tactical dashboard to analyze root cause of problems or analyze improvement.

Strategic dashboard

Executives use strategic dashboard for review performance and communicate strategy for the company. This dashboard more emphasize on management.

Integrating dashboard: As different dashboard serves different type of need, organization and organizational departments incorporate different type and different version of dashboard to fulfill each need.

3.9.2. Quality Assurance Improvement with Dashboard:

The ability for management, team members, and staff employees to report and monitor issues and events affecting the quality of service required to achieve very high standards is a crucial part of enforcing Quality Assurance performance and improvement and in terms of Quality Assurance, metrics contribute to compliance and make things better.(Summers, 2019) Galindo and Pertuz identified application of monitoring and digitization with performance indicator improve process and strengthen quality assurance (Galindo-Salcedo et al., 2022). Dashboard is most useful application for monitoring and visualization of indicators and as information displayed in dashboard plays significant role in making critical decision and has impact on overall performance of the company, it is crucial to develop dashboard considering most important factor for quality in manufacturing industry.

3.9.3. Quality assurance Dashboard in an SME

The production floor utilizes specifications, production samples and quality manuals to ensure that standards are communicated to everyone in the company. Glock and Kunz (2005:214) state that quality personnel will be involved in the evaluation of specific specification sheets, as well as samples from the production floor. One of the ways of ensuring that goods adhere to the expected quality is through an inspection process. Waters (1996:339) explains that organizations traditionally ensure that quality is maintained by a series of examining processes which are often seen as disrupting production

As discussed before, Dashboards facilitates visual management that support and improve decision making dashboard keeps management and employee focused as it shows the most important issue in organized manner, and it represents the importance of issues. Therefore, it influences decision making. As it influences decision making, appropriate design for dashboard is crucial. However, large companies are advanced in dashboard designing compared to small to medium companies. Issues like data availability, reliability and system maturity are the factors

that influence feasibility for dashboard design (Vilarinho et al., 2018). Data analysis and using dashboard required investment, knowledge, and technology awareness. According to researcher these three criteria are always challenge for an SME.(Masood & Sonntag, 2020).

3.9.3.1. Challenges for SME:

Use of dashboard facilitate digital monitoring and enable industry 4.0 adoption in QA field. However, the most established digital tools like dashboard are geared towards larger companies. SMEs has different priority compared to MNEs and SMEs lack of experience, knowledge and awareness are barrier for enabling tools like dashboard.

1. **Level of maturity in QA system:**

Regarding dashboard for quality, in most cases SMEs do not have organized quality management system., To understand the quality practices for SMEs and to find out where they can improve, Ching-Chow Yang developed a "systematic framework for quality management with five stages" for SMEs. Five stages are below(Yang, 2020):

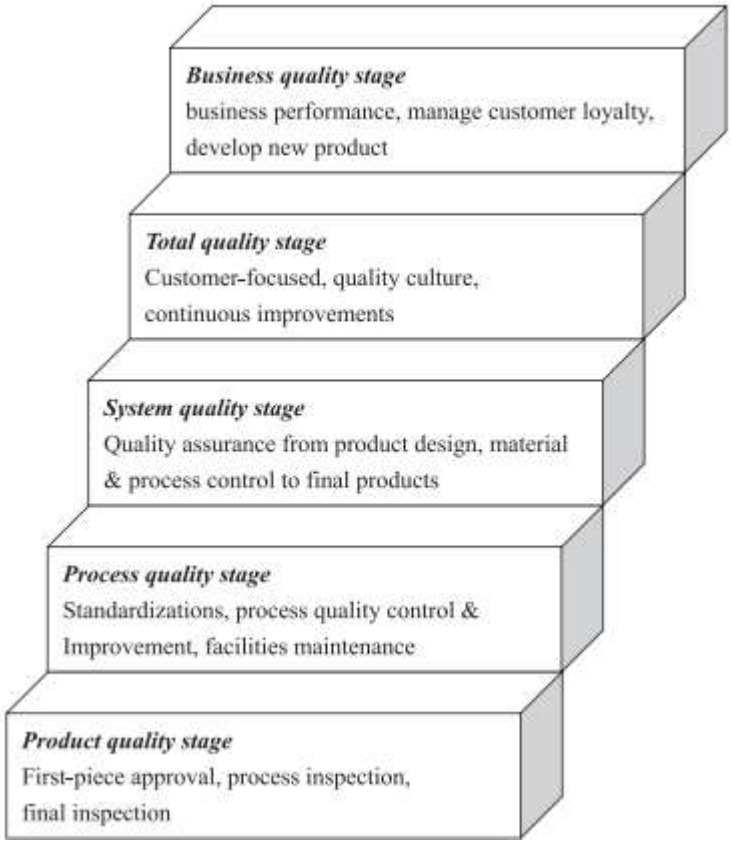


Figure 3.14: Five Stage of quality management maturity (Yang, 2020)

- Product quality stage:

In this stage, SMEs develop procedure to inspect product to control the quality of the product. This stage also includes in process inspection, full inspection etc.

- Process quality stage:

In this stage, SMEs acknowledge the importance of process quality along with the product quality. In this stage, SMEs includes statistical process control, standardization of process and documentations etc.

- System quality stage:

In this stage, SMEs emphasize in quality system with concepts like total quality control or implementing ISO 9000 system. This stage includes considering material quality control, quality of customer service, culture of quality besides product and process quality.

- Total quality stage:

In this stage, SMEs focus on total quality system with concept like total quality management. In this stage, SMEs emphasize on continuous improvement, customer satisfaction and quality culture

- Business quality stage:

In this stage, SME manage their strategies, performance evaluation systems, and human resources, along with taking advantage of TQM and customer relationship management, to achieve excellent business performance.

The maturity of the SMEs can be identified following these five hierarchy stages. The least matured SMEs will be in product quality stage and most matured SMEs will be in business quality stage. SMEs in product quality stage faces more challenges compared to matured stages. SMEs also can have low level of maturity in information management system. That make difficult for SMEs to design and develop a dashboard. To be Clearfield, authors mentioned that SMEs lack expertise in managing, planning, organizing and using information resources(Sousa et al., 2005).

2. Lack of talent:

As SMEs need to adapt with challenges to be competitive, some researchers investigated where SMEs should focus to be competitive into the market to deal with challenges. In a survey, it is found out that most companies believe that SMEs should highly focus on training their people. Training is to combat lack of knowledge limitation as well as technology awareness(Masood &

Sonntag, 2020). To gain knowledge research and development also play crucial roles. However, financial limitation act as barriers in research and development of company but some researchers suggested low investment research, hiring talent, collaborating with research organization and educational institute, and enabling knowledge sharing culture in company can bring competitive advantages for SMEs. With fear of investment, companies should not give up on technological advancement rather company should explore opportunities how technology and recent knowledge can contribute to the competitive advantages of company. Digital tools and social media network can be used for knowledge sharing within and outside the organization. Technical skills required for implementing technology, innovation, and critical thinking are also needed(Ali & Johl, 2022).

3. **Data Quality:**

A high-quality set of data is defined in ISO/IEC 25012 as "the degree to which it meets requirements" and the poor-quality data is defined as ‘’the degree to which sets of data does not fulfil the requirements. There are vast number of requirements discussed by several researchers that resembles the requirement that need to be fulfilled for high quality data. Author Omri shortlisted some requirement for data quality which are mostly sited in the literature. These are accuracy, completeness, timeliness, consistency etc. (Omri et al., 2020)

Accuracy: the degree at which data is recorded correctly

Completeness: It measures the proportion of missing values for a variable.

Timeliness: Assess if the data is up to date

Consistency: Assess if the data comply with all the constraints imposed by the context.

As mentioned above, SMEs faces challenges with data quality as data collected from different sources in SMEs does not meet the requirement of high-quality data. According to a study of Omri, data from SMEs are usually incomplete and with small volume(Omri et al., 2020)

4. **Technology awareness**

The implementation of I4.0 technologies in small and medium-sized businesses has been slow. Most of the time, they do not become early adopters because they are afraid of investing in the wrong technologies or adopting inadvertent practices. SMEs are not aware about latest technology, there is lack of research that address the specific need of SMEs to implement industry 4.0 technology. Therefore, SMEs use no or less technology that can collect high quality data like RFID, sensors etc(Mittal, Khan, et al., 2018).

Challenges and criteria to consider for dashboard in SME	Description	Reference
Low level of maturity in QA system	A dashboard's development involves dealing with factors strongly related to organizational capabilities or system maturity.	(Ali & Johl, 2022),(Masood & Sonntag, 2020)
Knowledge limitation	Because of knowledge limitation, SMEs are legging in technological advancement, critical thinking and innovation. Because of knowledge limitation, SMEs are not grabbing as much as opportunity of technological advancement like M	
Technology awareness	SMEs generally lack implementation of advanced technology to collect data like RFID, sensors, use of ICT, use of interfaces etc.	
Financial Resource limitation	One of the most powerful barriers for SMEs is to hindrance in financial investment. For a developed system for collecting data with technology, managing data and processing data requires investment.	
Lack of talent challenge	Because of lack of talent skills	
Data quality Challenge	SMEs lack the necessary infrastructure for data management. As a result, the data that SME's production process generates tend to be incomplete and with relatively low volumes	

Table 3.7: Typical challenges for SME to develop quality assurance dashboard

3.9.3.2. Existing Dashboard development procedure for SME

Vilarinho and Lopes describe a dashboard development procedure for production process improvement focusing production, quality, and maintenance department of an organization(Vilarinho et al., 2018). According to the procedure author described below steps:

Diagnosis of the productive areas

According to author a diagnosis should be performed to understand and assess the current state of the productive areas to identify improvement areas. The intention is to gather suggestion for dashboard to identify crucial indicators for the organization. Authors divided diagnosis in preparation stage, execution stage and in analysis and synthesis stage. In preparation stage information should be collected to understand organizational environment, priority needs, particular objectives, the products and process of the company, size and organizational structure of the company Also defining borders and understanding relevant departments procedure. Overall, this stage is intended to interview preparation for the next stage. Execution stage includes, interview, participation observation, meetings with employee and finally gather more information for analysis. Relevant information is associated with quality system of company, studying documents and quality policy, quality manual of the company that exists in the system. In order to understand current system of the company and current technology, information and procedures used by the company. In analysis and synthesis stage, analyzing the result and performing synthesis to identify improvement areas, indicators for developing suggestion for developing the dashboard is important

Dashboard requirements assessment:

The identification of dashboard requirements should be based on overall goal and objective of the company and aligned with company strategy The results from diagnosis phase should be analyzed to understand and identify important criteria for developing the dashboard.

To develop a dashboard, relevant components of the company´s strategy such as goals and objectives, metrics and targets, plans and initiatives should be analyzed. As per previous discussion, there are three types of dashboards can be found in the industry. Therefore, understanding level and type of dashboard required and identification of user is important for developing an effective dashboard.

In initial stage author provided more general guideline for companies to follow to diagnosis companies' productive area instead of detailed guideline. In 2nd stage Vilarinho provided some general guideline about identification of the requirement of the dashboard. As improper identification of dashboard requirement and improper understanding of company will result in developing misleading dashboard, this stage is also crucial for developing dashboard. Author described that it is important to select and customize metrics for developing dashboard. Because, without focus on selective metrics there is a risk of overloaded information instead of being organized and focused to present important information. Author also discussed it is also

important to consider capability of the company and limitations of the company. Overall, according to (Vilarinho et al., 2018), method to develop a dashboard should consider strategy, objective, goal of the company as well as it should consider capability of the company and risk and challenges associated with that. Detailed guideline to identify indicators and selecting appropriate tools with data collection strategy is lacking in his research paper.(Noonpakdee et al., 2018), covered the data flow of the dashboard and discussed about tool but did not covered detailed analysis to develop the dashboard content. However, Calidera and Rombach established a approach to identify metrics but that did not considered company characteristics. (Caldiera & Rombach, 1994).

3.9.3.3. Proposed steps for developing dashboard

As discussed above, scholars addressed need for research to develop dashboard for SMEs. However, existing literature did not cover guideline to identify indicators considering company different characteristics for developing dashboard. There is also lack of guideline that consider data collection strategy and tool selection for SMEs for developing the dashboard. Moreover, a framework or more specific detail guideline is required for companies with limitation of knowledge like SMEs. As discussed before, CODP is a concept that can help to understand the characteristics of a company. With the concept of CODP and based on characteristics of a company, it is effective to align planning and imitative with the companies. Therefore, in this research, it is proposed to utilize Table 3.1: Characteristics of Different CODP (For others CODP) and Table 3.2: Difference between ETO and MTO (For ETO CODP) to diagnosis company and to develop understanding for the company. Therefore, in this research, considering all the factors and challenges SMEs faces, below guidelines are proposed for ETO based SMEs.

1. **Profiling company:**

   The quality assurance dashboard is to ultimately improve company's performance. For designing system like dashboard identification of indicators are must. For identification of indicators, researchers suggest first step to understanding the company profile. For developing and design a system, a high level of awareness of the overall issue of an organization, its competitive position, the environment in which it exists, and its business processes are required. (Bjorn) According to Olhager, it is important to consider the CODP position when designing systems at the strategic, tactical, and operational levels as the new system must be adapted to the environment of the industry and consider competitive priorities of the company(Olhager, 2010). In literature review, different CODP is discussed. Table 1

provide a framework to understand and investigate characteristics of the company based on CODP.

2. Analysis of existing system

In this stage, a detailed analysis should be done for understanding the company from the perspective of quality in manufacturing industry and to find out the challenges. This analysis will facilitate to identify objective of the dashboard and combining company characteristics and analysing of existing system will enable identification of indicators for the quality assurance dashboard. As discussed previously, the stages of quality management for SMEs can be utilized to analysis existing SMEs system for quality. Moreover, to find out challenges, investigating if the common challenges of SMEs are present in the company can also lead to and effective design of dashboard with consideration of challenges and capability of the SMEs

3. Identify objective of the dashboard:

After the analysis of the company, it is important to define goal or objective of the dashboard. When a company measures purposefully, it needs to specify its goals first, then connect the goals to the data that will define those goals operationally, and then provide a framework for interpreting the data in relation to the stated goals.(Caldiera & Rombach, 1994). The goal question metrics approach is based upon this assumption and according to Caldiera and Rombach, it is important to identify the need of the organization and how this need can be quantified and measure to reach the goal for the organization.(Caldiera & Rombach, 1994) Calidera and Rombach explained the approach as below:

Concept level (Goal): It is the overall objective for designing the dashboard and it can be related product, processes, and resources.

Operational Level (Questions): A set of questions are for identifying characteristics and criteria for the assessment or that facilitate achieving the objective of the dashboard.

Quantitative level (METRIC): To answer a question quantitatively, a series of data must be collected for it. Metrics are used for answering question quantitively and facilitate analysis and visualization of performance

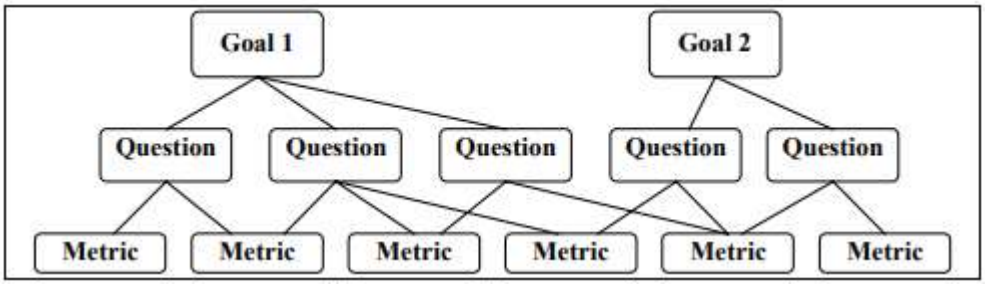


Figure 3.15 Goal Metric Approach(Caldiera & Rombach, 1994)

Therefore, before identification of metrics, identification of goal and criteria and characteristics to achieve the objective is crucial.

For development of the goal, Calidera and Rombach explained that there must be three sources of information.

The first source is related to the overall organizational understanding with strategic plan and policy of the organization and second source is related to the product and process of the organization and finally the third source is related to the model of the organization. These three kinds of information can be collected from the first two steps of this proposed solution. Therefore, the concept of GQM approach also support the steps of developing the dashboard identified in the project. However, other than the finding out overall goal, it is also important to find out specific level and user or the dashboard using the framework of the dashboard type. In this way, exploring concept for identification of criteria will be facilitated.

4. Concept Exploration for the identification of characteristics and criteria:

Based on the objective of the dashboard, next step is to identify the characteristics or important criteria that represents the specific information need for the user to observe and facilitate formulating question to identify specific metrics or indicators for the dashboard. For exploring concept for identification of characteristics, knowledge in the segment for which dashboard should be developed is crucial. Combining the knowledge regarding specific segment and findings from previous steps will facilitate identification of criteria for the dashboard. In this project, as developing dashboard is discussed for quality segment, investigating quality management and quality assurance identified some criteria from the literature in table two. However, for combining this with

5. Identify indicators:

Now based on the criteria or questions, indicators for the dashboard can be identified. In any system of measurement, metrics, or key performance indicators (KPIs) serve as a set of quantitative and strategic indicators that reflect a company's operational success. According to above discussion for step 1, an organizations competitive priority depends on production

environment. For identification of indicators, considering production environment is crucial. Indicators greatly varies on production type of the company. (Sjøbakk & Bakås, 2014),(Hwang et al., 2020). In below table, each product type has weighted indicators reflecting the production circumstances adequately(Hwang et al., 2020)

Make to Stock	Make to Order	Engineer to Order
- Waste of inventory - Rate of standardization	- Variation of process - Rate of on-time delivery - Rate of process comprehension	- Level of stock - Flexibility of human resource - Rate of on-time delivery - Rate of process comprehension

Figure 3.16: CODP based indicators(Hwang et al., 2020)

From literature review, indicators for quality and engineer to order company has been discussed. However, A performance metric may differ in its purpose, definition, and content. According to Iuga, three important criteria need to be considered for the optimal selection: Validity, helpfulness, and relevance. Moreover, KPIs could have mutual relationship like one KPI can contradict another KPI and from one KPI another could be derived or replaced. For example, throughput improvement of product line can have negative impact on product quality. Therefore, KPIs selection should consider all the relative factors and for utilizing dashboard with KPIs, user should have overall and detailed understanding of KPIs

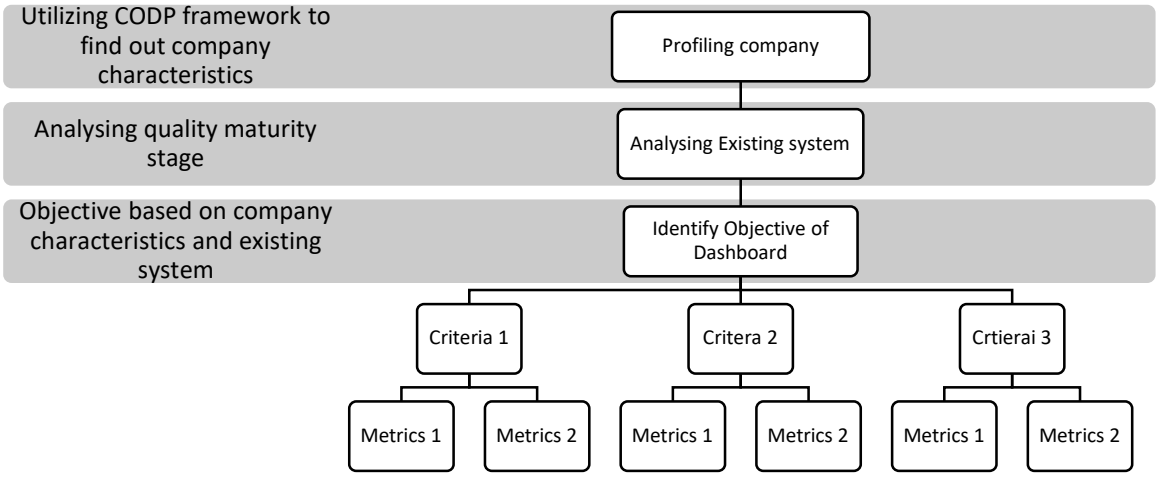


Figure 3.17 Developing quality assurance dashboard content (Caldiera & Rombach, 1994),(Hwang et al., 2020; Yang, 2020)

6. **Develop a data collection strategy:**

Once the metrics are identified and the objectives are set, data need to be collected and transformed into a format that will facilitate developing the dashboard. Below figure represent data flow for dashboard development. First data is collected from source the data is transformed and prepared and then represent in dashboard for monitoring and analysis.

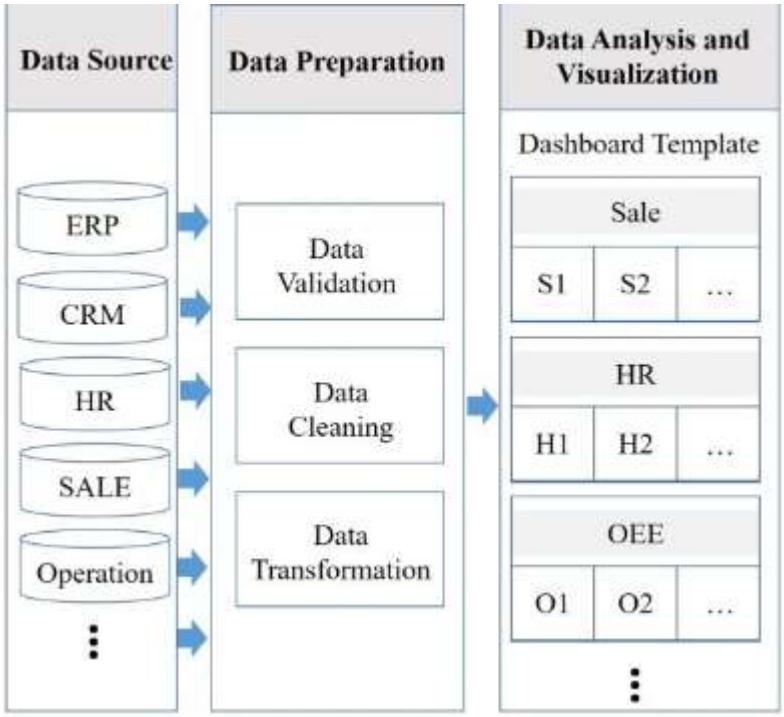


Figure 3.18 Example Data Flow(Noonpakdee et al., 2018)

The manufacturing data is generated from equipment, human operators, products, and process(Hashem et al., 2015). Based on metrics, what data need to be collected or could be availed need to plan. If data is not available feasibility of data acquisition can be checked. Then company need to have plan for data collection and need to explore technology or techniques to generate data. Big company's utilize advanced technologies to generate, collect and manage data and try to capture full potentials of data. Because of challenges in SME, SMEs lack advanced technology to acquire data and capturing the full potentials of data. However, with the understanding of potentiality of data, SMEs can set strategy to acquire data and explore technology based on their capacity. For example, a wide variety of useful data can be measured by sensors in most manufacturing circumstances. There are two categories of measurements in this stage: direct and indirect. In direct measurement refers to measuring the exact thing with higher accuracy and indirect measurement refers measuring with available techniques instead of measuring the exact thing (measuring the how many products are producing one machine find out speed of the machine instead of the measuring the speed of the machine)(Xu et al., 2020).

Indirect measurement is used for cost effectiveness as direct measurement can be expensive(Xu et al., 2020). Therefore, SMEs need to explore different techniques to feasibility to find out most suitable data acquisition technology or techniques for them. However, data is categorised as structured, semi structured, and unstructured data. Structured data are more useful compared to unstructured data. So SMEs should have planned to get more structured data so that they can utilize it

7. Select tool based on company capability

After physical data collection, data need to be stored, extract, transform and load to a tool for developing the dashboard. Different kind of business intelligence (BI) tools can be used for all the action altogether or for particular actions. Due to the necessity of the BI tools, market of BI tools are growing rapidly. According to Gartner, in 2017, world's BI tool market reached to 18.3 billion dollars. The large vendors of BI are, SAP, Oracle, IBM and Microsoft which are the leaders in the delivery of BI solutions (Ask, 2018)

Due to the challenges of SMEs regarding cost and complexity issue, many SMEs simply adopt a existing BI solution with spreadsheets such as MS Excel that is integrated with a database (Raj, Wong, Beaumont, & 2016). However, it is still possible for SMEs to apply BI in their businesses, despite the challenges they might face. shared data warehouse, which will help them overcome the cost issue (Ayoubi & Aljawarneh, 2018). Moreover, using open sources can be solution for SMEs as this required less or no cost but that come with some disadvantages. Cloud-based BI tools can be used by small and mid-sized enterprises due to their affordability and flexibility (Grabova et al., 2011). Cloud BI does not need any further installation of hardware and software and so affordable. Cloud BI has limited storge capacity and with the increase in capacity, cost increases. Therefore, this solution is mostly suitable for SMEs. The example of available cloud based BI solution that offers data integration, data transformation and developing dashboard are power BI, Qlik Sense, Tableau etc. Moreover, there are some consultant firms are nowadays growing that offers cloud based BI solutions. However, the applications are enterprise-friendly so far, but they require further data security enhancements. For companies with an MSDN license, Microsoft's Business Intelligence Solution for an SME is free to use. The problem is that many SMEs are unaware of such an opportunity, nor do they have the expertise needed to take advantage of it.

8. Risk assessment:

For any design and development, risk assessment is a vital step. As dashboard is related to dealing with company data, there is risk associated with data management that company need to consider before utilizing and managing data. For example, utilizing open sources sometimes come with disadvantages with low security of data. Therefore, data security would be concern in that situation. Moreover, companies can assume that there is no cost for retaining data in some specific BI solution. Therefore there is risk of poor data retaining planning that may result in unwanted cost later(Choi et al., 2016).

9. Develop dashboard:

After all the previous steps, it will be time to execute the plan with developing the dashboard. After implementing previous steps, companies will have dashboard contents and total plan to develop the dashboard. In quality PDCA is design and management tool for continuous improvement. Based on that, this stage is step for 'Do' from PDCA technique. During the developing of the dashboard, exploring different kind of chart related to the dashboard contents and visualization simplicity should be considered. As graphics design is out of the scope for this thesis, it is not discussed here but one can consider it while developing the dashboard

10. Evaluate dashboard and continuous improvement

As discussed in previous step about PDCA technique. After planning and execution, evaluation and checking is important steps for continuous improvement. Getting user feedback and evaluating the dashboard regarding the impact on the organization will facilitate continuous improvement which is one of the significant concepts of quality for manufacturing industry.

Below framework presents the total 10 steps for developing the dashboard:

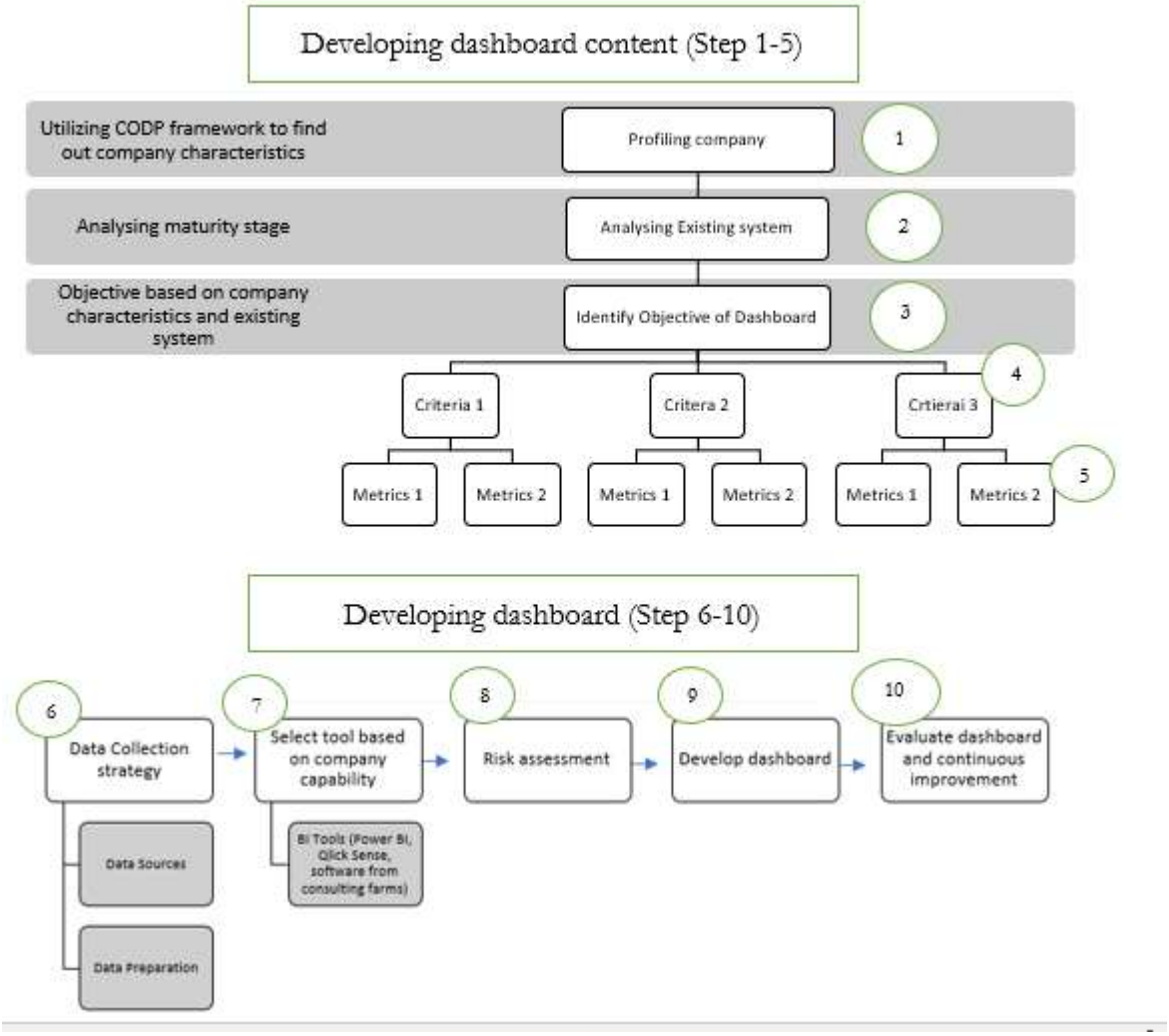


Figure 3.19: Step by step guideline to develop dashboard

4. Case Study

4.1. Case Company Introduction:

Probad AB a part of Bano group manufactures and delivers prefabricated bathroom cabinets in steel fiber reinforced concrete for new buildings. The company provide bathrooms for all purposes such as housing, hotels, health buildings and student housing. The company is certified and approved in accordance with the market's strictest quality requirements. Probad started this company in 2004 for producing prefabricated bathrooms cabinets. The company has established factory in Torckforce Sweden. In 2013, Bano Group acquired the factory in Torckforce of Probad AB. Bano AS is an international leading company that provide complete bathroom solution to the health sector. The company's sales office is located at Bergen, Stockholm, Helsinki, Copenhagen, Amsterdam and London. Its headquarters, a central warehouse, and its own factories are situated in Sandane, Norway. Until 2016, Bano group has spent almost NOK 150 million on building a completely new quality system, new machinery and new production routines for Probad AB. After the investments, the factory of Probad AB in Torkforce currently has a total area of 16,000 square meters. The vision of Probad AB is to be preferred choice of customers for excellent cooperation, high competence and for providing best quality solutions to the customer.

4.2.Probad Organizational structure:

Probad's organizational structure is as below for the production in concrete plant and main plant. So there are 5 department in Probad that includes production for concrete factory, production for main factory , QA and HSE department, Logistics and warehouse department and HR and administrative department.

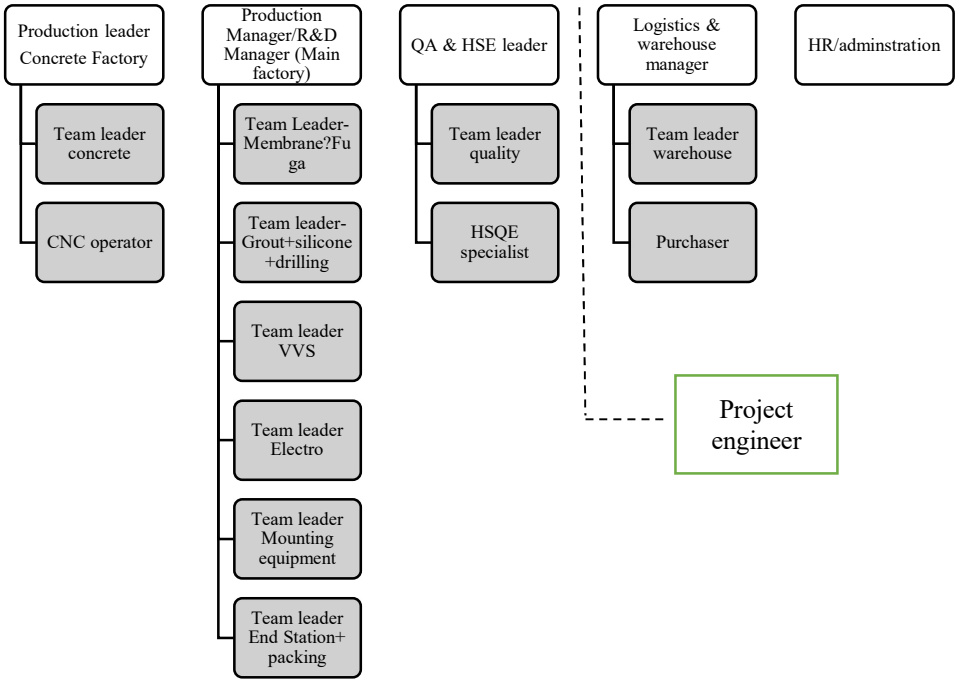


Figure 4.1 Probad Organizational Chart

4.3.Probad's product:

Probad's prefabricated bathroom Modules are readymade bathrooms that can be installed into a building construction separately. All bathroom modules are delivered with all necessary equipment and features such as piping, sanitary appliances, sockets, light fixtures including electrical cables for interconnection with water, drainage, and electricity networks. Each module is customized to meet the needs of individual construction projects with respect to dimensions and sanitary equipment.

Probad's product is prefabricated bathroom cabinets in steel fiber reinforced concrete that have many advantages compared to space-built bathrooms and shower cabins in light materials. The product is innovative, and it provide excellent solution to the customer with a focus on quality, functionality, and flexibility. Customer who relies on Probad's bathroom cabinet, they have peace of mind because Probads provide high quality bathroom cabinet with low price compared to space build bathrooms that saves their extra time and hassle to build a bathroom.

Probad's Bathroom cabinets save customers time that customer need to invest to design and develop a bathroom cabinet. Probad's product is Sintef approved and meets all requirements for falls against drains, sealing layers, tiling, fastening, and retrofitting of equipment. The construction is robust as floors, walls and ceilings are bolted and glued, which ensures easy transport without any displacement during transport. Also, it provide a significantly smaller possibility of wear in the tee layers and penetrations, and a possible leak. The bathroom has a

solid design in steel fiber reinforced concrete. The roof construction is also in steel fiber reinforced concrete. The roof has no visible box joints and is strong enough to be able to mount the patient rail. The fiber-reinforced concrete wall is strong enough to be able to assemble equipment without having to think about nails.

4.4.Probad's Business Process:

Probad's overall process starts with Tender and contracting. Every customer is assigned with a project manager in tender and contracting phase. From this stage, customer gets involved and project manager follows up and support customer throughout the process. After tender and contracting next step is engineering phase. In this stage a design manager involved with individual customer and design and draw the solution according to the needs. In this stage, design engineers also come up with several type of design to understand what suits customer best. After finalizing the design, production is carried out according to the design. There are two plants in the factory. In one plant walls, floor and roofs are produced with casting procedure. In another plant, all other process of producing complete bathroom cabinets is carried out that icludes coating of surface and equipment installation with the help of electrician, plumber and fitters.

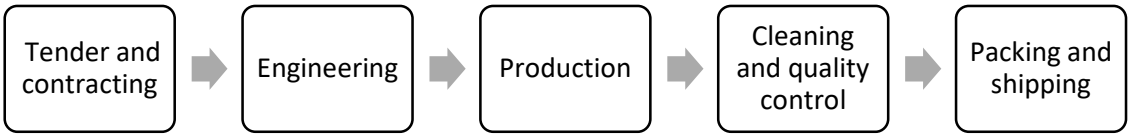


Figure 4.2 Probad's business process

After completing the production each bathroom cabinets goes through complete cleaning procedure and then the quality inspection. All elements are checked by executor, quality manager and production manager to ensure the quality of the product. When everything seems perfect, the cabins are packed with shrink plastic material and shipped to the desired location of customer.

4.5. Probad's Production process:

Casting Plant:

The production process of bathroom modules starts at casting plants. Stryfoam which is patterned with CNC machine is used as mold for the casting of the concrete floors, walls, and roofs. After that these casted floor, walls and roofs lifted to a trolly which is called family trolly for curing.

After curing levelling and then grinding process is carried out. After that floor, walls and roofs are assembled to a cabin structure. Finally, before delivering this structure to assembly plant an inspection is carried out. If there is no issue, then cabin is delivered to assembly plan. Otherwise, corrective actions are taken. A minimum of three weeks is needed for the walls, ceilings, and floors to harden before they are installed

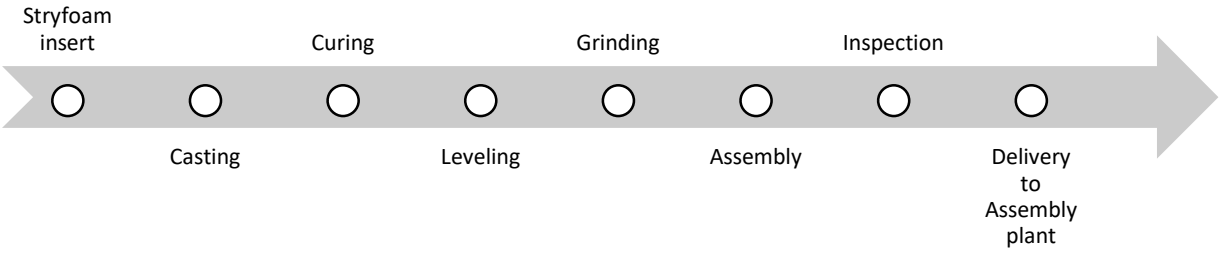


Figure 4.3 Production process of casting Plant

Assembly Plant:

In assembly plant, firstly cabins are categorized in two categories based on surface cladding. One type of cabins surfaces uses vinyl cladding and other type is tile flooring. after Cladding, all the necessary equipment's and components including electric and water lines ready to connect to construction sites are installed in the bathroom modules. After that final inspection and quality check is done and the modules are prepared for transport or storage after customer documentation and packaging.

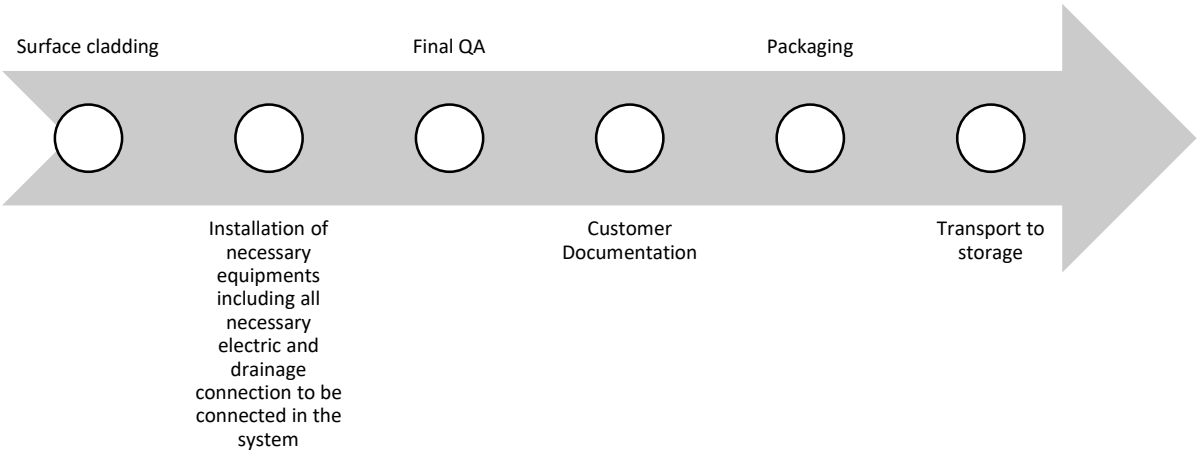


Figure 4.4 Production process of assembly plant

4.6. QA in Probad:

Probad aims to provide customers with prefabricated bathroom cabins of the highest quality. All processes are conducted according to industry standards. Employees need to read HSE handbook together with quality regulations and authorization list prior to starting work at each station. Each cabin follows dedicated specification list to ensure its quality to meet customer need according to the drawing approved by customer. It is important to meet many specifications when building a bathroom cabin. There are some specifications that are needed for public regulations and to meet customer need to approve the bathroom, and there are others required for the next process. In Probad, specification list named as quality book of cabin. All desired and exact specifications are listed in the book. After producing the cabin cleaning is carried and defects are recorded and reported immediately to supervisor. A final quality check is carried out after cleaning according to the QBC protocol. If there is any deviation, then it is recorded sent for corrective action.

The bathroom cabin is subject to many specifications. Some specifications are needed for the public rules and regulations to approve the bathroom others are needed for the next steps in the process of making the bathroom cabin or pod. Please note that all cabins must be treated as special design and therefore drawings must be used.

Example of specification:

Specification for approval:

For the electrical safety of the bathroom user, all electrical connections which are impossible to control later are installed. In the event the procedure is not performed according to regulations, electrocution might occur, or if this is found to be factually inaccurate, the whole series of baths may have to be reworked at great expense.

Specification for process:

If the precession is not maintained in earlier stages, bolts and assembly position could not match in later stages that can results in additional work for corrective action to fix the problem.

4.7. Dashboard design for Probad:

1. Profiling company:

As per discussion in the literature, an interview is held and one week was spent in the company for identified characteristic of the company. In below table characteristics of the company is displayed. As per the interview and observation from the company, it can be identified that company has very high level of customization. As discussed in company's business model, the company start it process with tendering. Therefore, it customizes it products based on customer preference from the very beginning and so the company has high level of customization characteristics. Companies like Probad, who start from tendering, usually design product after tendering. Therefore, for Probad, the company design new product every time and order come from several customer with larger quantities. For the characteristics of demand, it is identified that the demand in Probad generally is uncertain. For raw material, Probad has some defined supplier and as Probad is part of a group of company, it gets its raw material from other part of the group too. However, sometimes there could be development of suppliers based on tenders, but which is not common. For the characteristics of Layout, mostly Probad is with fixed layout. But as Probad produce product in two parts in two plants (Casting and Assembly). In casting there are station for processes like casting, curing, and grinding and product and after casting, casted floor and walls are transfer to only one station for further processing and after that is followed fixed layout position. As after casting, in the assembly part, product transferred to a fixed position and labour bring raw material and finished the product in that particular position. However, the most significant characteristics of Probad is that it involves customer from the very beginning of the business process. Therefore. as per the characteristics, it can be identified that the company is the engineer to order company. However, as the company produce large

quantities of product from only several customers throughout the years, there is a future possibility to improve the business model with shifting the CODP.

Characteristics Factors	Probad
Level of customization	Fully or most of the specifications are customized
Design Configuration	New design
Order Volume	Several customer order with larger quantities
Frequency of developing suppliers	Not that frequent (Unclear)
Demand	Highly uncertain to low predictability
Layout	Fixed position layout
Customer involvement	From Tender stage

Table 4.1 Probad company characteristics

2. Analysis of existing system:

As discussed in literature, after understanding the company characteristics, next step is to analysis existing quality system of the company. The different maturity level of the quality system for SMEs are discussed in the literature study. Based on that, the maturity of the Probad AB is discussed and for the maturity of a company. Moreover, challenges of the Probad AB is discussed with comparing common challenges found in literature study for SMEs. Below table presents the analysis of the existing system of Probad AB.

Challenges and criteria to consider for dashboard in SME	Description
Low level of maturity in QA system	It is also identified in Probad that the maturity of the QA system is low. Probad follows basic inspection with check list for the confirmation of the quality. It does not follow the total quality system or quality management system. As per literature when companies have higher level of maturity it gradually implements quality to the total organization, optimize process and control cost with the optimization of the product. Therefore, it can be identified that the level of QA system is low in Probad. The matured the

	company, it is possible to have more organized effective data. Because of low level of maturity company collect less data. Therefore, during developing a dashboard, challenges like this should be considered. The developing and implementation time of the dashboard will be longer because of the low maturity of the company.
Knowledge limitation	Probad is open to knowledge and recently it is developing platform for knowledge sharing. As there was no robust and effective knowledge sharing platform before and with lack of talent, they face challenges to gab as much as opportunity of technological advancement
Technology awareness	SMEs generally lack implementation of advanced technology to collect data like RFID, sensors, use of ICT, use of interfaces etc. Like other SMEs, Probad is also lacking advanced technology like this that make it difficult to gather quality data for using in a dashboard.
Financial Resource limitation	As an SME, Financial limitation of Probad affects it many ways. Using advanced technologies require high financial investment and/or hiring talent. SMEs that does not have technology for collecting storing and processing data, using dashboard is more challenging. Because of less financial resources, Probad use limited advanced technology that has impact on the availability of total system to collect data and integrate into another system. Furthermore, while developing a dashboard, SMEs need to consider available solutions based on the capabilities of the company.
Lack of talent challenge	Because of lack of talent and skills in advance technology, SMEs like Probad cannot implement in house solution for being ahead of the company. Moreover, another important factor of developing dashboard is knowing about important KPIs for the dashboard. This requires talent with profound knowledge for the specific topic. Lack of talent, to design, develop a dashboard with background knowledge in quality is significant challenge

Table 4.2 Challenges for Probad to develop dashboard

3. Identify objective of the dashboard.

Based on company characteristics and existing system of Probad AB, the objective of the overall dashboard is to improve overall quality for Probad AB and facilitate to improve maturity of the existing quality system from product to process quality system.

As we discussed in literature that dashboard can be categorised in three types based on the objective and user. Quality assurance dashboard for Probad AB is more tactical dashboard to improve the quality. Therefore, the objective of the dashboard is to measure progress and analysis performance of the quality assurance. For this purpose, discussed quality indicators and tools can be utilized to analysis quality performance and measure progress. This dashboard can be useful for manager and analyst to take decision and perform continuous improvement. As per the quality indicators, it can be updated weekly or monthly to find out the focus area.

Purpose	Measure progress, and analysis performance to improve overall process and product quality
User	Manager and or analyst
Scope	Departmental: Quality Assurance
Information	Detailed and/or Summary
Updates	Weekly/Monthly
Emphasis	Analysis and Management

Table 4.3 Dashboard objective for Probad

4. Concept Exploration based on the capability of the company:

In this stage, concepts for developing dashboard can be explored. Concept exploration is an important stage for any design and development. After understanding the company profile and objective of the dashboard, concept should be explored to design a dashboard. .In this stage, critical factors of quality management system for an ETO based SMEs are utilized as the basis of concepts and analysed how related the factors with the company.

5. Identify indicators based on company profile and objectives.

After finding the critical factors, next step is to identify indicators for the dashbaord. As our findings from analysing the company is that, Probad is an ETO company with the objective to provide high quality product to customers, some selected indicators found

from literature that closely related to Probad objective is as below based on company profile and literature from the critical factors of the quality assurance system.

Critical Factors	**Dashboard indicators selected for Probad AB**
Customer Satisfaction	On-time delivery, Rate of quality issues, Avg time to resolve complain
Process **Quality metrics**	Rework cost, Rework Hr, Count of Defect, Scrap Rate
Supplier Quality Metrics	Top supplier based on Supplier defect rate, and delivery time
Process **Improvement**	Improvement action, Reported issues, resolved issues
	CAPA process
Employee involvement	Top Performer bonus

Table 4.4 Indicators identified for Probad

6. Develop a data collection strategy:

Developing data collection strategy will be based on maturity of the company. The more matured the company the more possibility to have available data. With the low level of maturity, availability of data and good data quality can be challenging. However, for developing data collection strategy, it requires more exposure to the company and investigating about availability of the data. Due to security concern, in this project, Probad's available data and format of data is not analysed. Therefore, data collection strategy is not developed. However, following the guidelines discussed in literature, SMEs can develop data collection strategy. In this project, dummy data for Probad is utilized instead of actual data.

7. **Select tool based on company capability**:

As discussed in literature, cloud based BI tool is suitable for cost effective solution. In this project Power BI is utilized as Power BI provide better data integration facility and visualization compared to others tool.

8. Risk assessment

For avoiding any risk related to the data security, in this project dummy data is utilized

9. Develop dashboard:

Below is the dashboard developed for Probad using dummy Data from Probad and with indicators based on literature and objective of the company for quality assurance manager or analyst in Probad. This dashboard is developed Using Power BI tool a cloud based BI tool suitable for SMEs. The dashboard shows (Figure 4.2) the critical indicators like rework cost, rework hr and count of defects. For developing this dashboard data is collected in excel and excel file is loaded to Power BI software. After loading, based on indicators data columns are selected and matched with visualization graph. For example, for defect classification pie charts visualisation is selected for better understanding. With this visualization, user can measure progress and performance of the company from quality aspects. For instance, it presents defect classification to identify what kind of defects are more found in the production or from where the defects are found. In this way user can prioritise focus area and take data driven decision. Moreover, there is an impact indicator that shows percentage of defects with different impacts severity of the defects in the company. This dashboard is a dynamic dashboard. Therefore, user can select higher impacted defects to locate from which area or from which category more high impacted defects are coming.

More example of dashboard for Probad considering identified critical factors and indicators are presented in *Figure 4.6*, *Figure 4.7*, *Figure 4.8*. This dashboard facilitates defect analysis with histogram and pareto chart to identify trend of the defects found over a period and from which raw material most of the defects are found. Then monitoring customer satisfaction, top supplier, top performer and improvement actions with different dashboards.

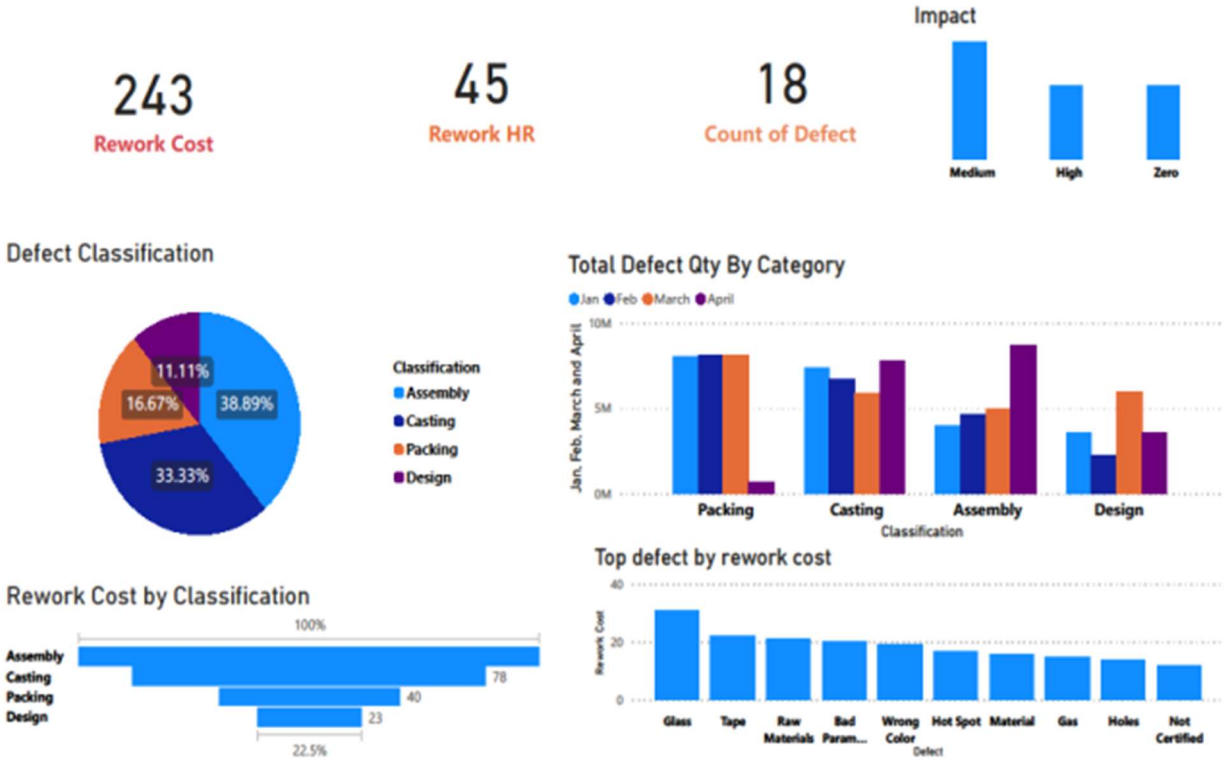


Figure 4.5 Developed dashboard with quality indicators (Attached in Appendix C)

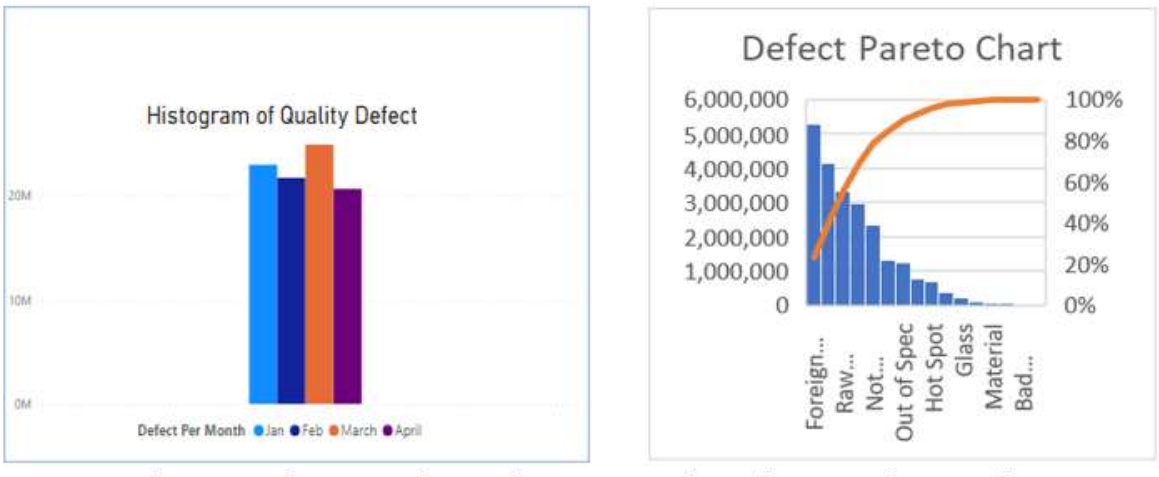


Figure 4.6 Defect Analysis dashboard with Quality Control Tool for data-driven decision

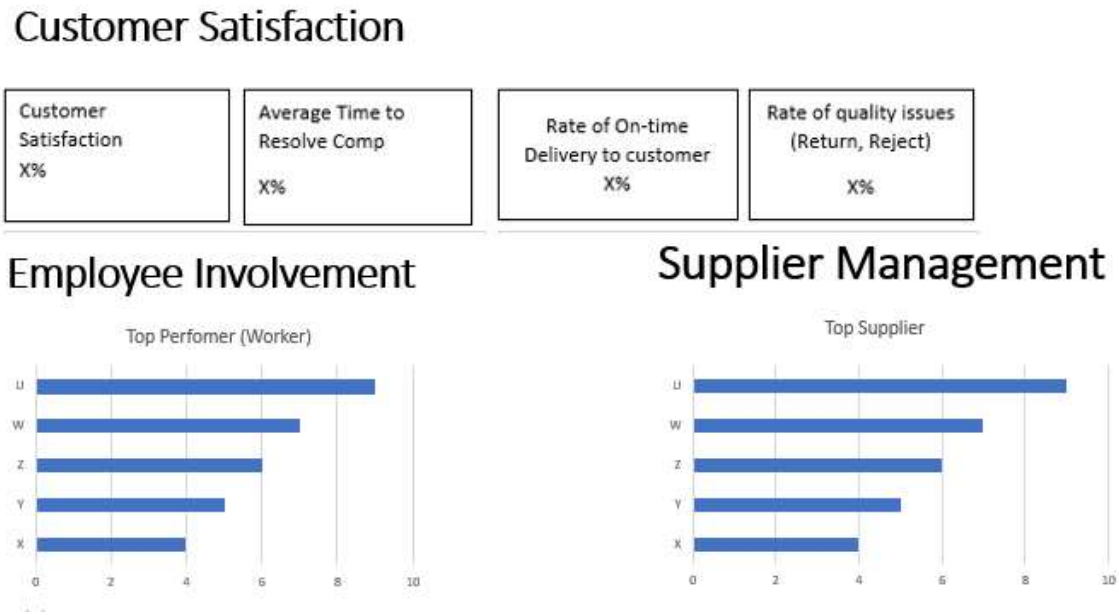


Figure 4.7 Performance measurement related to quality with dashboard

Improvement Action					
Title	Description	Assigned To	Origin	Action Status	Due Date

Figure 4.8 Quality improvement action dashboard

10. Evaluate dashboard and continuous improvement:

Evaluation steps is not presented here, because after developing the dashboard, user first need to use this than based on user experience evaluation and improvement is planned. There are some criteria like user friendliness, easy to drill down, through which Probad can evaluate the actual dashboard and continuously improve

5. Discussion and Conclusion

5.1 Discussion

5.1.1. RQ1.

What are the critical factors need to be considered for identification of quality assurance indicators for manufacturing of ETO based SMEs??

Quality assurance techniques are used by large organization to be competitive in the market. With the advancement of technology, quality assurance dashboard became popular among large farms and with the consulting farms. Despite of importance of quality assurance in SME, SMEs are deprived of utilizing advance tools like quality assurance dashboard due to many challenges. For developing the quality assurance dashboard, it is crucial to identification of critical factors for quality assurance for SMEs considering specific company characteristics like ETO. The general basic principles for quality management are equally applicable for the companies in regards of size and characteristics of the company. However, the size and characteristics of the company can, however, be taken into consideration when prioritizing principles. According to the literature study, most of the quality model and scholars agree that for ensuring overall quality of the manufacturing and adopt quality management in a company, critical factors are customer satisfaction, leadership, employee involvement, process improvement and supplier quality management (see ***Table 3.4: Critical factors in QMS***). Among these customer satisfaction, leadership and employee involvement is emphasized by researchers for SMEs and besides these factors, supplier quality management is emphasized for ETO companies as in ETO company characteristics, delivery time and ensuring quality from raw material is curial due to complexity of the ETO companies.

5.1.2. RQ2

What are the dashboard indicators for quality assurance for manufacturing for ETO based SMEs?

After identification of critical factors, it is important to identify suitable KPIs for developing the dashboard. Indicators that can be categorised with the critical factors. Moreover, as discussed in literature that indicators for different CODP company are also different. On time delivery which can be categorised in customer satisfaction as it is directly related to the customer satisfaction. Rework cost and defect rate can be categorised as process quality metrics are the most significant indicators for ETO companies according to

the scholars. In ETO company rework cost is comparatively high if the defect is detected in later stage as the manufacturing cost became high. Moreover, there could be different type of defects but there is need of more focus for some defects compared to others. Because the severity and impact of the all the defects can be varied widely. Therefore, scholars also agreed to the importance of the cost of defects as important indicators. However, for an SME, these indicators are feasible too as these are easy to implement. For SMEs, quality tools can also make a significant contribution. According to scholars, quality tools are easy to learn and implement. Therefore, utilizing dashboard that facilitate quality tools is also suggested in this project. However, as identified in literature, that SMEs need to emphasize in employee involvement with motivating and rewarding employee, top performer indicator is the simplest indicator that will facilitate employee involvement for SMEs. See *Table 3.6: Dashboard indicators based on quality critical factors* for identified indicators that are suitable for SMEs and ETO based companies.

5.1.3. RQ3

How to develop QA dashboard for manufacturing for ETO based SMEs?

For developing dashboard, challenges of SMEs are considered. However, as per previous literature there are less literature that provide guideline for dashboard for SMEs and specially there is no literature that considered quality assurance dashboard for SMEs and ETO CODP of the company. Company CODP is crucial for identification of KPIs which are one of the most important part of the dashboard. Moreover, for developing dashboard, SMEs face several challenges like, financial restriction, lack of knowledge and talent etc (See *Table 3.7: Typical challenges for SME to develop quality assurance dashboard* (See *Table 3.7*). Considering all these challenges, this research established guideline with step-by-step process for developing quality assurance dashboard (See *Figure 3.19: Step by step guideline to develop dashboard)*. The main steps for developing the dashboard are: Profiling company, analysis existing system, identification of objective, concept exploration, identification of indicators, data collection strategy, selecting tool, risk assessment, develop dashboard, evaluation and continuous improvement.

These steps are described with detailed guideline. For example, for understanding company profile, CODP framework can be utilized. For understanding maturity of the SME regarding quality assurance system, five stages of quality framework can be followed. After that objective of the dashboard for quality is found from identified critical factors of quality form literature and considering the company characteristics. Based on critical factors, metrics are also

identified considering same factors. For quality assurance dashboard, any ETO based SMEs can utilize identified critical factors and indicators. However, after having dashboard contents, guideline to develop the dashboard considering challenges of SMEs is also discussed in this paper. For developing the dashboard, SMEs need to have data collection strategy. After the identification of contents, what data is required is known to SMEs. For example, to identified defect rate, SMEs need to collect data of different defect in different stage. For collecting data, SME can utilize advance technology like sensor or manual identification of defect after inspection. In this paper, indirect data collection technique is advised for SMEs considering financial challenges to identify defects. With the indirect data collection, SMEs can avoid installing expensive sensor(Xu et al., 2020). Though it has advantage to identify defect directly and accurately indirect data collection is more appropriate for the SMEs according to scholars. With indirect data collection strategy SMEs can collect correlated data and measure the actual data. Overall, in this stage SMEs need to have total planning about what data need to be collected, how to collect the data and frequency of the data collection, format of the data collection and volume of the data. After collecting data, SMEs need to extract, transform, and load data to any tool for developing the dashboard. In this paper, considering SMEs challenges and strength, cloud based BI tools are suggested for SMEs. Cloud based BI tools does not require extra hardware or software thus comparatively inexpensive. Cloud base BI tools became expensive when data storage capacity need to be high. SMEs generally need less data storage capacity compared to large organization. Therefore, cloud-based BI are suitable for SMEs.(Grabova et al., 2011) Though cloud based BI also have some other limitation like less customizable and there is concern for data security. SMEs can discuss these issues with consulting firms that provide cloud based BI solution with monthly subscription rate and contract for data policy. Moreover, cloud based BI tools like Power BI, Qlike sense and Tableau are also feasible options for SMEs due to the feasibility of data integration. In this project, dashboard is developed with power BI tools. However, after selecting tool, SMEs need to assess the risk regarding data privacy with the service provider or investigating risk factors to utilize open sources. If any risk factors are found, the company should consider how to avoid this risk. After selecting tool and understanding how to avoid risk factors, it will be time for developing the dashboard and after development evaluation.

In the case study, the guideline is followed to develop the dashboard and it is found practical and easy to follow. Content for the dashboard is inspired from the literature study and had to adjust with selecting most appropriate indicators for Probad AB among all the indicators. Moreover, the project utilize power BI tool and dummy data is utilized for developing the

dashboard. The case company found the developed dashboard as practical and useful for their company as the dashboard is capable to measure progress and monitor crucial indicators to take data driven decision. Operation excellence manger Velin stated that

‘’The work is highly practical and valuable to us in regard to creating a Quality Assurance Dashboard in correlation with the capabilities of SMEs, such as Probad’’ he also added that ‘’We are highly satisfied with the preliminary results’’

5.2. Contribution:

The research filled the gap in identifying quality assurance dashboard content with identification of critical factors related to quality for SMEs and ETO and based on that with identification of most suitable indicators for this kind of company. Moreover, this research contributed to develop quality assurance dashboard considering the characteristics and capabilities of SMEs that is less addressed in previous literature. Further, this research is able to contribute to the practical field since ETO based SMEs can use it to develop a quality assurance dashboard that is specifically tailored to their needs and takes advantage of modern tools.

5.3. Limitation:

The main limitations of the thesis are

Lack of actual data:

For the data security concern, in this project dummy data is utilized. Therefore, challenges with data quality and developing data collection strategy is explored for the case company.

Evaluation of the dashboard from user experience:

As the dashboard is developed based on dummy data and there is time limitation, evaluation of the dashboard is not carried out. Thus, the user experience could not be explored for a suitable time period.

Single case study:

Another limitation is that the dashboard development guideline is implemented in one company. Therefore, suitability of the dashboard with different kind of company can not be explored

5.4. Future Work:

Future work of this research will be to identify dashboard content from other CODPs. The dashboard method has been applied to only one case. Therefore, in the future, multiple companies can be considered to include more diverse or complex company characteristics. Considering visual design was also out of the scope of this project, therefore, in future research, researchers can include that for better interaction with the user through dashboards.

5.5. Conclusion:

This research aimed to develop a quality assurance dashboard for ETO based SMEs with practical guidance including identification of dashboard content like indicators that support the achievement of their business objectives related to quality. Existing dashboard development guidelines found in literature are geared towards larger companies. Moreover, there is no literature found that is focused on quality assurance dashboard for ETO based SMEs. In this project, guidelines are developed considering capabilities of SMEs. For example, this research considered financial capabilities of SMEs, data collection challenges for SMEs and suggested to used indirect data collection technique and utilizing cloud based BI tools. Moreover, this research established total procedure to develop a dashboard that covered from identification of indicators to developing the actual dashboard. As for developing the dashboard contents quality assurance of ETO manufacturing is considered, this research to develop quality assurance dashboard is uniquely geared toward ETO based SMEs. The most appropriate indicators for ETO based SMEs are identified for developing the dashboard. Therefore, company with ETO manufacturing characteristics and capabilities like SMEs can utilize this research for developing the quality assurance dashboard for their company. Thus, this research contributed in practical field besides scientific field.

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Appendix A: Interview Questionaries

Interview Questionaries:

The interview was held digitally with predefined questions and in Survey form. Questions were sent with Survey Monkey tool and interview attendees answered in their available time. There were three participants for this interview and questions are as followed.

1. How will you define the level of customization of products for Probad?

- Fully customer specific
- Some specifications are allowed
- Most of the specifications are allowed
- None (Fully Standard)

2. Is it common for Probad to configure existing design instead of new product design?

- Yes
- No

3. Is there a pre-defined set of suppliers for buying raw materials for Probad?

- Yes, we buy raw material from specific suppliers
- No, we buy from random suppliers based on order
- Other (please specify)

4. How will you define the volume of the order?

- Few large customer orders per year
- Several customer orders with large quantities per year
- Large number of customer orders with medium quantities per year
- Frequent call-offs based on delivery schedules
- Other (please specify)

5. How frequent is it to develop a new supplier for Probad?

6. Type of procurement for Probad?

- Order by customer order procurement
- Order to stock considering the delivery schedule
- Other (please specify)

7. Inventory accuracy for the finished product and raw material?

- Low inventory based on orders
- Medium level of inventory
- High Inventory level
- Other (please specify)

8. How will you define the demand of products?

- Highly Predictable Demand
- Low Predictable Demand
- Uncertain Demand
- Highly Uncertain Demand
- Other (please specify)

9. How will you characterize the process of production (Select multiple)

- The product positioned in a fixed place and materials move towards the product positioned
- Product moves to different station towards resources
- Production of one unit at a time
- Production in small lot sizes
- Other (please specify)

Appendix B: Company Statement

Confirmation from the case company that the company found developed dashboard as beneficial

probad

CONFIRMATION

Probad hereby confirms that Ifrat Jahan Tisha wrote her master thesis on the topic of *Designing Quality Assurance Dashboard for Manufacturing Industry in an SME* for our company. Her work is highly practical and valuable to us in regard to creating a Quality Assurance Dashboard in correlation with the capabilities of SMEs, such as Probad.

We are highly satisfied with the preliminary results her scientific and novel work provided us and we are in the process of offering her a summer job with prospects for a full-time position.

We are happy that her competency and personal interest were able to provide us with the groundwork for the creation of a modern Quality Dashboard using our pre-existing ways of working and tools.

It was a pleasure to collaborate with Ifrat and be her company supervisor during the process of writing her thesis. She is an exceptional engineer and has my best references!

Velin Aleksandrov Georgiev
Automation Responsible
Bano Group AS

06.06.2022
Oslo, Norway

Appendix C: Dashboard

Dashboard for case company

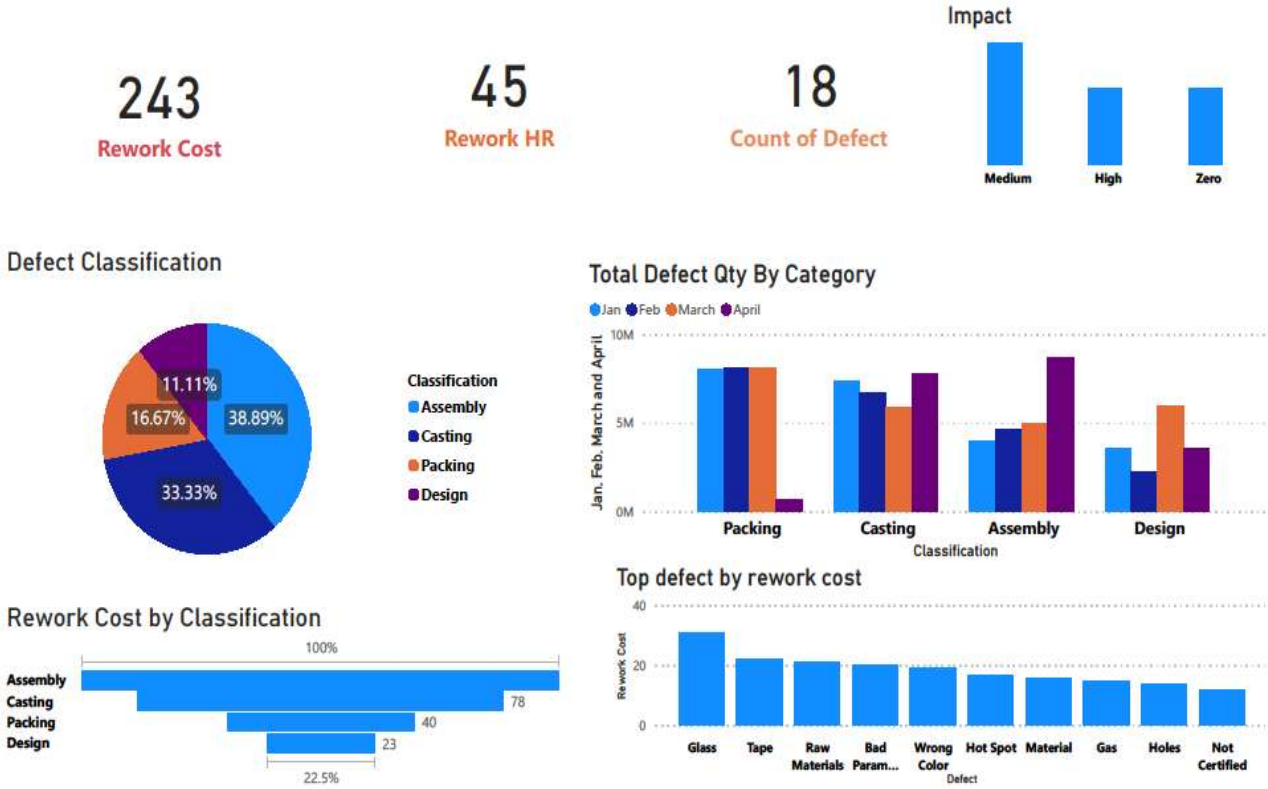

Figure 4.4: Power BI dashboard with quality indicator

Figure: Defect Analysis dashboard with Quality Control Tool for data-driven decision

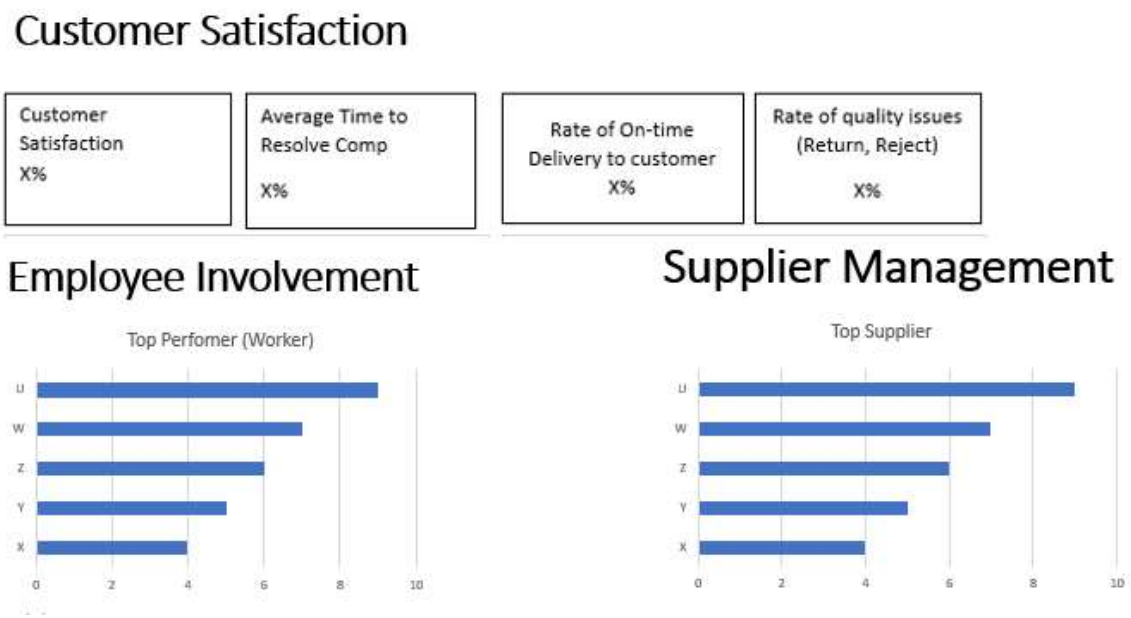

Figure: Performance measurement related to quality with dashboard

Improvement Action					
Title	Description	Assigned To	Origin	Action Status	Due Date

Figure: Quality improvement action dashboard