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Towards the integration of Quality Management and Business Analytics

A case study at Volvo GTT PE

Master's thesis in Quality and Operations Management

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Report No E2014:084
Department of Technology Management and Economics
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SUMMARY

With the increase of digital data and the rise of concepts like *big data*, the need for business analytics is assumed to increase. Business analytics relationship to other research areas is yet to be investigated. This thesis will therefore contribute to bridging the research gap by focusing on quality management and its support to business analytics. The relationship is discussed in general terms and a quality management practice is investigated for its ability to support the business analytics process.

A literature review is conducted in order to display the relationship between the two research areas. Quality management is presented as a system of principles, practices and techniques. Several business analytics processes are presented and compared and the Knowledge Discovery in Database process is chosen as a representative process. A case study is conducted at Volvo GTT PE and through an abductive research approach a customized version of Quality Function Deployment is developed in order to support the business analytics process. The proposed methodology consists of four stages; *Requirements investigation, Outcome planning, Process planning* and *Taking action based on findings*, each involving several steps. The methodology is explained in the context of the case study.

The quality management principles, practices and techniques that can support business analytics are investigated and displayed in a framework. The framework shows that the quality management principles should be considered in all phases of the business analytics process. The case study has also shown that the customized version of Quality Function Deployment can support all phases while the quality management techniques can be used in specific phases.

Keywords: Business analytics, Quality management, Quality Function Deployment, House of Quality.

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Finally we would like to thank each other for a great collaboration and lessons outside the scope of the thesis.

Gothenburg, July 2014

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Neda Abdolrashidi Niklas Glaerum

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1. Introduction

This chapter introduces the research area and outlines the purpose as well as the research questions associated with this study.

1.1. Introduction

According to Bergman and Klefsjö (2011) quality has always been important to customers. Quality management (QM) is therefore a mature and relatively old research field (Sousa & Voss, 2002). Although diversity in definitions of quality and QM still exists most studies show a positive correlation between QM efforts and operational and business performance (Sousa & Voss, 2002). This is best exemplified by the "Japanese miracle" between 1950 and 1985 when the Japanese industry went from having a very poor quality reputation to being world leading (Bergman & Klefsjö, 2011). This thesis use the definition of QM as an approach to management involving a system of principles, practices and techniques presented by Dean and Bowen (1994).

The recent years have seen a large increase in the amount of digital data produced (Loshin, 2013) which has led to the rise of concepts like big data and business analytics (BA) (Mayer-Schönberger & Cukier, 2013). BA is defined as ensuring that the right users get the right information at the right time (Laursen & Thorlund, 2010). All collected data needs to be translated into information and knowledge for full understanding (Laursen & Thorlund, 2010). This translation is the output of BA (Davenport et al., 2001). BA has traditionally been performed manually but the increasing amount of data makes manual analysis slow, expensive and impractical (Fayyad et al., 1996). Meanwhile data left without analysis is a waste (Davenport et al., 2001) which is why an increase in the amount of data will lead to an increased need for BA. The adoption of BA comes with benefits in terms of better decision making (Davenport, 2009) as well as improved business performance (Bronzo et al., 2013; Kiron et al., 2011).

As BA grows in importance other research areas need to reflect over the implications on their activities. This applies to QM as well as other research areas. If companies want to keep the competitive advantages they get from QM (Bergman & Klefsjö, 2011) while capitalizing on BA the support and conflicts with between the improvement concepts need to be fully understood.

This thesis is a case study at Volvo GTT PE in Gothenburg. Just like many other companies (Davenport et al., 2001) this company struggles with analyzing the amount of data currently produced in their business processes. More specifically two processes, the Conformity of Production (CoP) and the Hot test, will be investigated. With quality being one of the company's core values, the aim is that a part of the solution to this problem lies in the QM field.

1.2. Purpose

The purpose of this research is to discover how quality management can support business analytics process in the organization.

1.3. Research questions

The purpose will be fulfilled by answering the following research questions:

RQ1: How can quality management principles support business analytics process?

RQ2: How can quality management practices and techniques support business analytics process?

1.4. Delimitations

At present, the CoP- and Hot tests are performed in several locations worldwide. This project is limited to the tests performed in Sweden. The aim is however to provide the results in a way that they are applicable to other sites and processes. The project will provide a framework on how quality management can support business analytics. The project is delimited from implementing the suggested guidelines into the organization. The BA process is long and stretches from decision framing to executing the decisions taken based on analytics. This study is delimited from the support of decision making and decision execution as decision making is a research area on its own.

2. Research Methodology

In this chapter the methodology used in this study is described.
The chapter also addresses research quality and ethical considerations.

2.1. Research strategy

This study has utilized a qualitative research strategy. According to Hacohen (2004) research methodology is highly dependent on the distinction between induction and deduction. The qualitative research strategy involves induction where theory is developed from the research findings (Bryman & Bell, 2011). Deduction on the other hand is the testing of a hypothesis (Bryman & Bell, 2011). Both inductive and deductive research has elements of the other research stance (Bryman & Bell, 2011). Induction which has a deductive explanatory nature is called abduction (Kuipers, 2004). This study has used an abductive approach called systematic combining where theory, framework, empirical world and the case all influence the research process (see Figure 1) (Dubois & Gadde, 2002). The theoretical frame and empirical study thus evolved simultaneously.

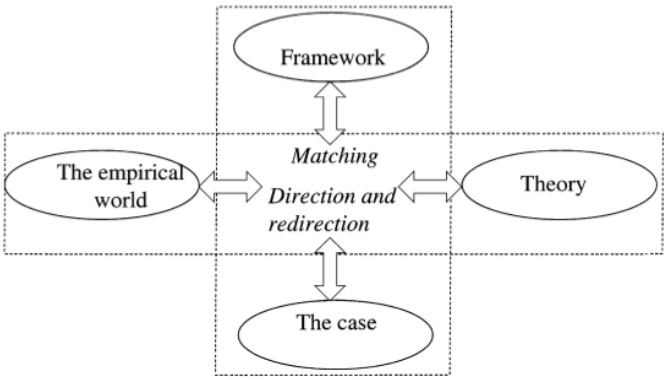


Figure 1 Systematic combining framework (Dubois & Gadde, 2002)

2.2. Research design

The systematic combining approach involves matching of several data sources (Dubois & Gadde, 2002). The study employs a case study design where a case and literature is examined. The case study design provides the opportunity to study an organization and its activities related to the research area in detail (Bryman & Bell, 2011). Yin (2009) suggest that a case study is suitable when the research questions are of an exploratory nature and explain that these research questions often begin with the words how or why. The two research questions in this study fits well into this description. According to Dubois and Gadde (2002) the case evolves during the research process as more theory and data are gathered. Corbin and Strauss (2008) emphasize that some theoretical knowledge can facilitate a researchers understanding of a case while too much theoretical knowledge inhibits it. This relates well to Gummesson's (2000) ideas of Preunderstanding as a stepping stone to understanding. The authors' preunderstanding is discussed further in the research quality chapter (Chapter 2.5).

2.3. Research Method

According to Bryman and Bell (2011) a research method denotes the means of data collection. In this study several means of data collection were used such as literature review, interviews, observations and the study of internal company documents and test results from the two test procedures investigated (see results chapter for more information about the tests).

Table 1 Matching research questions with research method

Research question	Research method
RQ1: How can quality management principles support a business analytics process	Literature review, interviews
RQ2: How can quality management practices and techniques support a business analytics process	Literature review, interviews, observations and internal documents

Table 1 shows the connection between the research questions and the method used to answer them, the research process can be explained as in Figure 2

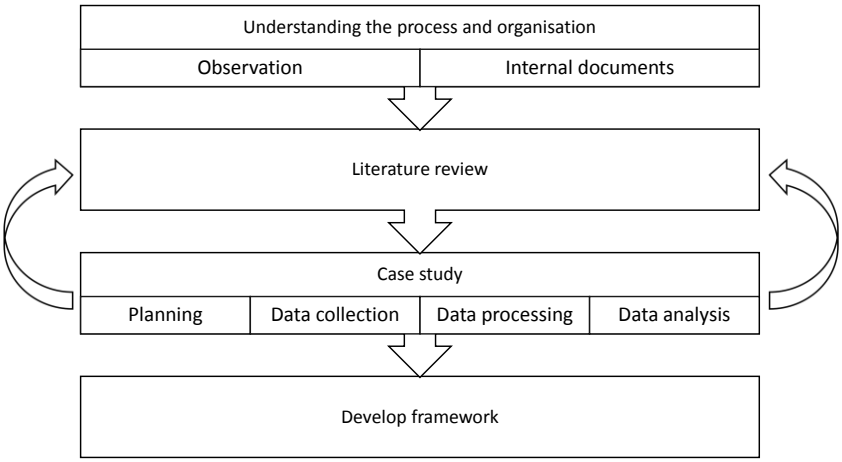


Figure 2 Research process

2.3.1. Understanding the case and test procedures

In order to investigate the CoP and Hot test there was a need to understand the data that was collected and the processes that creates the data. Therefore two weeks were spent on observation of related processes in internal management systems and reviewing available documents. In addition, informal conversations as well as four unstructured interviews with one process owner, two test engineers responsible for collecting the test results and one analyst were conducted. The test rigs were also visited and similar tests observed in order to enhance the understanding of the test procedure.

2.3.2. Literature review

In order to answer the first research questions the data collection method was mainly based on the literature review. In order to gain knowledge about quality management principles, tools and techniques and also the concepts and frameworks regarding business analytics, as two main areas of research, a literature review was performed using mainly Science direct (sciencedirect.com) and Web of Science (apps.webofknowledge.com). The following keywords were investigated: *Quality management, Quality Function Deployment, Business analytics, Decision making, data analysis, data presentation, visualization.* The articles and books found using these keywords were evaluated based on their relevance to the research. In total around 70 articles and books were found to be useful and read more thoroughly. The knowledge gained from the literature was then used as an input to data analysis part of the research and to run the case study. However, the data collection process was

iterative and went back and forth between the case study and the literature review. The knowledge found in the literature was used as a guide to run the different phases of the case study and the findings from the case study was used as a guide to which areas were needed to be further investigated.

2.3.3. Interviews

The data collection through interviews was initiated with the identification of stakeholders to the testing procedures. All stakeholders were internal customers working in the same part of the organization (Volvo GTT Powertrain Engineering). Throughout the report the names stakeholders and customers will be used interchangeably for this group. This was done through a snowball sampling where the customers at management level were identified by two persons currently performing analysis on the test results. The management group was chosen as customers based on that they are affected or interested in the test results. These managers were then during the interviews asked to identify specialists in their section that uses, or would benefit from using, the test results in their activities. This resulted in a total of 30 interviewees spread over eight sections. The distribution can be seen in Table 2.

Table 2 Respondents split by section

Section	Number of interviewees	Managers	Specialists
Engineering Quality	4	1	3
Maintenance and verification	2	1	1
Base engine	4	1	3
Combustion system	5	1	4
New products	5	1	4
Platform Chiet Engineer HD	2	1	1
Control Systems Technology	6	1	5
Combustion Performance Calibration	2	1	1
Total	30	8	22

The interviews were based on an interview guide. Semi-structured interviews were chosen as research method since the method fits the inductive orientation better than structured interviews (Bryman & Bell, 2011) allowing more flexibility to the interviewer and interviewee. An interview guide was then developed where the authors first brainstormed areas of interest. After these were identified, interview questions that correspond to the research areas were then derived and improved. According to Bryman and Bell (2011) the language should be relevant to the interviewees and this was considered when improving the questions. An introduction that set the scene was also developed to ensure that all the interviewees had information about the purpose of the study and interview as well as relevant knowledge about the tests. Also instructions to minimize misunderstandings and faulty information were included in the introduction.

The questions were then arranged in order of invasiveness starting with questions about actions, then knowledge and finally philosophy in accordance with Price's (2002) theory of laddered questions. This facilitated the creation of rapport between the interviewee and researchers which according to Dundon and Ryan (2010) is a key factor to collecting rich data. The interview guide was then tested, both on imaginary customers and one of the already identified customers in a pilot study. A list of risks with the chosen research method was also brainstormed by the authors along with potential solutions (see Table 3). These solutions along with the feedback from the pilot study were then used to improve the interview guide. Slightly different interview guides were developed for the managers versus the specialists due to the fact that some questions only were relevant to one

of the groups. The final interview guides can be seen in appendices A and B.

Table 3 Risks with chosen research method and ways of mitigating the risks

Risks	Solutions
The respondent misunderstand the question	Allow time for questions during the interview
The respondents is unable to explain what they mean	Allow updated answers after the interview
The respondent is not relevant for the study	Perform a stakeholder analysis to weight respondents unequally
Stress due to time restrictions	Book enough time and allow for follow-up interviews
Lack of interest in the study	Present the potential benefits with the study

The interviews were then conducted. With the permission of the interviewees all interviews were recorded. Both authors attended all the interviews and the interview guide was divided so that the same questions were asked by the same researcher, in the same way, in all interviews. Follow-up questions were asked when anything was unclear. The researcher not asking questions focused on taking notes that were used to support the summary and analysis of the interviews. All interviews took place in private rooms except for one interview conducted via Lync (an online solution). The lengths of the interviews were between 15 minutes to 3,5 hours depending on how much the interviewee had to say in relation to the research area. If the interview took longer time than expected a new time and place was arranged for the following interview.

All interviews were summarized and sent to the interviewees for validation. The interviewees were given one week to change any answers that they felt did not reflect reality due to misunderstandings or a change of mind. Lincoln and Guba (1985) refer to this technique as member checking and presents it as a technique for increasing credibility in qualitative research. Cho and Trent (2006) warns that this technique requires that the respondents have integrity, an idea that is shared by Lincoln and Guba (1985). Buchbinder (2011) also notes that the power balance between the respondents and researchers shift when the researchers are reliant on the respondents to accept their work which in turn could affect the analysis. When summarizing an interview one of the researcher would listen through the recorded interview and use the interview guide to fill in the answers to all questions. The summary was then scrutinized by the other researcher who compared it to the notes taken during the interview as well as his or her memory of the interview. If there were any disagreements these were discussed between the authors and an agreement was reached. The summarized interview was then sent to the interviewee for validation along with any follow-up questions.

2.4. Data analysis

2.4.1. Analysis of interview data

After receiving a validation from the interviewee or the passing of deadline for validation the interview data was copied into an excel sheet where each row corresponded to an interviewee and each column corresponded to a question. The sheet also included information about which section the interviewee belonged to as well as whether it was a manager or a specialist. The interview guide contained many questions that were not aimed at only finding the needs (Appendix A and Appendix B). These questions were instead used to understand the current situation. The authors then codified

the answers individually. The codes were written down on post-its and compared with the other researcher's codes. In case any codes were identical one of them were discarded. The different codes were then explained and grouped with other similar codes with the aim of having 6-10 groups. No codes were forced into a group if it was not perceived to belong there. Each answer was then categorized as belonging to one of the decided codes.

From the codes a number of requirements on the specific BA process (CoP and Hot test) were then identified. These were then evaluated on whether they were real needs or quality attributes to an underlying requirement. If they were considered to be a quality attribute the underlying requirement was identified by the authors and added to the list of needs. A large table inspired by the House of Quality in QFD (Bergman & Klefsjö, 2011) with every interviewee in a separate row and every requirement in a separate column (HoQ1, Figure 31) was constructed. Based on the interviews each interviewee was then matched with the needs he or she had expressed. In the case that any requirement was implied by another requirement these were also added. If the requirement was requested by an interviewee the corresponding cell was marked with a "1". If it was not requested the cell was marked with a "0". The number of interviewees mentioning a specific requirement was then summed up to give an indication of the importance of each requirement.

Since the summarized values only show the frequency of mentioning they were not considered to give a good estimation of needs relative importance. The stakeholders were then evaluated based on their level of current usage, their interest in using the test results and the impact their activities had on the final outcome in order to give different weights to responses from different customers. This was incorporated into the HoQ and a new importance rating on needs were derived. The roof of the matrix was filled out to show correlations between needs.

Each requirement was now considered in order to brainstorm quality attributes that reflected the needs. This was done individually by the authors and the quality attributes were then compared and a comprehensive list developed. A new table (HoQ2, Figure 32) was created with the needs from the first table corresponding to a row in the new table and the developed quality attributes corresponding to a column. The quality attributes were then matched with needs in the same way that the needs were matched with the stakeholders. The rating scale used in the relationship matrix was 0,1,3,9 as the relationship now could be of different strength. The importance of each requirement gave different weight to the quality attribute corresponding to that requirement. The multiplied numbers were summarized for each quality attribute. This was used as an importance rating of the different quality attributes. The roof of the second HoQ was also filled out to establish any correlations between quality attributes.

The quality attributes and their summed up importance rating were then included in a third HoQ (HoQ3) as rows with the columns occupied by actions that corresponded to the quality attributes. The actions were brainstormed by answering the question "what needs to be done for this quality attribute to be present?". The list of actions was validated by company representatives familiar with the test processes. The relationship matrix was filled in using the same rating scale as the previous HoQ (0,1,3,9) and the sum of each rating multiplied with the importance of the quality attribute it corresponded to was calculated. The three HoQ can be found in the results and analysis chapter.

2.5. Research quality

According to Bryman and Bell (2011) the use of the same criteria when evaluating qualitative research as when evaluating quantitative research is insufficient. Lincoln and Guba (1985) instead present the concept trustworthiness. Trustworthiness consists of the four criteria credibility, transferability, dependability and confirmability (Lincoln & Guba, 1985). Bryman and Bell (2011) relate these criteria to the quantitative criteria in the following way (Table 4).

Table 4 Matching qualitative and quantitative evaluation criteria (Bryman & Bell, 2011)

Qualitative criteria		Quantitative criteria
Credibility	=	Internal validity
Transferability	=	External validity
Dependability	=	Reliability
Confirmability	=	Objectivity

Credibility relates to the extent that multiple researcher accounts of a social reality is similar (Bryman & Bell, 2011). There are several techniques for ensuring credibility in a research study (Lincoln & Guba, 1985). One of these is member checks which entails the validation of research findings with respondents (Lincoln & Guba, 1985). This technique was utilized in this research study as the summaries of interviews were sent to each respondent for validation. As explained earlier this technique and its benefits are debated. Another technique that was used to some extent in this study is triangulation. By interviewing several stakeholders with similar work assignments as well as reading internal documents some answers from respondents could be questioned and through the use of follow-up questions accepted or rejected. According to Lincoln and Guba (1985) this technique establishes credibility and thereby trustworthiness.

Transferability relates to the ability to generalize the research findings to another time or to a larger population than the sample (Lincoln & Guba, 1985). Both Lincoln and Guba (1985) and Bryman and Bell (2011) agree that transferability is best established by a detailed description of the study subject. This way other researchers can read and decide whether the findings are applicable to their sample or not. In this case the authors have attempted to describe the case as detailed as possible for enhanced transferability. To what extent it was successful is for other researchers to evaluate.

Dependability instead relates to the ability to audit the study as such (Bryman & Bell, 2011). This is according to Lincoln and Guba (1985) established through a detailed description of the research process. In this study it is attempted to explain the methodology in an exhaustive manner in order to satisfy this evaluation criteria.

Confirmability is according to Bryman and Bell (2011) the degree of objectivity shown by the researchers. Lincoln and Guba (1985) mean that this should be audited by others and is hard for the researchers to evaluate themselves. All of the evaluations were made separately by the authors and later compared which is believed to reduce the risk of subjectivity in the research.

As previously mentioned Gummesson (2001) emphasize the importance of preunderstanding in research programs. It is therefore relevant to explain the authors relation to the case company and research area. Both authors are studying QM at master level and are therefore familiar with the

research area while the BA research area was new to both authors although statistical analysis as a part of BA is also frequently used in QM. In terms of the company one of the authors has been working at the department where this study was conducted and therefore had knowledge about the organization and the people in the group where the study was conducted, while the other researcher was new to the organization without any previous knowledge of the specific industry.

2.6. Ethics

Bryman and Bell (2011) presents four ethical principles to consider when conducting a research study. These areas are; harm to participants, lack of informed consent, invasion of privacy and deception. This study has attempted to consider these principles. No harm came to the respondents as no invasive questions were asked and all interviews were conducted on a voluntary basis. The interviews were recorded but the respondents were always asked for permission first which combined with the ability for respondents to read and validate all that had been written after the interviews addressed the issue of lack of informed consent. No questions were of a private nature and the respondents were informed that no anonymity was promised. Therefore it is believed by the authors that no invasion of privacy was committed. Before each interview the respondent was informed about the purpose of the research and interview along with other relevant information about the authors and the study (see Appendix A and Appendix B). This was an attempt to avoid deception.

3. Theoretical framework

In this chapter the theoretical framework is presented.
The two main research areas quality management
and business analytics are presented individually
before expressing the theory synthesis.

3.1. Quality management

There are many definitions of quality available as can be seen in Figure 3.

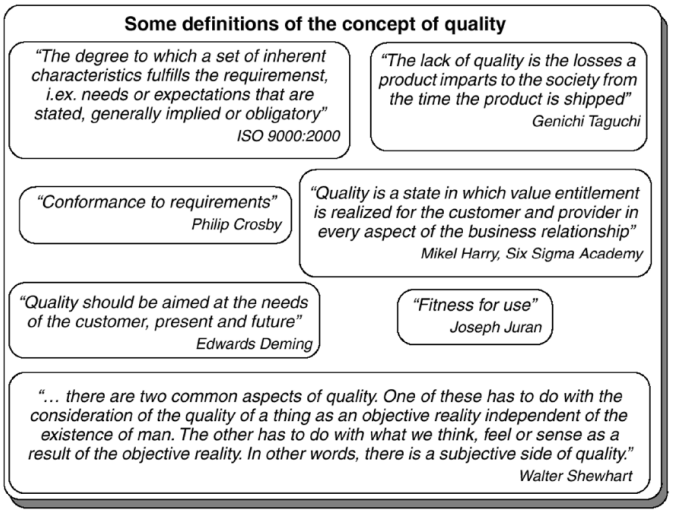


Figure 3 Definitions of quality (Bergman & Klefsjö, 2011)

Garvin (1988) categorizes the definitions into five approaches to quality; the transcendent, user-based, manufacturing-based, value-based and product-based approaches. According to this approach, the transcendent refers to the quality as an entity beyond something that can be define, and according to the transcendent approach quality is a condition of reaching the excellence and achieving the highest standard.

In addition, according to Garvin´s (1998) approach, the focus of user- based is on the consumer needs. He defines quality as something that fits to consumer preferences and satisfies their desires. Moreover, regarding the product-based approach, he emphasizes reaching the desired attributes and ingredients of the product as the definition of quality. According to the manufactured-based approach quality is conformity to the established specifications and any deviation from specifications lead to quality reduction, and regarding the value-based approach quality can be defined in terms of cost, prices or any other attribute (Garvin, 1988).

This diversity in definitions enhances the importance of choosing a representative definition. Bergman and Klefsjö (2011) define quality as a product´s ability to satisfy, or preferably exceed, the needs and expectations of the customers. They further define customers as "Those we want to create value for" (Bergman & Klefsjö, 2011:28).The definition of customers is important since the customers, according to the above definition of quality, determines if we produce a product of good quality or not. In this research the definition of customer by Bergman and Klefsjö (2011) is used.

Dean and Bowen (1994) view TQM as a system of principles, practices and techniques. This view is supported by Hellsten and Klefsjös (2000) view of TQM as a management system consisting of values, techniques and tools. The techniques are explicit ways of performing the practices which are activities to support the principles (Dean & Bowen, 1994). This explanation of practices and techniques show that they relate well to Hellsten and Klefsjö's (2000) techniques and tools. The structure of these frameworks can therefore be viewed as in Figure 4. The QM system used in this research is based on the view of Dean and Bowen (1994) since the idea of principles, practices and techniques was first discovered by them and later on supported by Hellsten and Klefsjö (2000).

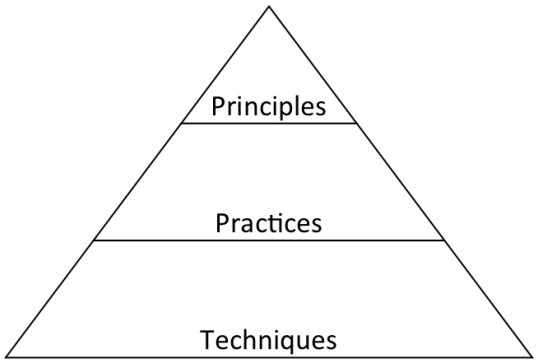


Figure 4 QM framework (Dean & Bowen, 1994)

According to Hellsten and Klefsjö (2000) there are different viewpoints about which the principles of QM are but some are however generally agreed upon. These are presented as the corner stones of Total Quality Management (TQM) by Bergman and Klefsjö (2011) (Figure 5). TQM is defined by the same authors as "a constant endeavor to fulfill, and preferably exceed, customer needs and expectations at the lowest cost, by continuous improvement work, to which all involved are committed, focusing on the processes in the organization" (Bergman and Klefsjö, 2011:37). The corner stone model is a representation of the values behind TQM and involves focus on customers and processes, continuous improvements, decisions based on facts and committed leadership as well as letting everybody be committed (Bergman & Klefsjö, 2011).

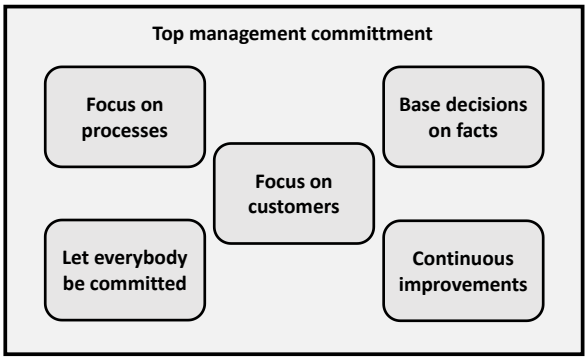


Figure 5 The corner stone model (Bergman & Klefsjö, 2011)

As previously stated, each principle in QM need to be performed through a set of practices. According to Dean and Bowen (1994), there are several practices that can be used to support different principles such as making direct contact with the customer and identifying the customer needs through collecting information are the proposed practices to support customer focus. In addition, there are a wide range of techniques that can be used for supporting different practices e.g. flowcharts, control charts, process maps, etc. Examples of tools and techniques are also presented by Hellsten and Klefsjö (2000) (Figure 6).

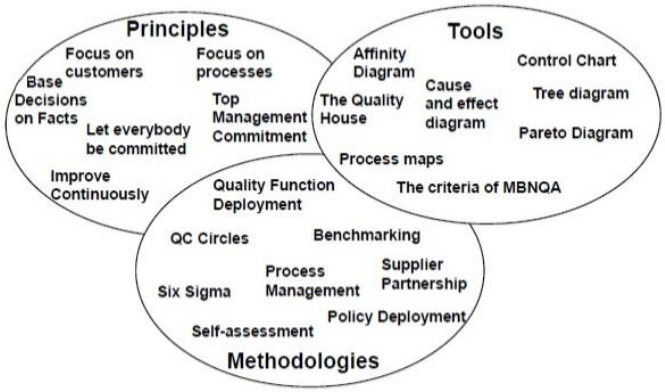


Figure 6 Principles, techniques and tools according to Hellsten and Klefsjö (2000)

In this research, a set of practices and techniques are used in order to support the QM principles in the cornerstone model. These practices and techniques are explained in the following sections.

3.1.1. Collecting information about the customer

At the center of the corner stone model is the focus on customers, which relates well to the definition of quality as being determined by the customer. Bergman and Klefsjö (2011) mean that companies should determine the needs and wants of the customers and attempt to fulfill them in a systematic way.

The process of investigating customer needs naturally start with identifying the customers. This task is not limited to the external customers but also include customers within the company (Bergman & Klefsjö, 2011). The notion that customers can be divided into internal and external is shared by Kondo (2001). Lengnick-Hall (1996) elaborates on this theory by presenting five roles that a customer can have and even say that a customer orientation requires an understanding of these roles. The roles are the customer as a resource, co-producer, user, buyer and product. The role a customer has influences the way that customer can contribute to increased quality (Lengnick-Hall, 1996). Maylor (2010) also present three groups from which the stakeholders come from; internal team, core externals and rest of the world which could be helpful when identifying the stakeholders.

As customers are a form of stakeholders (Mitchell, Agle & Wood, 1997) the definition of what a stakeholder is becomes relevant. Freeman (2010, p.46) defines a stakeholder as “any group or individual who can affect or is affected by the achievements of the organizations objectives”. Not all stakeholders are of equal importance (Maylor, 2010). When identifying stakeholders Mitchell, Agle and Wood (1997) mean that the dimension stakeholders are evaluated upon should reflect who is really important. Further they suggest three dimensions to consider; power, legitimacy and urgency (Mitchell, Agle & Wood, 1997). A stakeholders position on these three dimensions also give an indication of how they will be treated by managers (Mitchell, Agle & Wood, 1997). Maylor (2010) instead present power and interest as dimensions on which to evaluate the stakeholders.

In order to be customer focused there is a need to understand the customer needs. These needs are often referred to as “the voice of the customer” (Griffin & Hauser, 1993). Griffin and Hauser (1993) promote the use of interviews and focus groups with approximately the same outcomes in terms of collected needs. Around 20-30 interviews lead to the capture of 90-95 percent of the needs (Griffin & Hauser, 1993).

3.1.2. Quality Function Deployment

The voice of the customer is used as an input to Quality Function Deployment (QFD), a quality management practice (Hellsten & Klefsjö, 2000) for systematically translating the customer needs into product characteristics and further into requirements on what actions need to be taken (Bergman & Klefsjö, 2011). QFD is supported by the House of Quality (HoQ)(Figure 7), a QM technique.

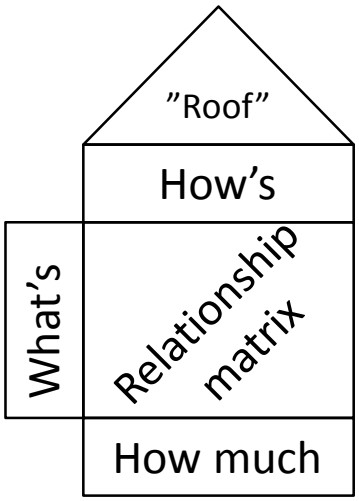


Figure 7 The house of quality (Govers, 2001)

In the HoQ the different areas are called rooms (Lager, 2005). According to Raharjo, Brombacher and Xie (2008) there are generally five different inputs to the HoQ; “the customer requirement, the technical attribute, the relationship matrix, the correlation matrix, and the benchmarking information” (Raharjo, Brombacher & Xie, 2008:253). In one of the rooms, the relationship matrix, the “what’s” are matched with the “how’s”. The what’s represent customer needs while the how’s represent quality characteristics (or technical attributes) in the first HoQ (Govers, 2001). Franceschini and Rupil (1999) explain the what’s as goals while the how’s are the means to achieve the goals. The what’s are listed in the rows and given an importance rating. The importance rating could, according to Matzler and Hintlerhuber (1998), be based on the Kano classification of the customer needs.

Tan and Shen (2000) presented another framework with the same idea. The how’s are then listed in columns providing the opportunity to fill in the relationship matrix between the what’s and how’s. The relationship can be shown in a number of different ways (Franceschini & Rupil, 1999). According to Akao (1992) the relationship needs to be quantified and provided in a numerical form. An important choice is then whether to have nominal or ordinal scales as rating as well as whether the ordinal scales should be proportional or logarithmic (Franceschini & Rupil, 1999). Examples of the different scales are 1,2,3 (proportional) and 1,3,9 (logarithmic). According to Franceschini and Rossetto (1998) an important and often forgotten issue is that everyone involved in the rating should understand the rating system. If a rating scale will be used for multiplication it will have the implication that a rating of 9 is nine times a high as a rating of 1.

In the roof of the HoQ the correlation matrix displays synergies and conflicts between the how’s (Hauser, 1988). The correlation can be positive, negative or non-existing (Magnusson, Kroslid & Bergman, 2000). According to Johnson (2003) the emphasis is on finding conflicts between needs.

The QFD methodology can be explained in two ways (Lager, 2005). One is as a set of four matrices representing four phases in QFD; product planning, product design, process design and production planning (Bergman & Klefsjö, 2011). The other view is a matrix of matrices suggested by Akao (1992) which consists of 16 matrices divided into four areas; quality deployment, technology deployment, cost deployment and reliability deployment (Lager, 2005). Although a simplification, QFD is often represented by the series of houses as illustrated below (Figure 8)

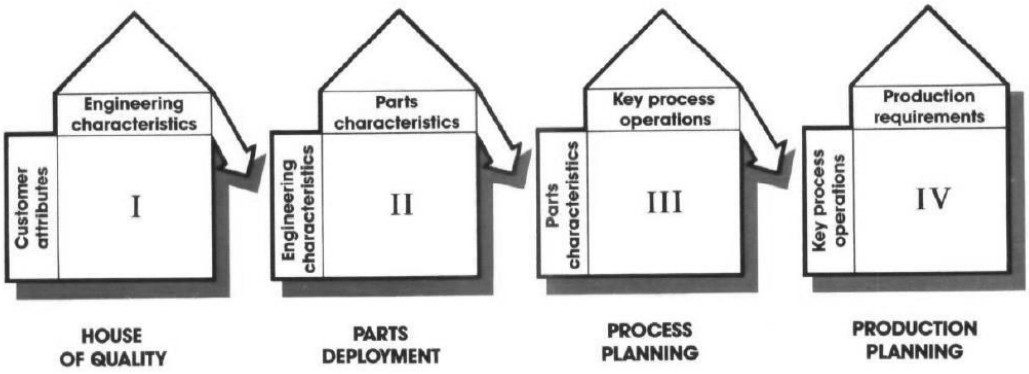


Figure 8 The four phases in QFD according to Hauser and Clausing (1988)

According to Bergman and Klefsjö (2011), in the first phase the customer attributes are translated into engineering characteristics; in the second phase the engineering characteristics are then translated into parts characteristics; and the third phase includes translating the part characteristics into key process operations which are translated into production requirements in the fourth phase.

According to Franceschini (2001) there is a step before the first phase which he calls identifying customer needs. The phases can be divided into the following steps (Franceschini, 2001) (Table 5).

Table 5 The stages in QFD according to Franceschini (2001)

Customer needs	Determine who the customers are
	Determine customer needs
	Prioritize customer needs
Product planning specifications	Identify product design requirements
	Drawing relationship matrix
	Planning and deploying expected quality
	Analyzing correlations between design requirements
Part/Subsystem planning specification	Identify part characteristics
	Drawing relationship matrix
	Planning and deploying product characteristics
	Analyzing correlations between part characteristics
Process planning specification	Identify key process operations
	Drawing relationship matrix
	Planning and deploying part characteristics
	Analyzing correlations between key process operations
Quality control specification	Identify production requirements
	Drawing relationship matrix
	Planning and deploying key process operations
	Analyzing correlations between production requirements

Although QFD is fully applicable to service industries there is a need to align the methodology with the intangible products (Akao, 1992; Mazur, 1993). Although Akao (1992) keep the same terminology Mazur (1993) instead divides QFD for services into nine steps with similar content as QFD for products.

3.1.3. The Kano model

All customer needs are not the same (Löfgren & Witell, 2005). According to the Kano model customer needs can be divided into basic needs, expected needs and excitement needs (Bergman & Klefsjö, 2011). The relationship between how well these needs are fulfilled (degree of achievement) and customer dissatisfaction/satisfaction is displayed below (Figure 9). According to Bergman and Klefsjö(2011), the collection of these groups of needs is different. In one hand the basic needs are rarely mentioned in interviews as they are assumed to be present. On the other hand the expected needs are mentioned while the excitement needs are seldom known by the customers themselves (Bergman & Klefsjö, 2011).

According to Löfgren and Witell (2005) the nature of a specific customer need is not stable over time. Instead needs travel from being excitement needs, to being expected needs and finally basic needs. Therefore the customer needs have to be constantly updated.

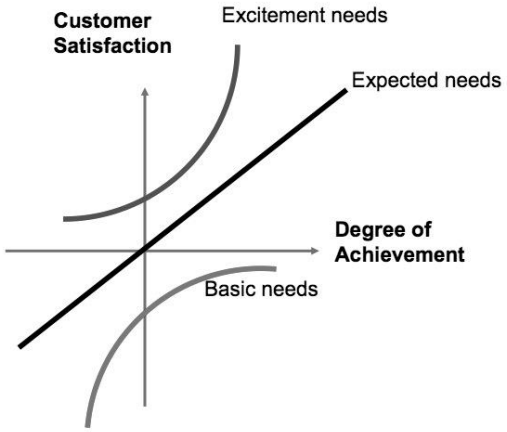


Figure 9 The Kano model (Matzler and Hinterhuber, 1996)

3.1.4. Improvement and management tools

Basing decisions on facts is one corner stone of TQM. According to Bergman and Klefsjö (2011) basing decisions on fact is facilitated by the seven improvement tools and the seven management tools. The seven improvement tools are designed to process information while the seven management tools are designed to handle unstructured verbal data (Bergman & Klefsjö, 2011). A summary of the tools are shown below (Figure 10 and 11).

In this research different set of tools are used as a support for implementing the practices of QM. For example, during different phases of the study the Affinity Diagram or the Affinity Interrelationship Method (AIM) is used for grouping and clustering reasons since according to Ryan (2011), the AIM is a structured way of organising a brainstorming result that involves grouping and clustering (Ryan, 2011). This technique involves seven steps from generating ideas to discussing the results (George,

2005). Stratification is another tool that is used in this study since it is a tool that splits up the data based on different criteria (Magnusson, Kroslid & Bergman, 2000). In addition, the control chart is found as a useful tool to meet some of customer needs in this research. Control chart is a visualization of results over time and is based on stochastic variation theory where an upper and lower specification limit is chosen based on the common variation within the process (Du Toit, Steyn & Stumpf, 1986).

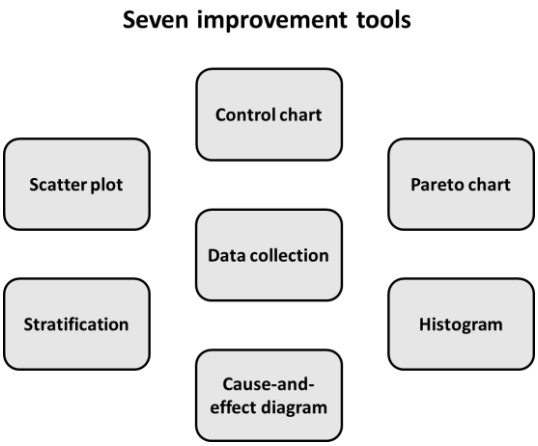


Figure 10 The seven improvement tools (Bergman & Klefsjö, 2011)

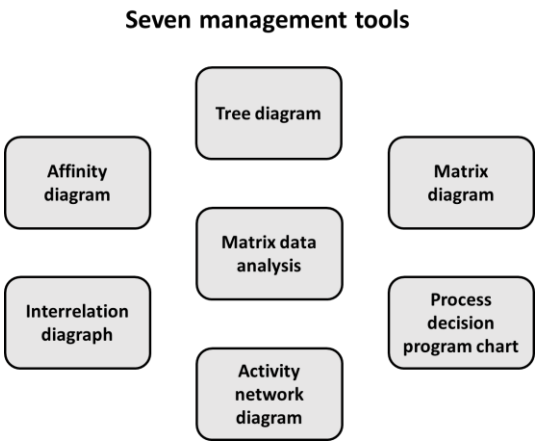


Figure 11 The seven management tools (Bergman & Klefsjö, 2011)

3.1.5. Summary

A summary of the presented principles, practices and tools can be seen in Figure 12.

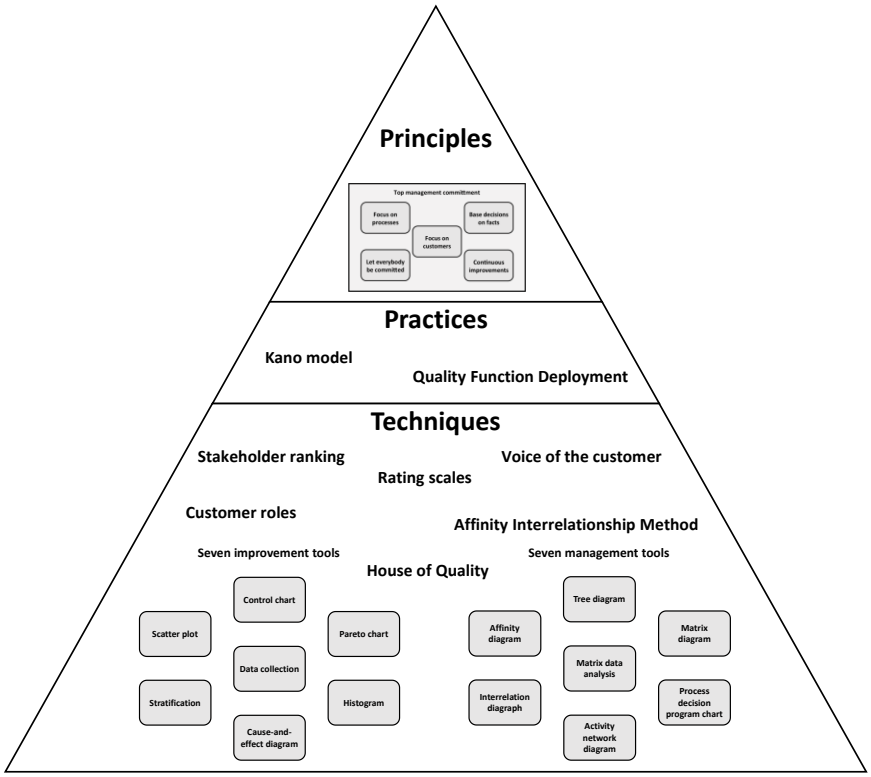


Figure 12 A summary of the principles, practices and techniques of QM

3.2. Business analytics

business analytics (BA) can be defined as ensuring that the right users get the right information at the right time (Laursen & Thorlund, 2010). This definition is identical to Bogza and Zaharies (2008) definition of Business Intelligence (BI) and according to Saxena and Srinivasan (2013) BI is often used as a synonym for BA although they mean that BI is only a part, and not all, of BA. Loshin (2012) on the other hand means that BI encompasses BA tools which illustrate the similarities of the two concepts.

Today the key role of big data and analytics in providing support for the business to achieve the strategic goals is known for many organizations. However, there is still not a best known way of organizing the analytics activities and defining the core processes to support the analytics efforts in the organization (Grossman and Siegel, 2014).

According to Saxena and Srinivasan (2013) rational decisions are made in four steps; Idea, Analysis, Decision and Execution. Analytics can support this process to different degrees. They advocate what they call “full lifecycle support” which can be described as an extensive use of analytics to support the process for rational decisions. This support comes from six areas in the analytics domain; decision framing, decision modeling, decision making, decision execution, data stewardship and business intelligence. The first four correspond to a step in the process for rational decisions while the last two supports all of the steps as can be seen in Figure 13 (Saxena & Srinivasan, 2013).

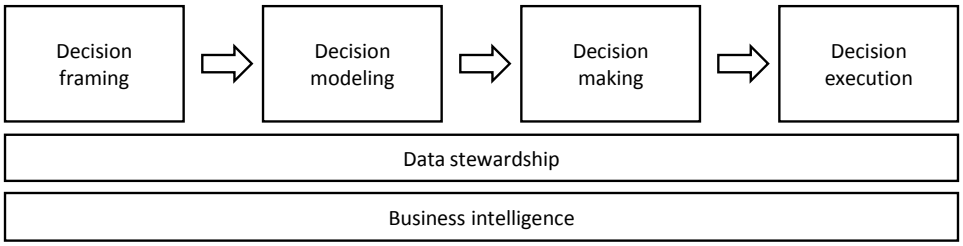


Figure 13 The BA process according to Saxena and Srinivasan (2013)

The decision framing is the area of defining the decision need. This step starts with mapping the current state of the business and identifying the requirements for decision-making. In addition, understanding both current and future capabilities of the processes is a crucial factor since the organization should be able to execute the decisions. However, the decision frame is not fixed and can be iteratively improved based on the feedback from the decision execution area.

As the second step in BA, key variables and relationships are shown through the decision model to give a better understanding of the context. In this area of the framework the important factor is to identify the target variables amongst a mass of available variables and focus on those variables that are related to the decision needs. Therefore, the decision model should be made based on the decision frame. There are several techniques and models to show different types of contexts. For example, the different types of diagrams, the mathematical models and techniques such as control charts, correlation and regression, project management with CPM and PERT, decision trees, etc. The decision modeling step can be broken into other sub steps. Saxena and Srinivasan (2013) define these sub steps as; formulation, data collection, development, testing, evolution and presentation.

The output from the first two BA steps are then used as the input to the informed and rational decision making as the following step before the last step of business analytics when the decisions need to be executed in a way that lead to an added value for the business (Saxena & Srinivasan, 2013).

BI is another part of the BA framework. There is an interaction between this area and other mentioned areas of the framework. In fact, the different databases, systems and tools to support data management, data analysis and decision making are provided by BI. In addition, in order to prevent incorrect and misleading analysis it is necessary to provide usable data for analysis. Therefore, the quality of the data should be measured and its fitness for usage in decision models should be assessed. This requirement can be reached through data stewardship as a part of the BA framework.

Another framework related to BA is provided by Fayyad et al. (1996). This framework is called knowledge discovery in databases (KDD) and includes the process of extracting knowledge from data. There are several steps included in this process with the aim of making the data more compact, abstract and useful in order to gain useful knowledge from the data (Fayyad et al., 1996). An overview of the KDD process is provided in Figure 14.

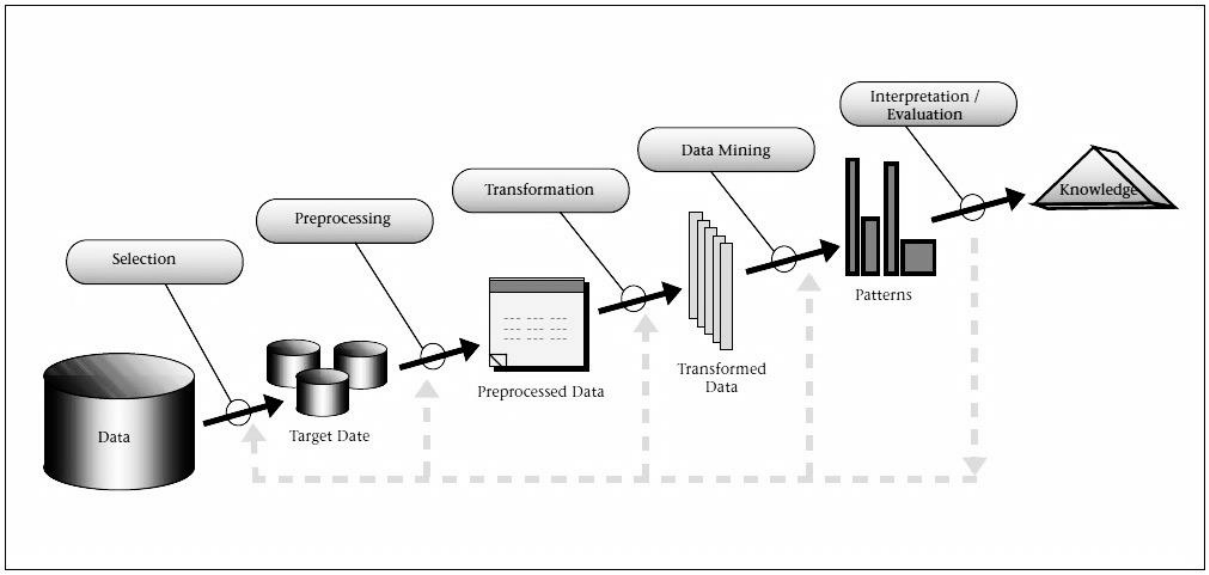


Figure 14 The KDD process (Fayyad, 1996)

According to Fayyad et al. (1996), the KDD process contains a number of different steps. The process, according to them, starts with identifying customer needs in order to define the goal of the process. Creating a target data set and focusing on the relevant variables, which are selected based on the process goal is the second step. At the preprocessing step, the main sub steps are data cleaning, removing noise from the data and handling the missing data (Fayyad et al., 1996). Further, they mean that in the next step, through the transformation methods, the number of variables is reduced to those that are effective and invariant representations of the data. At the data mining step several processes are performed such as selecting a particular data mining method based on the goals of KDD, exploratory analysis and selection of data mining algorithm to be used in searching for patterns in data (Fayyad et al., 1996). The next step is, according to them, to visualize and interpret the patterns and other information derived from previous steps. The final step is to take the discovered

knowledge into action through using it directly or reporting it to the people who are interested or need it (Fayyad et al., 1996). The overview of the KDD process can be seen in Figure 14.

Similar to KDD the cross industry standard process for data mining (CRISP-DM)presented by Shearer (2000) comprises of a process model to conduct data mining projects through six phases including business understanding, data understanding, data preparation, modeling, evaluation, and deployment. According to Shearer (2000), the CRISP-DM process can be explained by Figure 15.

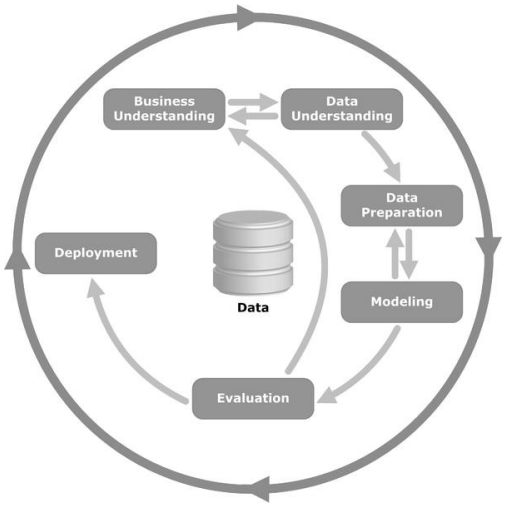


Figure 15 The CRISP-DM process (Shearer, 2000)

As it can be seen in Figure 15, in this process the focus of business understanding phase is on defining the problem through assessing the current situation and understanding the business goals (Shearer, 2000). The results of business understanding lead, according to him, to the understanding of which data that need to be analyzed and how. The second phase of the model generally focuses on data collection and data quality verification, which is then the input to the data preparation as the third phase of the model (Shearer, 2000). Shearer (2000) further mean that the data modeling phase will be fed by the final data set provided through previous phase and will be evaluated in the next phase. Finally, the knowledge derived from the created model need to be organized and presented in a proper way to the users that can be achieved through processes included in the deployment phase (Shearer, 2000).

The mentioned six phases of the process model by CRISP-DM are simplified by Runkler (2012) through introducing a four phase process model including preparation, preprocessing, analysis and post processing. The framework of this process model together with different sub steps of each phase can be seen in Figure 16.

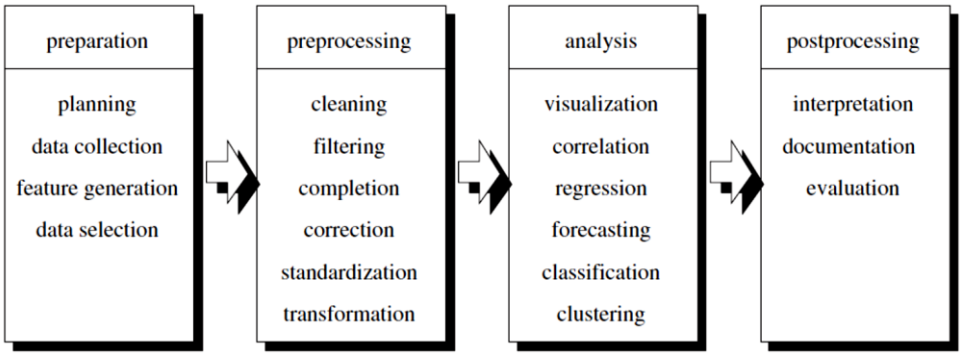


Figure 16 The BA process according to Runkler (2012)

Three of the six areas suggested by Saxena and Srinivasan (2013) have parallels to the traditional view of analytics. BI is seen as traditional IT, decision making as traditional business and decision modeling as traditional analytics.

Similarly, Grossman and Siegel (2014) believe the integration of analytics, business knowledge and IT as an important factor in defining the organizational BA framework. According to them analytics should be integrated to other operations in the organization and therefore it needs to be viewed as a value adding function of the organization. In addition, they believe having deep data analytics knowledge is an important element to create information from data and manage the information and this knowledge would not bring real value to the business unless it is completed with business knowledge. Kiron et al. (2011) also emphasize the importance of a data-oriented culture as it enables the company to act on the data. Furthermore, the knowledge about information technology tools and infrastructure also need to be available for applying the BA functions in the organization (Grossman & Siegel, 2014). See Figure 17 for a visualization of this framework.

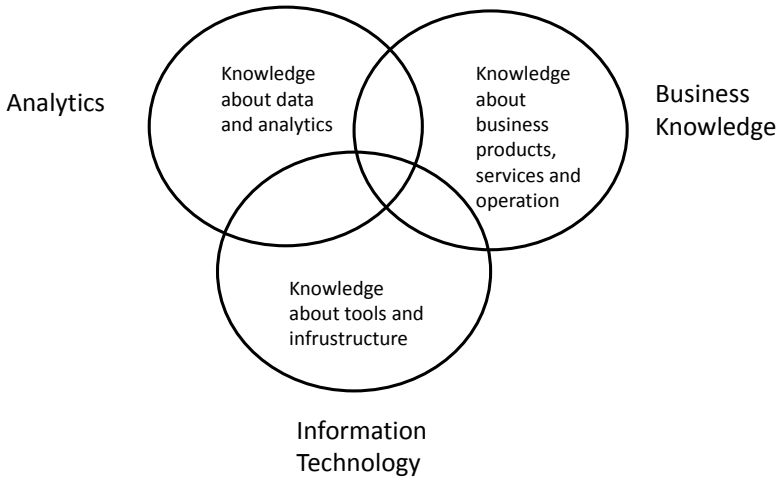


Figure 17 The organizational BA framework (Grossman & Siegel, 2014)

This indicates that all three of these business environments are included in BA, a statement which is supported by Laursen and Thorlund (2010) that views analytics as a bridge between the business-driven environment and the technically oriented environment (Figure 18).

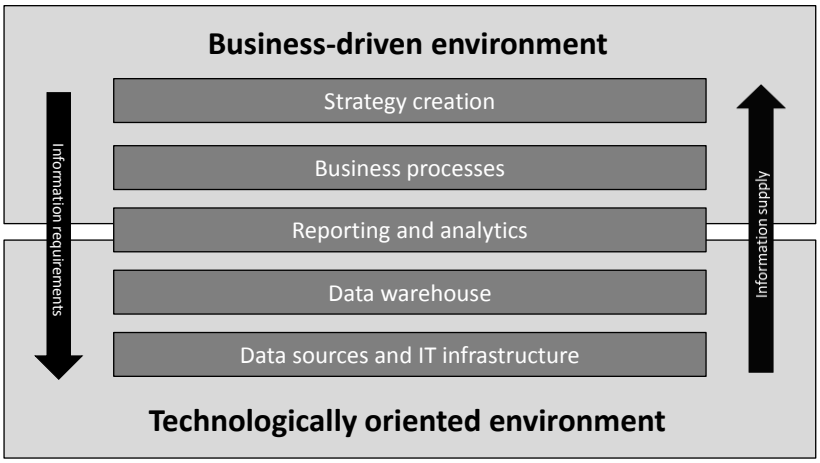


Figure 18 The BA process according to Laursen and Thorlund (2010)

Holsapple, Lee-Post and Pakath (2014) present a holistic perspective on BA. They present the Business Analytics Framework (BAF) developed from the many different definitions of BA. BAF consists of six core perspectives; a movement, capability set, transforming process, specific activities, practices & techniques and decisional paradigm. Parallels can be drawn between the BA processes described above and the core perspective *a transformation process* where "evidence is transformed via some process into insight or action" (Holsapple, Lee-Post & Pakath, 2014:14). This relates well to Davenport et al. (2001:128) definition that "the analytics process makes knowledge from data". This statement identifies a need to differentiate between data and knowledge as well as a third concept, information, which is frequently mentioned when discussing BA.

According to Laursen and Thorlund (2010) data is an information carrier while information is aggregated data. The two concepts are also different in their ability to be understood as data is hard to interpret without any processing which means converting it to information. The ability to interpret the data is important for converting it into knowledge which is the understanding you get from analyzing the data (Laursen & Thorlund, 2010).

In addition, Laursen and Thorlund (2010) divide the Information into lead information and lag information depending on the use in the process. Lead information is used as an input to the process and supports decisions on what activities to prioritize while lag information is used to follow up on executed activities. If the activities have been performed before there is a record of lag information, which we can use to create lead information giving us a forecast for future activities (Laursen & Thorlund, 2010).

Laursen and Thorlund (2010) further emphasize the importance of understanding the business requirements when conducting an analysis. This is in line with the corner stone models idea of putting the customer in the center (Bergman & Klefsjö, 2011). The authors also identify three areas that the analyst needs to define before analyzing the data. These areas are the overall problem, the delivery and the content. Laursen and Thorlund (2010) finally suggest interviews as a method for collecting these business requirements.

3.2.1. Big data

The amount of data produced in the world is increasing rapidly (Loshin, 2013), especially digital data (Mayer-Schönberger & Cukier, 2013). This has facilitated the use of new expressions such as big data. The meaning of big data is debated (Loshin, 2013). McKinsey for example define big data as data that is too big to store (Manyika et al., 2011) which would indicate that it is impossible to use big data. Gartner define it as "high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making" (Gartner, 2013) while Mayer-Schönberger and Cukier (2013) say that it is dependent on the degree to which the whole data set as opposed to a sample is used. Mayer-Schönberger and Cukier (2013) therefore say that data is abundant today and the need for sampling is reduced with big data. However, according to them the problems that can arise from big data make using it challenging. Some of these challenges according to Helland (2011) are related to data collection e.g. the data might come from different or unclear sources over a period of time. Another part of the challenges are related to data processing where a part of information might be lost during converting or transferring efforts. In addition, there is the risk of changes in data during data transaction and it means while processing the data received from a data source it might have changed right now at the origin source (Helland, 2011).

3.2.2. Data analysis

Fayyad et al. (1996) stated that the data analysis method depends on the purpose of extracting knowledge from data. They divided the goals of knowledge extraction into two main categories as verification of the user's hypotheses, and discovery of patterns in data. The discovery of the patterns is divided into prediction and description. The prediction refers to finding the patterns to predict the future of data patterns, and description is related to present data to the user in an understandable form (Fayyad et al., 1996). Similarly, Kenett and Shmueli (2009), classify the general data analysis goals into causal explanation, prediction and description.

In addition, Laursen and Thorlund (2010) classify the analytics methods into hypothesis-driven, which is proper for when wanting to describe correlations of data in pairs, and data-driven, which is preferred when having a large amount of data which is constantly changed or updated and there is limited knowledge about the correlations in data. According to them, in case of using the data-driven method there are different techniques that can be applied depending on the purpose of the analysis. They believe if the purpose is to identify different kinds of patterns in data, one need to reduce the large number of variables to a smaller number without losing the information value and interpret different kind of information to know which factors really mean something. This can be done through the techniques such as data reduction to find the variables that contain information and are relevant to what we need, and cluster analysis that focuses on algorithms to combine observations that are similar (Laursen and Thorlund, 2010). However, if the purpose is to examine the correlation between given variables then data mining techniques can be applied for this reason (Laursen and Thorlund, 2010).

Fayyad et al. (1996) mentioned data mining as the core of the process of KDD in order to discover the patterns in data and extraction. According to them, KDD is the overall process of extracting knowledge from data and data mining is a specific step in that process. Knowledge extraction, information discovery and information harvesting are some of the names historically used for data mining (Fayyad et al., 1996). However, they believed using data mining without considering the

statistical aspects of the problem can lead to discovering a significant pattern in data which in reality is insignificant. Therefore using a blind data mining can lead to the discovery of invalid or even meaningless patterns in data (Fayyad et al., 1996).

In addition, according to Fayyad et al (1996), the patterns that are identified through the process of converting data into knowledge should have four main characteristics. These characteristics are validity, novelty, usefulness, and simplicity. The validity refers to the degree of certainty of the new data. Regarding the novelty the identified patterns need to be novel to the system and preferably to the user. The usefulness refers to containing benefit for the user, and simplicity means that the pattern should be understandable.

3.2.3. Presentation

According to Orna (2005) there is a continuous transformation between information and knowledge through the organization since people use the information to create knowledge and in order to transfer the knowledge created in their mind to other users they present it in the shape of information. Communication is the factor that plays a key role in creating knowledge and affects the transformation process between information and knowledge (Orna, 2005). In other words, in order to create knowledge both information and communication are needed.

Kenett and Shmueli (2009) mentioned effective communication as a factor that directly affects the quality of the information. In their studies among both research environment and industry, they realized that even if the analysis results have high quality, miscommunication can lead to the risk of misunderstanding of the results by the people. According to Marchese and Banissi (2013), knowledge visualization is a factor that leads to improved communication. Therefore proper knowledge visualization improves the business process in the organization. The focus of knowledge visualization specifically in the context of management is on using interactive graphics in a collaborative way to create, integrate and apply the knowledge (Marchses and Banissi, 2013).

According to Few (2005), removing the distractions is a factor that contributes to effective communication. Regarding that, anything that does not lead to any added value and does not essentially contribute to the meaning of a graph is a distraction that negatively affects the communication (Few, 2005). One of the common distractions in graphical presentation such as charts and graphs are misuse of color. Overwhelming the user by using different colors without reason or using a mix of bright colors that visually harm the user are the common examples in misusing the color. Regarding this issue using soft colors which are lowly saturated and exist in nature in the graphs and using bright, dark or highly saturated colors only for making a specific data highlighted are recommended (Few, 2005). Tufte (2009) mentioned the issue of devoting too much of the ink to add unnecessary graphical features such as gridlines and detailed labels that do not contain added value for the viewer. Tufte (2009) further believe that the data graphics should lead the user`s attention to the meaning and substance of data and not to anything else. According to that theory, erasing non-data ink and redundant data-ink, maximizing the data-ink ratio and focusing on showing the data above all else are the principles that Tufte (2009) introduces regarding the data graphics theory related to the design options.

3.3. Synthesis of theoretical framework

According to the literature related to the BA, several processes are introduced by different researchers. An overall view of mentioned processes is provided in Figure 19 in order to show the

relationship between different phases of them. Considering the overall view, although the first phase in different processes is named differently, the main idea is to identify the users requirements by for example identifying the business objectives, understanding the current status of the business and processes and identifying the decision needs. The preprocessing phase in the process introduced by Runkler (2012) is divided in two sub steps in the CRISP-DM and KDD but all of them follow a similar process. By comparing the data analysis phase in the different processes it can be realized that the main focus of the KDD is on data mining while the other processes emphasize no specific analysis method. The last phase before decision making in the different BA processes is named differently (interpretation, deployment and post processing) but the overall focus of all these phases is on interpretation and evaluation of the output.

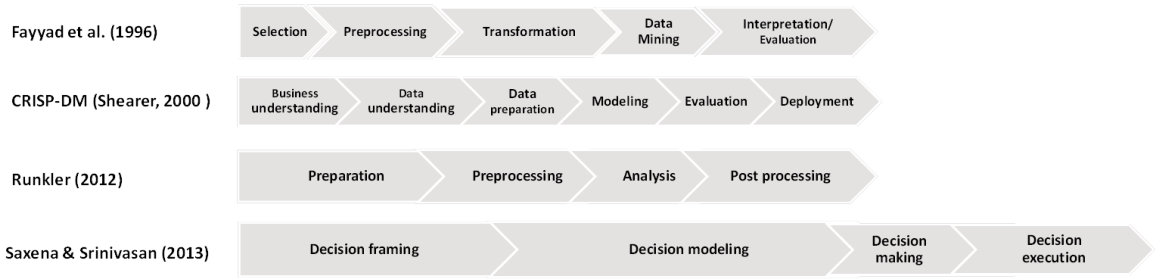


Figure 19 Comparison between BA processes

As suggested in the figure above the processes have considerable overlaps between phases as well as a difference in level of granularity. In order to provide an appropriate level of detail as well as for the sake of clarity one process was chosen, the KDD by Fayyad (1996) (Figure 20). This process is frequently used in literature and the article in which it is presented is referenced 5842 times (Google scholar, 2014). The frequent use combined with the displayed similarities with other models indicates that KDD can be representative for BA processes.

Figure 20 The suggested BA process (Fayyad, 1996)

Earlier in the theory chapter a framework for displaying QM as a system of principles, practices and techniques was presented. Considering these QM principles, practices and techniques and the BA process presented above a framework for their relationship can be visualized in the following way (Figure 21).

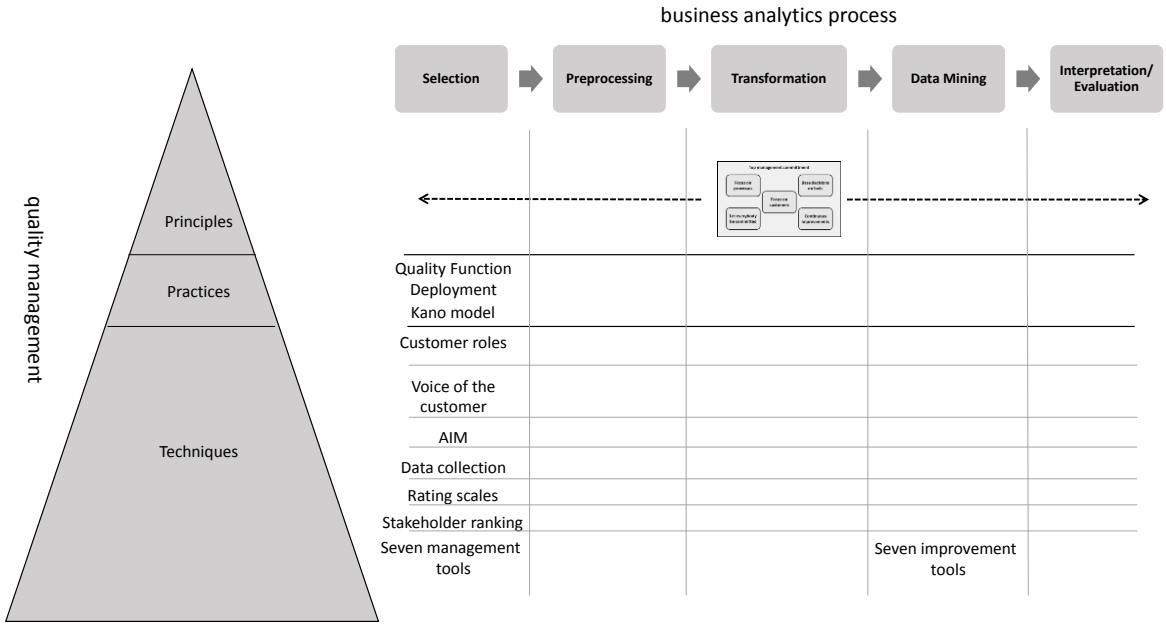


Figure 21 Initial framework integrating QM and BA

The corner stones presented by Bergman and Klefsjö (2011) should according to the them form the basis for the company culture, which then would require that it should be integrated in all steps of the BA process. Hellsten and Klefsjö (2000) also emphasized that the corner stones should be viewed in conjunction and not separately, the corner stones work together as a system. QFD as a practice is used to collect and translate customer needs into design requirements and on to production requirements (Lager, 2005). This aligns well with the purpose of the selection phase (Fayyad et al., 1996). The obvious phase to use QFD would therefore be the Selection phase. The same applies to the Kano model. Using QFD involves using techniques such as the HoQ, AIM, data collection and rating scales, which would then also be used to support the selection phase.

Furthermore, In the first phase the "goal of the KDD process from the customer's viewpoint" should be established (Fayyad et al., 1996:42). This could be supported by the stakeholder identification and ranking techniques such as customer roles and stakeholder ranking. If the goal should be based on the customers' viewpoint they also need the opinions of customers which is facilitated by the collection of Voice of the Customer. Since the voice of the customer is qualitative data (Griffin & Hauser, 1993) and the seven management tools are designed to handle the verbal and qualitative information (Bergman & Klefsjö, 2011) the use of these techniques in the selection phase could be beneficial. For example, the affinity diagram that is one of the seven management tools could be used in order to group different customer needs together.

The data mining phase consists of data analysis and a search for patterns (Fayyad et al., 1996). The seven improvement tools are used for structuring the numerical data and data analysis (Bergman & Klefsjö, 2011), therefore the use of these tools such as control charts and scatter plot would facilitate data analysis in this phase. However, based on the KDD goal different data analysis methods can be used in this phase (Fayyad et al., 1996). The improvement techniques that are used to support the data analysis can then be selected based on the data analysis method.

The blank cells in the framework represent no known relationship. The authors have not, through the literature review, found a way for QM to support all phases of BA. Therefore, the framework will be updated with the findings from the case study in section 4.8.6.

BA on the other hand has the purpose to provide the right information to the right people at the right time (Laursen & Thorlund, 2010). This facilitates basing decisions on facts, which is one of the corner stones in quality management (Bergman & Klefsjö, 2011). According to Fayyad (1996) the last phase of the BA process (or KDD as he refers to it) is to evaluate and improve the process. This is in line with the quality management principle of continuous improvements (Bergman & Klefsjö, 2011). Grossman and Siegel (2014) as well as Laursen and Thorlund (2010) present BA as a bridge between different organizational functions and emphasize the need to understand the requirements on the BA process. This indicates a focus on customers at the same time as it involves more people and thereby lets more people be committed, both of which are principles in QM.

4. Results and analysis

This chapter will show the results from the case study as well as analyze the results in order to answer the two research questions.

4.1. The case – Volvo

The company chosen for this case study is Volvo GTT, a part of the Volvo Group. The study was performed at the Powertrain Engineering department in Gothenburg.

The Volvo Group provides transport solutions on a global scale with 115000 employees (Volvo, 2014a) and a turnover of SEK 273 billion during 2013 (Volvo, 2014b). The group services markets in 190 countries through its manufacturing sites in 18 countries (Volvo, 2014a). The Volvo group is divided into 8 business entities; 3 sales & marketing entities, Group Trucks Operations (GTO), Group Trucks Technology (GTT), Construction Equipment, Business Areas and Volvo Financial Services. Group Trucks Technology work with product development while Group Trucks Operations work with manufacturing.

Volvo GTT is the product development organization for trucks manufactured all over the world. The business entity employs 10 000 people worldwide (Volvo, 2014c). Sixty percent of R&D is conducted in Sweden (Volvo, 2014d) with the head quarter in Gothenburg. Volvo GTT is divided into seven departments; Product Planning, Project & Range Management, Complete Vehicle, Volvo Group Advanced Technology & Research, Volvo Group Powertrain Engineering, Vehicle Engineering and Volvo Group Purchasing (Volvo, 2014d).

Volvo Group Powertrain Engineering is a global organization with 2000 employees in six countries Brazil, France, India, Japan, Sweden and USA. The Sweden main office of Powertrain engineering is located in Gothenburg with the work scope of engineering and design of engines, transmissions and drivelines for Volvo Group customers. The Gothenburg organization is the platform and application center for Heavy Duty engines as well as for Hybrids and Transmissions. The organizational chart of Powertrain Engineering in Sweden can be seen in Figure 22.

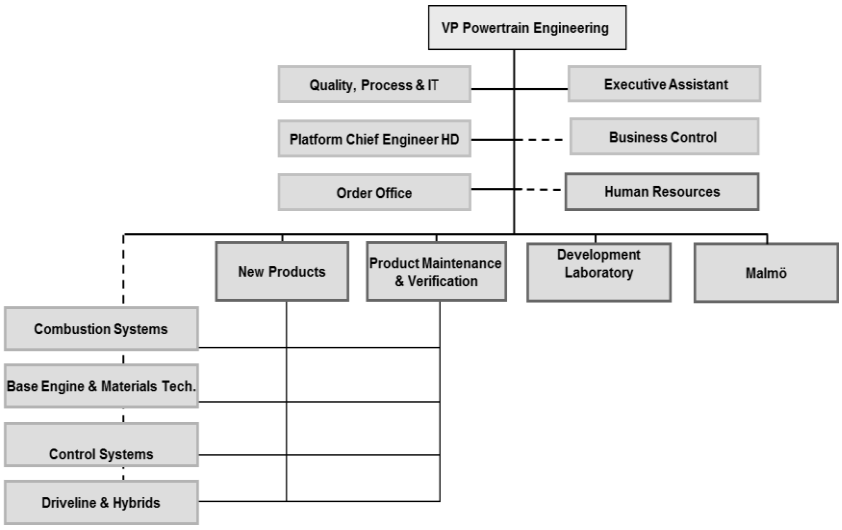


Figure 22 Organizational structure at Volvo GTT PE Gothenburg

4.1.1. The COP and Hot test

The product development process at Volvo PE includes a number of tests such as K1, K2 and certification tests. Two of these tests are called Conformance of Production (CoP) and Hot test. Although a part of the development process, these tests are initiated after the development efforts have ended and the tests are performed at the manufacturing sites by GTO. Despite the fact that the engines are manufactured by GTO the product ownership never shifts over. There is still a section within Volvo GTT PE that owns all the engine models. This section is called the maintenance and verification section. Because of this the tests are analyzed by specialists in Volvo GTT PE in order to find and solve issues surrounding the engine.

The Hot test is a short test, less than 30 minutes, where mainly performance parameters such as power, torque, temperatures and pressures are measured. The test is performed at the end of the production line in special test rigs. The sampling of the Hot test is conducted so that new engines and engines with major changes are tested to 100% while engines that have been in production for a long time without any issues between 3% and 10% of the engines are tested. The test results from the Hot test therefore have a large sample size compared to the CoP test.

The CoP test is a longer test, 15-30 hours, and mainly focused on measuring emission parameters such as NOx, carbon monoxide and soot although the test also measures some performance parameters. The overlap between the different test parameters are sometimes used to verify the Hot test results as the CoP test rigs have a better measurement accuracy. A long test time requires smaller sampling sizes for the CoP test. Just as with the Hot test the sample size depends on production volume, a high volume engine is tested more frequently than a low volume engine.

4.2. QFD as a supportive practice for business analytics

As explained in the Theory chapter, QFD involves a number of steps (Franceschini, 2001) although there is a need to adapt the practice to a service such as BA (Mazur, 1993). With the steps suggested by Franceschini (2001) as base the following steps for QFD as a support for BA is suggested (Table 6)

Table 6 Suggested stages and steps for QFD when supporting BA

Requirements investigation	Determine who the customers are
	Understand the current situation
	Determine customer needs
	Prioritize the customer needs
	Analyze correlations between customer needs
Outcome planning	Identify quality attributes
	Draw a relationship matrix
	Summarize quality attribute weights
	Analyze correlations between quality attributes
Process planning	Identify actions
	Draw a relationship matrix
	Summarize actions weights
	Analyze correlations between actions
Act on findings	Prioritize actions
	Assign actions to appropriate BA phase

The process will be explained and justified in the context of the case study used to develop it. In the following section the case will be presented and each phase explained with examples from the case study. In section 4.6 a methodology is suggested.

4.3. Requirements investigation

The first stage involves finding and evaluating the customer needs. The stage is divided into five steps; Determine who the customers are, Understanding the current situation, Determine customer needs, Prioritize customer needs and Analyzing correlations. Each step is further explained below.

4.3.1. Determine who the customers are

According to the literature, identifying the customer needs, decision needs, and defining the goal of KDD are different expressions of the early phase of all mentioned business analytics process and the overall emphasize is on identifying the needs (Fayyad et al., 1996; Saxena & Srinivasan, 2013; Runkler, 2012).

During the case study stakeholders to the test results were identified and ranked. The stakeholder identification and ranking is an important method for ensuring a customer focus in the BA process which is one of the principles of QM (Bergman & Klefsjö, 2011). This phase has the best potentials for fulfilling customer needs if the customers are first identified and their needs collected (Griffin & Hauser, 1993). Collecting the voice of the customer (VoC) enables BA to set up the BA process for greater customer satisfaction. As most customers to a BA process are internal customers the collection of VoC should be relatively easy. In identifying the customers a snowball sampling was used in this study as it was hard to determine who was using the test results in such a large organization. The first stakeholders were identified as eight of the section managers. This identification was made by two experienced users of the test results familiar with the organization. Letting the managers participate and recommend specialists was a step towards supporting the QM principle of top management commitment. According to Griffin and Hauser (1993) a sample size of 20-30 customers leads to the capture of 90-95% of the needs which indicates that this is a sufficient sample size. In this case 30 stakeholders were identified and included in the study.

Since the stakeholders were believed to be different in their level of current knowledge about as well as their interest level and need to use the test results, a stakeholder prioritization was necessary. The stakeholders were evaluated based on three dimensions; Interest level, current usage and impact. The interest level was subjectively evaluated by the authors based on their behavior during the interviews as well as their answers to how they could use the information derived from the test data in the future. The idea was that stakeholders with many ideas about how to use the test results in the future display a higher interest level than those with few ideas. The current usage was decided based on the interview data. One of the questions during the interview was if they are currently using the test results in their daily activities. A stakeholder that answered yes to this question got a higher score on this dimension than a stakeholder that answered no. The final and most heavily weighted dimension, impact, was evaluated by a company representative familiar with the organization. The scores ranged from one to three where the customers that scored three contributed three times more to the result than those scoring one. This ranking resulted in the following scores (Figure 23).

	Interest	Current usage	Impact	
	0,2	0,3	0,5	Total
Stakeholder 1	3	3	2	**2,5**
Stakeholder 2	2	3	2	**2,3**
Stakeholder 3	3	2	1	**1,7**
Stakeholder 4	1	1	2	**1,5**
Stakeholder 5	3	2	1	**1,7**
Stakeholder 6	3	3	1	**2**
Stakeholder 7	2	2	3	**2,5**
Stakeholder 8	3	2	1	**1,7**
Stakeholder 9	1	1	1	**1**
Stakeholder 10	1	1	1	**1**
Stakeholder 11	2	1	2	**1,7**
Stakeholder 12	1	2	3	**2,3**
Stakeholder 13	2	2	1	**1,5**
Stakeholder 14	2	1	1	**1,2**
Stakeholder 15	3	3	2	**2,5**
Stakeholder 16	2	1	1	**1,2**
Stakeholder 17	2	2	1	**1,5**
Stakeholder 18	2	1	1	**1,2**
Stakeholder 19	1	1	1	**1**
Stakeholder 20	2	1	1	**1,2**
Stakeholder 21	2	2	2	**2**
Stakeholder 22	2	2	1	**1,5**
Stakeholder 23	3	3	3	**3**
Stakeholder 24	2	1	1	**1,2**
Stakeholder 25	3	3	2	**2,5**
Stakeholder 26	2	2	2	**2**
Stakeholder 27	3	2	2	**2,2**
Stakeholder 28	2	2	1	**1,5**
Stakeholder 29	2	1	1	**1,2**
Stakeholder 30	3	3	3	**3**

Figure 23 Stakeholder ranking

A visualization of the results can be seen in Figure 24. The figure shows that stakeholder 23 and 30 are most important to the study while stakeholder 9, 10 and 19 are the least important stakeholders.

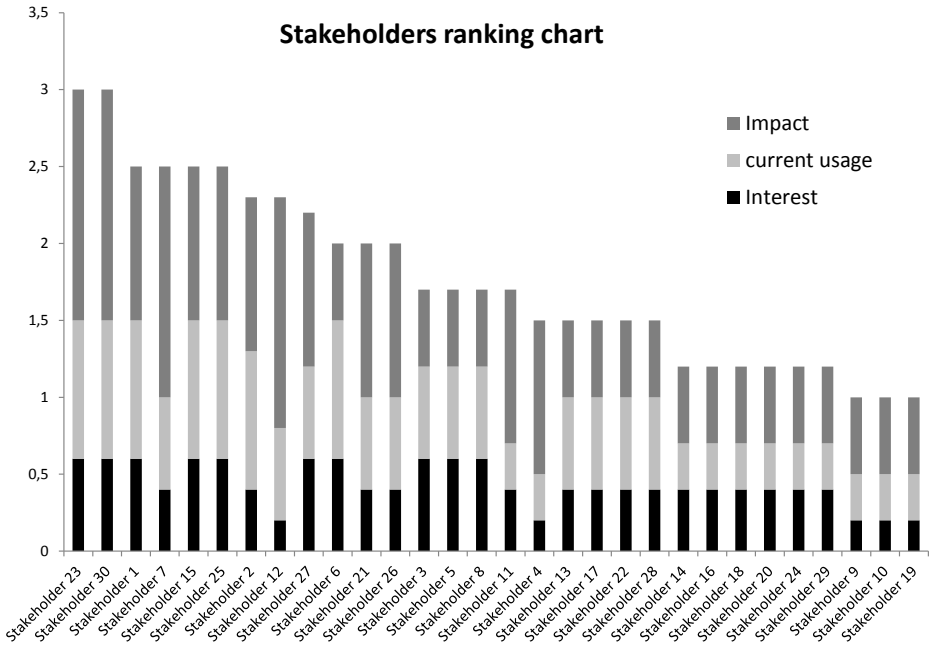


Figure 24 Barchart over customer ranking

Which dimensions to choose can be context dependent and should reflect which customers are really important (Mitchell, Agle & Wood, 1997). If no dimensions can be identified a generic model such as Maylors (2010) or Mitchell, Agle and Woods (1997) can be used.

The stakeholder ranking worked as a way to give different weight to individual stakeholders. This use of the stakeholder ranking provides more stakeholders with the opportunity to contribute as some of them would otherwise be disregarded as having too low significance to the study. If only the main stakeholders were asked some needs might be missed. This way of collecting needs from more stakeholders and then weighting them differently therefore supports the principle of letting everybody be committed. If the assumption that the weighted customer needs give a better picture of the situation than the unweighted is accepted then the technique also supports the principle of basing decisions on facts. Mitchell et al. (1997) and Maylor (2010) have shown that there can be different dimensions on which to evaluate the stakeholders.

When performing the stakeholder ranking the dimensions have a big impact on the result. Therefore it is important that the dimensions reflect what separates important stakeholders from less important ones. The dimensions chosen here (current usage, interest level and impact) worked well for this case. The ideas behind them were that needs from people that used the test results often (current usage) and were interested in using the test results (interest level) should be weighted higher than those from stakeholders not using the test results and with a low interest in using it. The idea was also that what the stakeholders use the test results for have unequal effect on the final output of the company which is reflected in the impact dimension. A stakeholder working with certification was for example considered more important than one working with product development since this activity affects the company's final output more. Since the dimensions were believed to contribute to an unequal extent to the customer ranking they too were weighted (Interest 0,2; Current usage 0,3 and Impact 0,5). These weights were developed by the authors and validated by two company representatives with insight to the BA process. The sum of 1,0 was distributed on the three dimensions based on the extent the dimension affect the importance of a customer.

4.3.2. Understanding the current situation

According to Laursen and Thorlund (2010) in order to provide value added information first of all the analyst should gain knowledge about the process status related to the business. In this research, an understanding of the status of related processes has been gained through observations, studying the documents available in the company and interview with process specialists. In addition, a part of the knowledge about the current status gained through the information from interview with stakeholders. The gained information is visualized in different figures and charts in this section.

Regarding the current status, one part of the interviews was assigned to know to what extent the identified stakeholders are currently using the test results or will use them in the future. As can be seen in the Figure 25, a big proportion (more than half) of the interviewees are using the test results in their activities such as setting engineering targets or verifying product changes even though the usage is to a limited extent for some of them. Overall, this can be an indicator that shows the output of the process of extracting knowledge from test results affects the company functions.

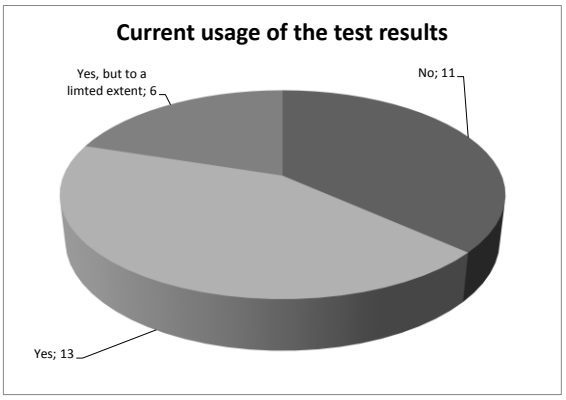


Figure 25 Current usage of the test results

However, it can be realized from Figure 26 that the usage is not equally distributed over all sections. This indicates that some the test results are more important to some sections than others. The usage level in every section is not used for ranking the stakeholders as this ranking is done on an individual level but for the BA process it is relevant to know where the current stakeholders reside.

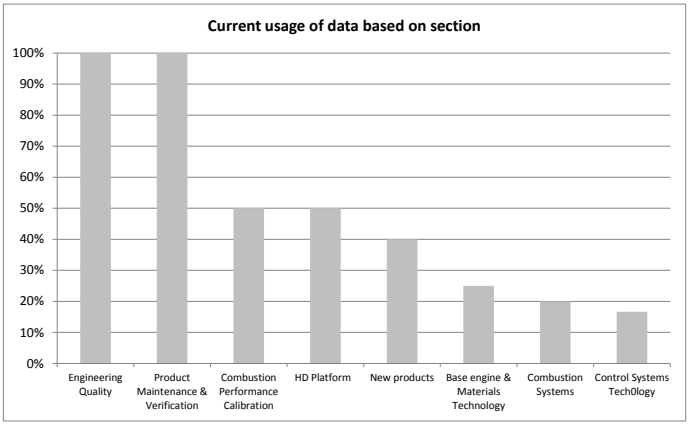


Figure 26 Current usage split by section

According to Grossman and Siegel (2014) in order to successfully deploy BA in the organization it should be perceived as a value added function through the organization. The information shown in Figure 27 reveals the perceived impact of the test results on the processes or activities from the interviewee's viewpoint. As it can be seen although the biggest number belongs to the "high" category, but still a significant number of stakeholders see a low impact from CoP and Hot test results on their activities. However, considering Figure 28, it can be revealed that a big proportion of perceived low impact comes from lack of awareness of the data as well as that they are not aware about the benefits of using the data in their processes which causes them to view the data as far from what can be used in their processes.

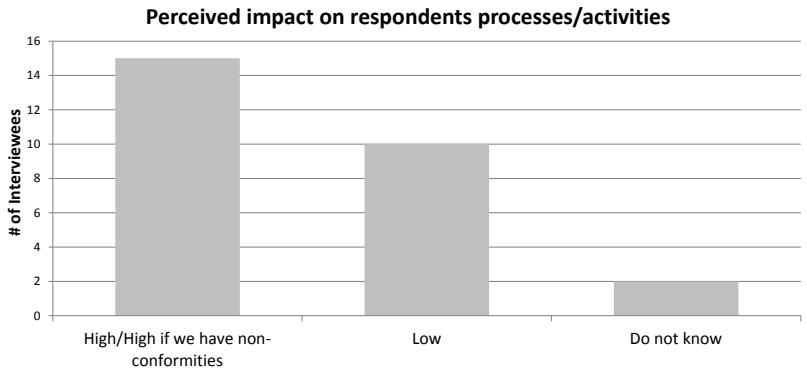


Figure 27 Perceived impact on activities

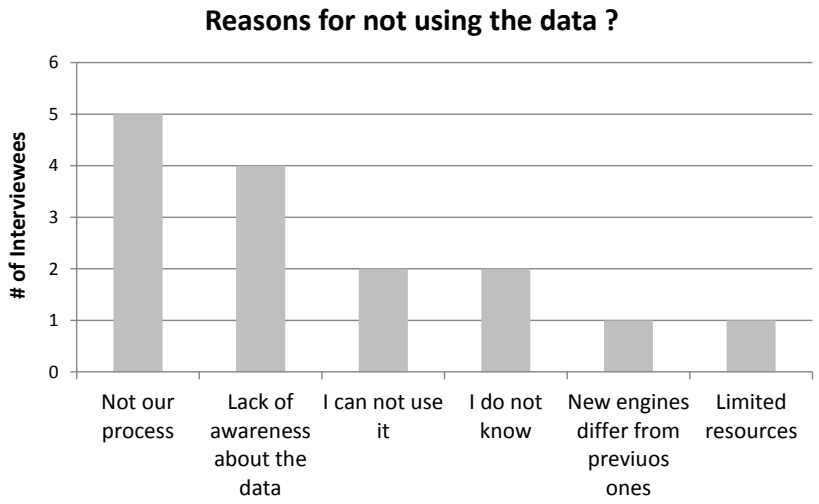


Figure 28 Reasons for not using the test results

Another part of the interviews focused on the parameters measured in the two tests. These questions were asked in order to understand what parameters are most important to the users and if there are specific parameters that they are interested in. As it is mentioned in the theory part, at the early phase of the business analytics the emphasize is on identifying the target data amongst the whole database and focus on the variables that are relevant to the needs instead of analyzing a large amount of available variables (Fayyad et al., 1996). The results regarding the interesting parameters related to both emission and performance can be seen in Figure 29.

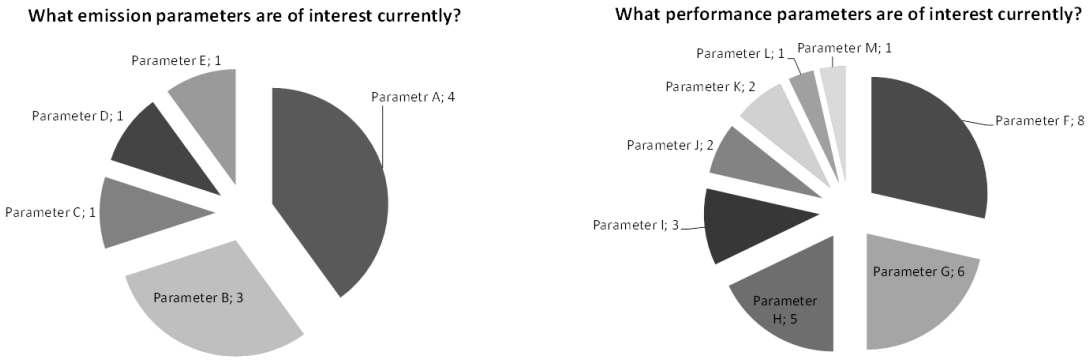


Figure 29 Emission and Performance parameters of interest

4.3.3. Determining customer needs

QM presents many structured ways of collecting the VOC. In this case interviews were conducted in order to collect the customer needs. Interview guides (Appendix A and B) were developed and tested before usage. All stakeholders were given the opportunity to change anything they had stated in the interviews as the interviews were summarized and sent to the stakeholder for validation. A detailed explanation of the data collection can be found in the method chapter. When conducting the interviews the collection and analysis of the test results were explained as a process instead of individual activities. Viewing BA as a process following the QM principles and facilitates the improvement work that is the reason for this study (Bergman & Klefsjö, 2011). The activities the stakeholders performed were collected together with information about how these activities relate to the main product development process. This was accomplished because knowing which process to support with BA should influence the analytics process (Grossman & Siegels, 2014; Laursen & Thorlunds, 2010). Quality managements' emphasis on processes therefore support a better end result in BA.

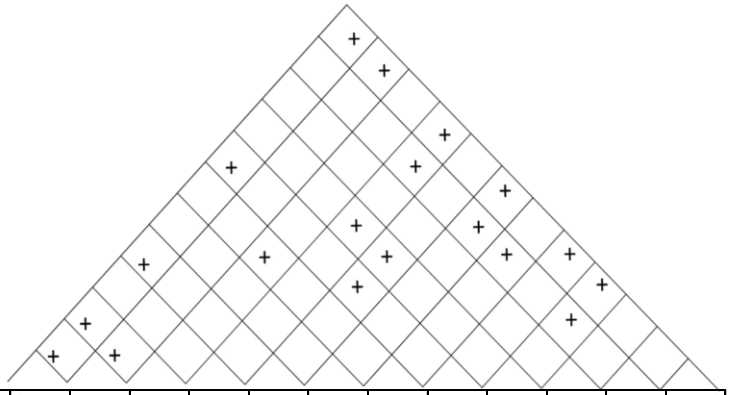
There is also a decision to be taken on how much the BA process should focus on existing needs in relation to expected future needs. If the focus is too heavily on the current needs then an update will soon be needed while a too heavy focus on future needs risk reducing the quick benefits.

The validated data was then codified and grouped into 12 generic needs. The codification process is explained in the methodology. The AIM method was used for grouping the generated needs as too many needs are hard to manage. According to Franceschini (2001), 20-30 needs are an absolute maximum.

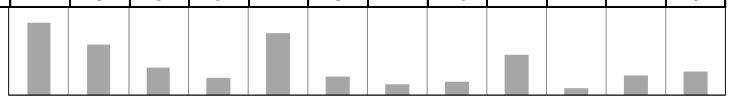
4.3.4. Prioritize customer needs

The data was then aggregated using a House of Quality (HoQ)(Figure 30). The stakeholder ranking was included to give different weight to the stakeholders' needs in order to better reflect the actual situation. Empty cells represent no relationship and has the value "0". If a relationship is established the value 1 is given. The total of each requirement is a sum of the stakeholder ranking of each stakeholder mentioning the requirement during the interviews. This total weight gives an indication of the demand for the needs in relation to each other. The mathematical operations can be described in the following way:

$$
\begin{aligned}
&Weight\ of\ customer\ requirement\ i \\
&\quad = relationship\ between\ stakeholder\ 1\ and\ customer\ requirement\ i \\
&\quad \times weight\ of\ stakeholder\ 1 + \cdots \\
&\quad + \ relationship\ between\ stakeholder\ 30\ and\ customer\ requirement\ i \\
&\quad \times weight\ of\ stakeholder\ 30
\end{aligned}
$$



	Stakeholder	Stakeholder ranking	A	B	C	D	E	F	G	H	I	J	K	L
Managers	Stakeholder 1	2,5	1	1			1				1			1
	Stakeholder 2	2,3	1		1		1							
	Stakeholder 3	1,7	1				1			1				1
	Stakeholder 4	1,5	1	1				1		1				
	Stakeholder 5	1,7	1		1				1		1		1	
	Stakeholder 6	2	1		1		1							
	Stakeholder 7	2,5		1			1			1	1			
	Stakeholder 8	1,7	1	1			1						1	1
Specialists	Stakeholder 9	1	1											
	Stakeholder 10	1	1											
	Stakeholder 11	1,7	1	1	1		1							
	Stakeholder 12	2,3				1						1		
	Stakeholder 13	1,5		1		1	1							
	Stakeholder 14	1,2		1				1						
	Stakeholder 15	2,5	1	1			1	1			1			
	Stakeholder 16	1,2	1	1							1			
	Stakeholder 17	1,5					1		1	1			1	1
	Stakeholder 18	1,2	1			1	1							
	Stakeholder 19	1			1	1								
	Stakeholder 20	1,2	1			1	1							
	Stakeholder 21	2	1								1			
	Stakeholder 22	1,5	1				1					1		
	Stakeholder 23	3	1				1				1			
	Stakeholder 24	1,2	1				1							
	Stakeholder 25	2,5	1	1	1	1	1				1		1	1
	Stakeholder 26	2		1				1			1		1	
	Stakeholder 27	2,2	1	1										1
	Stakeholder 28	1,5	1	1	1		1						1	1
	Stakeholder 29	1,2	1	1										
	Stakeholder 30	3	1	1	1		1	1	1		1			
	Total		41,3	28,7	15,7	9,7	35	10,2	6,2	7,2	22,9	3,8	10,9	13,6
	Rank		1	3	5	9	2	8	11	10	4	12	7	6



A	Gain knowledge about the engine/ production
B	Understand the variation on production
C	Decrease risk of non-conformities in production
D	Support for verification purpose

E	Feedback on previous product development
F	Spend less manhours on using the data
G	Reducing time between error and reaction
H	Give a direction for RCA

I	Support fact based decisions
J	Reach certification agency requirements
K	Easy access to information
L	Easy to understand information

Figure 30 House of Quality 1

The result from HoQ1 which are related to the needs prioritization based on stakeholders needs is summarized in Figure 31.

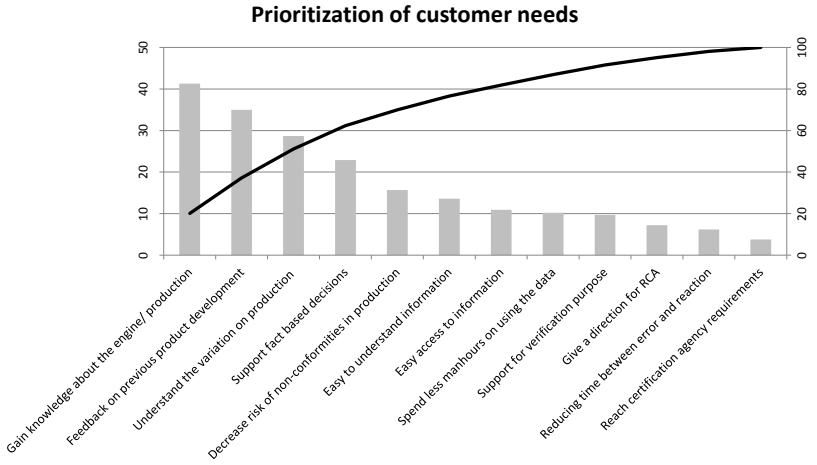


Figure 31 Prioritization of customer needs

As it can be seen in Figure 31, the first four high ranked needs are mostly related to availability and analysis of long term data. This highlights the role of BI and data stewardship as two supportive areas of business analytics that provide high quality data, databases, and systems for data management, data analysis, and decision making (Saxena and Srinivasan, 2013). In addition, considering other identified needs such as easy access to information, easy to understand information, spending less man-hour on using the data, it can be realized that the three knowledge areas namely, IT, statistical and business knowledge are required to satisfy such needs. This is a practical evidence from this case study to highlight the role of integration of IT, technical knowledge and business knowledge as an important factor to achieve a successful business analytics (Grossman and Siegel,2014; Saxena and Srinivasan, 2013).

4.3.5. Analyzing correlations

The roof of the matrix shows the correlation among the different needs. A ”+” indicates a positive correlation, a ”-” indicates a negative correlation while a blank cell shows no correlation between the needs. Looking at the roof of HoQ1, the correlations between different needs can be considered as an indicator of how fulfilling a requirement can affect the fulfillment of the other needs. For example, gaining knowledge about the engine/ production can lead to decrease the risk of non-conformities in the production as the knowledge is inevitably used in new product development. The requirement “Easy to understand information” has many correlations which is logical when considering that understanding the information is a prerequisite for gaining knowledge from it as well as giving a direction for root cause analysis (RCA). This was not used when calculating the importance rating of each requirement but should be taken into account when analyzing the results. Integrating the correlations to the importance rating of each requirement is a potential future improvement of the methodology in the same way that integrating the Kano model could lead to a more accurate representation of the actual situation (Matzler & Hintlerhuber, 1998). No negative correlations were found in this case which is the main purpose of the correlation analysis (Johnson, 2003).

4.4. Outcome planning

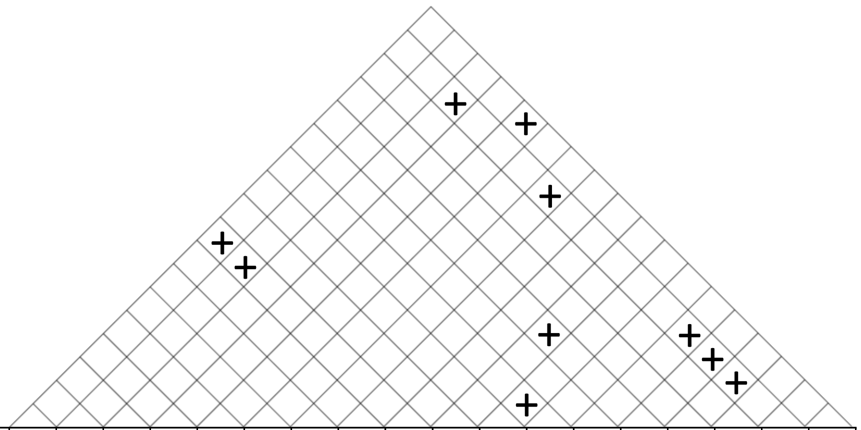
During the outcome planning stage the customer needs are translated into quality attributes which are rated in terms of the degree to which they fulfill the customer requirement. Quality attributes are characteristics that if present contribute to fulfilling the customer needs. The stage is divided into four steps; Identify quality attributes, Drawing relationship matrix, Planning and deploying customer needs and Analyzing correlations. The steps are further explained in the following subsection.

4.4.1. Identify quality attributes

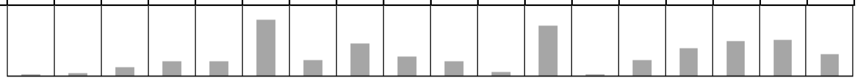
The quality attributes were in some cases suggested by the stakeholders. In other cases they were brainstormed by the authors. The quality attributes were developed so that if a design attribute is present then that will help to fulfill the requirement. When needed the quality attributes were grouped using the AIM method. Laursen and Thorlund (2010) stresses the importance of a connection between analytics and the business environment which is why the suggested quality attributes need to be validated by people with great business knowledge. In this case study the quality attributes were validated by the same business specialists that identified the customers on management level. This was performed by presenting the quality attributes to the business specialists and asking them to consider the quality attributes in the company context. For example the “automatic warnings” was considered applicable as this was currently used in another part of the organization for similar purposes.

4.4.2. Relationship matrix

The total of each customer requirement followed the requirement into the next HoQ and acted as the weight of that requirement. In this HoQ the customer needs were connected to quality attributes (Figure 32). The relationship between the needs and quality attributes were then evaluated and wieghted using a scale of {0, 1, 3, 9}. The difference in rating scales between the first and second HoQ is due to that a customer requirement is either present or not while a quality attribute can fulfill a requirement to different degrees. The choice of a logarithmic scale was due to our aspiration to differentiate the more important quality attributes from the less important. There are several other rating scales as explained in the theory chapter. Important notes are that the relationship should be quantified (Akao, 1992) and that everyone involved in rating are aware of the implications of the rating system (Franceschini & Rossetto, 1998).



Requirements	Weight	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Gain knowledge about the engine/production	41,3	1	1	9	1	1	9	3	3	1	1	9	9	1	1	3	3	3	3
Understand the variation on production	28,7	1	1	3	1	1	3			1	1	3	9			1	3	3	1
Decrease risk of non-conformities in production	15,7	1	1	1	1	1	3	3	3	1	1	3	9	1	1	1	3	1	1
Support for verification purpose	9,7	3	3	3	3	1	3			1	1			9	3	3	1	3	3
Feedback on previous product development	35	1	1	3	1	3	9		9	1	1	1	1	1	1	3	1	1	3
Spend less manhours on using the data	1,2	1	1	9			1	3		1	3			3	9	3	1	9	
Reducing time between error and reaction	6,2	3	9	1						1	3			1	9	1		1	
Give a direction for RCA	7,2	3	3	3	3	3	3	9	3	3	1	3	3	1		3	3	3	1
Support fact based decisions	22,9	3	3	9	3	1	3	1	3	3	3	3	3	1	1	3	9	3	3
Reach certification agency requirements	3,8	1	1	1			1			1				1		3			3
Easy access to information	1,9	9	9							9	1						3	3	
Easy to understand information	13,6			9	1	1	3							3		3	3	9	
Total		37,8	48	160	254	259	994	289	576	339	266	63,2	897	29,8	292	482	613	633	390
Rank		17	16	14	13	12	1	10	5	8	11	15	2	18	9	6	4	3	7



A	Direct access to raw data
B	Direct access to information
C	Proper graphical presentation
D	Test accuracy evaluation
E	Test conditioning values
F	Descriptive statistical information
G	Potential causes of variation
H	Correlation analysis
I	Pull information system
J	Push information system
K	Variation over time
L	Variation analysis
M	Highlighted deviations
N	Automatic warnings
O	Customized report
P	Training
Q	User friendly tool
R	More measured variables

Figure 32 House of Quality 2

4.4.3. Planning and deploying customer needs

The total score for each design attribute was then calculated as the sum of the weights of the needs explained in the previous subsection multiplied with the weight of each specific customer requirement. The mathematical operations can be explained by the following equation:

$$
\begin{aligned}
&Weight\ of\ quality\ attribute\ i \\
&= relationship\ between\ customer\ requirement\ 1\ and\ quality\ attribute\ i\ (R_1) \\
&\times weight\ of\ customer\ requirement\ 1 + \cdots \\
&+ relationship\ between\ customer\ requirement\ 12\ and\ quality\ attribute\ i(R_{12}) \\
&\times weight\ of\ customer\ requirement\ 12 \\
&R_i \in \{0,1,3,9\}
\end{aligned}
$$

The total gives an indication of the importance of each quality attribute. In this case the quality attributes “Proper graphical presentation”, “Descriptive statistical information” and “Variation analysis” received the highest ranking while the “Test accuracy evaluation” and “Push information system” received the lowest ranking. This indicates that the BA process should focus more on these high-ranked quality attributes than on the low-ranked.

The results related to the prioritization of quality attributes can be seen in the bottom of Figure 32. Regarding this figure the three highest ranked quality attributes are proper graphical presentation, descriptive statistical information and variation analysis. According to the KDD framework different types of data analysis such as correlation and descriptive analysis together with data visualization are belong to the data mining process (Fayyad et al., 1996). According to that, it can be realized that all these three quality attributes and some of the other defined attributes in this case study relates to the data mining process. Therefore, it can be concluded that the data mining process is the most important phase of the analytics in this case. On the other hand, the data mining phase is dependent on the previous phases. In addition, considering other quality attributes it can be seen that all of them are very aligned with the different phases of KDD. For example, more measured variables and test accuracy evaluation belong to the preprocessing phase, and customized report and training facilitate interpretation and evaluation of the analysis which is the last phase of KDD.

4.4.4. Analyzing correlations

The correlations between quality attributes are displayed in the roof of the HoQ2. The logic behind how to define positive and negative correlations is mentioned in previous stage. Although the correlation between different quality attributes are not applied in ranking them these correlations can still show how meeting one quality attribute can affect another quality attribute in a positive or negative way. In this case, no negative correlation was found but there are some positive correlations. For example “Proper graphical presentation” is correlated with the “user friendly tool”. One explanation for this is that the tool becomes more user friendly if it includes proper graphical presentations. Another correlation is between “Variation analysis” and “Variation over time”. If a variation analysis is performed then some of the information for variation over time is available and vice versa. The correlations can also indicate which quality attributes that belong together. For example “Direct access to raw data” and “Direct access to information” are correlated with “Pull information system” as both of them are examples of pull information systems. It can therefore be discussed whether to include all of them. In this case they were all included as a pull information

system can be more than direct access to raw data and information. The same logic applies to "Automatic warnings" and "Push information system".

4.5. Process planning

In the process planning stage the quality attributes are translated into actions. First the actions are generated. Then the relationship to the quality attributes are evaluated. The importance rating of each action is finally calculated.

4.5.1. Identify actions

As the next step, in order for these quality attributes to be present certain actions need to be taken. A number of actions were therefore brainstormed through thinking about what each quality attribute would require in terms of actions. The defined action plans are specific solutions related to this case study. Since the BA should be aligned with organizational cultures, systems and processes (Saxena & Srinivasan, 2013) it is important for the action plans in this case to be aligned with the business process capabilities and business analytics culture of the organization. This fact once again highlights the role of business knowledge in BA deployment that is emphasized by several researchers in this field. Therefore, in order to assure the validity of the action plans, they are reviewed and confirmed by two of the stakeholders who have deep business knowledge and insight to the related processes in the organization.

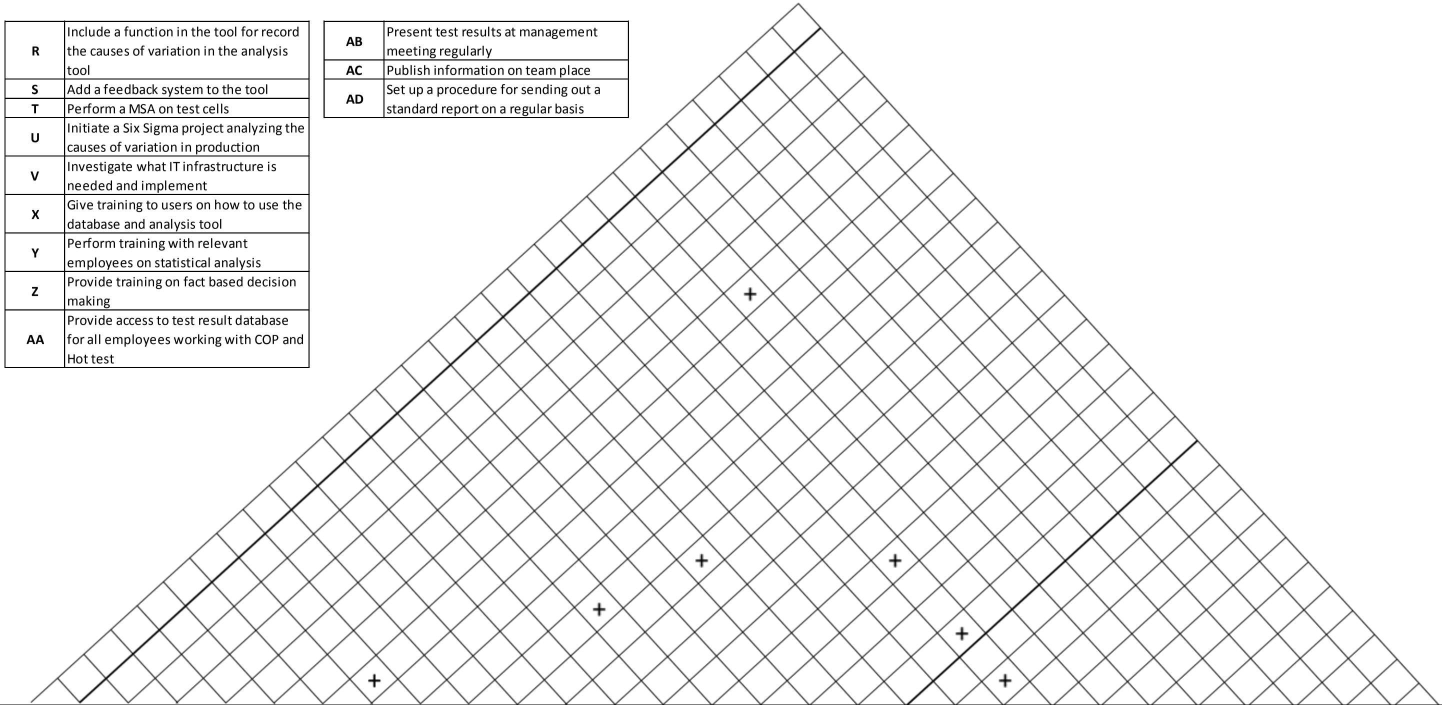
4.5.2. Drawing relationship matrix

The defined actions were then connected to the quality attributes in a third HoQ (Figure 33). For example the third HoQ shows that there is a strong relationship between the quality attribute "Proper graphical presentation" and the action "Develop charts based on visualization guidelines". The figure also shows that the action "Perform a MSA on test cells" (MSA = Measurement System Analysis) is a way of fulfilling the quality attribute "Test accuracy evaluation". If the third HoQ (Figure 33) is compared to the second HoQ (Figure 32) it is noticed that the third HoQ contains many more zeros indicating no relationship between the action and quality attribute. The actions have relationship to fewer quality attributes than the quality attributes have to the customer needs. This indicates that the actions are more tailored for specific quality attributes while the quality attributes are more general.

A	Include ECU test results in data base
B	Include ISC results in data base
C	Put a link from the tool to test prerequisite document
D	Link the tool to PROTUS
E	Always include test results in PROTUS or QJ
F	Explain terms and concepts in the tool
G	Include a function for comparing trends in the analysis tool
H	Include a control chart in the tool
I	Develop charts based on visualisation guidelines
J	Include a table in the analysis tool with the test result in red if outside specification
K	Include a table with desriptive statistics in the analysis tool
L	Include a function in the tool for performing correlation analysis between parameters of choice
M	Develop a system that gives automatic warnings on trends
N	Develop a system that gives automatic warnings on non-conformities
O	Develop a function for recording product changes in the analysis tool
P	Include a function for getting customized reports from the tool
Q	display the statistical significance of the test result next to test results

R	Include a function in the tool for record the causes of variation in the analysis tool
S	Add a feedback system to the tool
T	Perform a MSA on test cells
U	Initiate a Six Sigma project analyzing the causes of variation in production
V	Investigate what IT infrastructure is needed and implement
X	Give training to users on how to use the database and analysis tool
Y	Perform training with relevant employees on statistical analysis
Z	Provide training on fact based decision making
AA	Provide access to test result database for all employees working with COP and Hot test

AB	Present test results at management meeting regularly
AC	Publish information on team place
AD	Set up a procedure for sending out a standard report on a regular basis



Quality attributes	Weight	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	X	Y	Z	AA	AB	AC	AD
Direct access to raw data	37,8			1		3																	1	1			9			
Direct access to information	48				3	1																	1	1					9	
Proper graphical presentation	159,5							1	1	9	1	1																		
Test accuracy evaluation	253,7																	9			9				1					
Test conditioning values	258,5			9																										
Descriptive statistical information	994,1											9																		
Potential causes of variation	289,3			1	1			3	3	1		1	3			9			9											
Correlation analysis	576,3							1					9																	
Pull information system	339			1	3	3											3						3				9		9	
Push information system	266,4													9	9								3					9		9
Variation over time	63,2							9	9																					
Variation analysis	896,6															1			3		3	9								
Highlighted deviations	29,8										9				3															
Automatic warnings	291,6													9	9															
Customized report	481,7																9													
Training	613,2																							9	9	9				
User friendly tool	633,2			1	3		3	3		9	3		3	3	3	1	9	3	3	3			3							
More measured variables	389,7	9	9																											
Total		357	357	3959	4430	2537	1900	10075	7599	15524	5576	1296	7954	6922	7794	4134	1151	4183	7193	1900	4973	869	4495	6298	5773	5519	6388	2398	6723	2398
Rank		26	26	19	16	20	22	2	5	1	12	23	3	7	4	18	24	17	6	22	14	25	15	10	11	13	9	21	8	21

Figure 33 House of Quality 3

4.5.3. Planning and deploying quality attributes

The third HoQ uses the same principles as the second HoQ for summarizing the total weights of each action. This results in a prioritized list of actions to be taken (Figure 34). The figure shows that developing charts based on visualization guidelines and including a function for getting customized reports are the most important action to be taken.

Figure 34 Prioritized action plans

4.5.4. Analyze correlations

Just as in the previous HoQ the correlations should now be analyzed with a focus on the negative correlations. If a negative correlation is found between any of the actions a decision on the balance between them needs to be made. The prioritization mentioned above can support this decision. If one of the actions has a much higher weight than the other then this factor can be executed at the expense of the other. According to Bergman and Klefsjö (2011) a systems perspective should be emphasized to ensure good quality. Another alternative decision support is to trace the actions back

to their quality attributes, customer needs and customers through the relationship matrices in HoQ1, 2 and 3.

4.6. Taking action based on findings

According to Kiron et al. (2011) the development of action-oriented insights is a differentiator between companies competing on analytics and those less proficient. In the final stage the actions are prioritized so that the most important actions are performed first. The actions are then distributed to the people that should perform them in each BA phase.

4.6.1. Sort actions in order of importance

Since the organization resources are limited, it is important that a prioritized action list is considered for resource assignment and other planning efforts. Therefore, in this step the defined actions from the previous stage are sorted based on their total weighted score in HOQ3. In order to facilitate communicating the prioritized actions they are grouped in different categories. As seen in Figure 34, the four highest ranked action plans are those that according to the grouping on the HoQ3 lead to improve the analysis tool. Other action plans belong to other groups such as communicate the results, training and initiating different sub projects to support fulfilling the required quality attributes. However, grouping the action plans in this step is optional.

4.6.2. Divide actions based on BA phase

The actions derived from the QFD should now be delivered to the phase in the BA process affected by the result. For the case study this results in the following division (Figure 35)

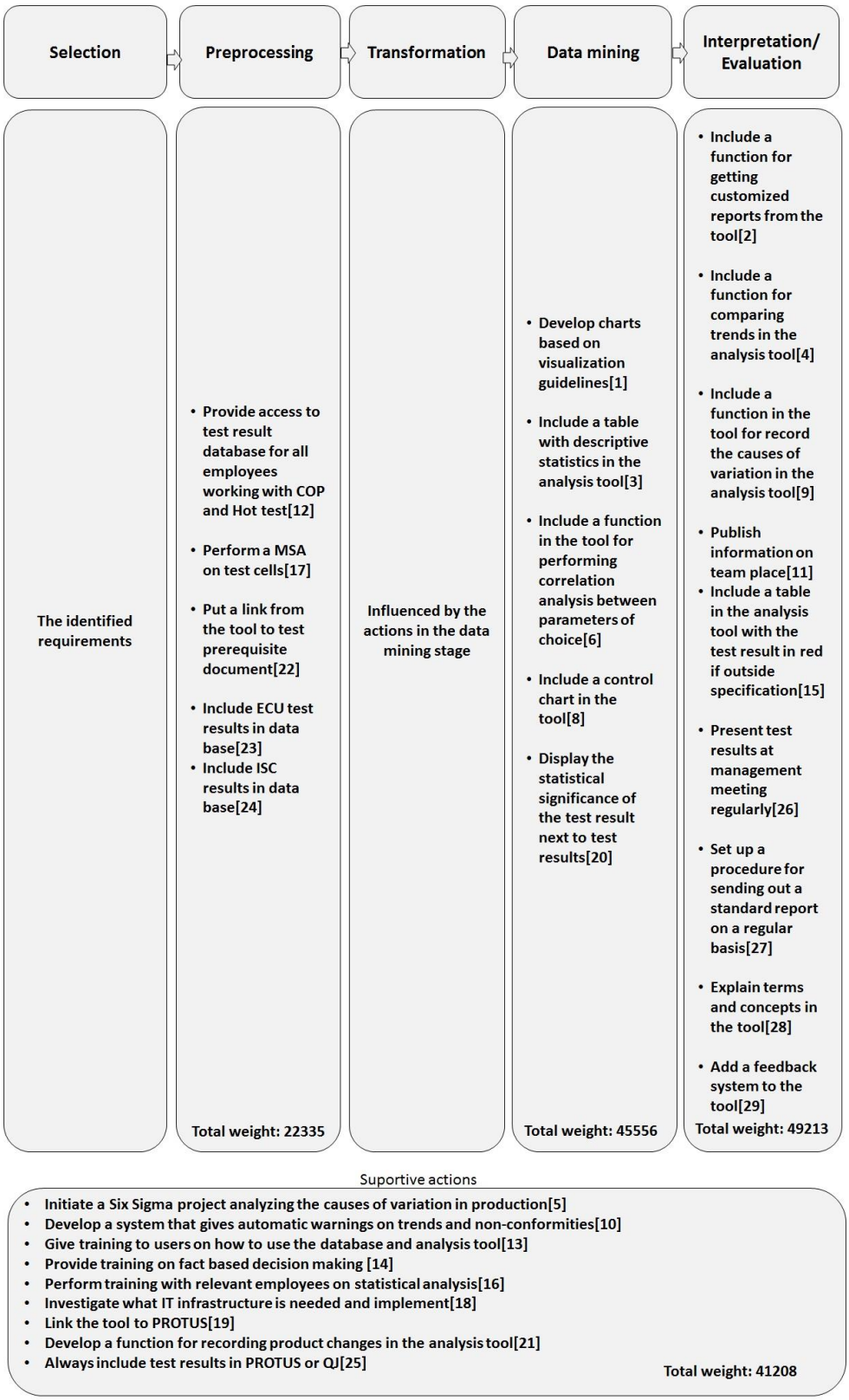


Figure 35 Actions split by BA process phase

As can be seen in the figure above some of the actions lie outside any of the phases in the BA process. Some of them, for example “investigating what IT infrastructure is needed and implement” and “develop a system that give automatic warnings on trends”, relate to supporting areas such as BI and data stewardship described in Saxena and Srinivasans (2013) framework.

4.7. General QFD methodology for support of BA processes

From the literature and case study a general methodology for using QFD to support BA can be derived. The proposed methodology will be explained step by step here together with visual presentations of the methodology.

The methodology consists of four stages. They are called stages as opposed the phases of BA in order to limit the confusion. The output of each stage is the input to the next stage. Through the stages the customer needs are collected and translated into quality attributes which in turn is translated into actions. The actions are finally prioritized and assigned to the phase in the BA process it belongs to. Each stage consists of between two and five steps. The proposed methodology can be seen in Figure 36.

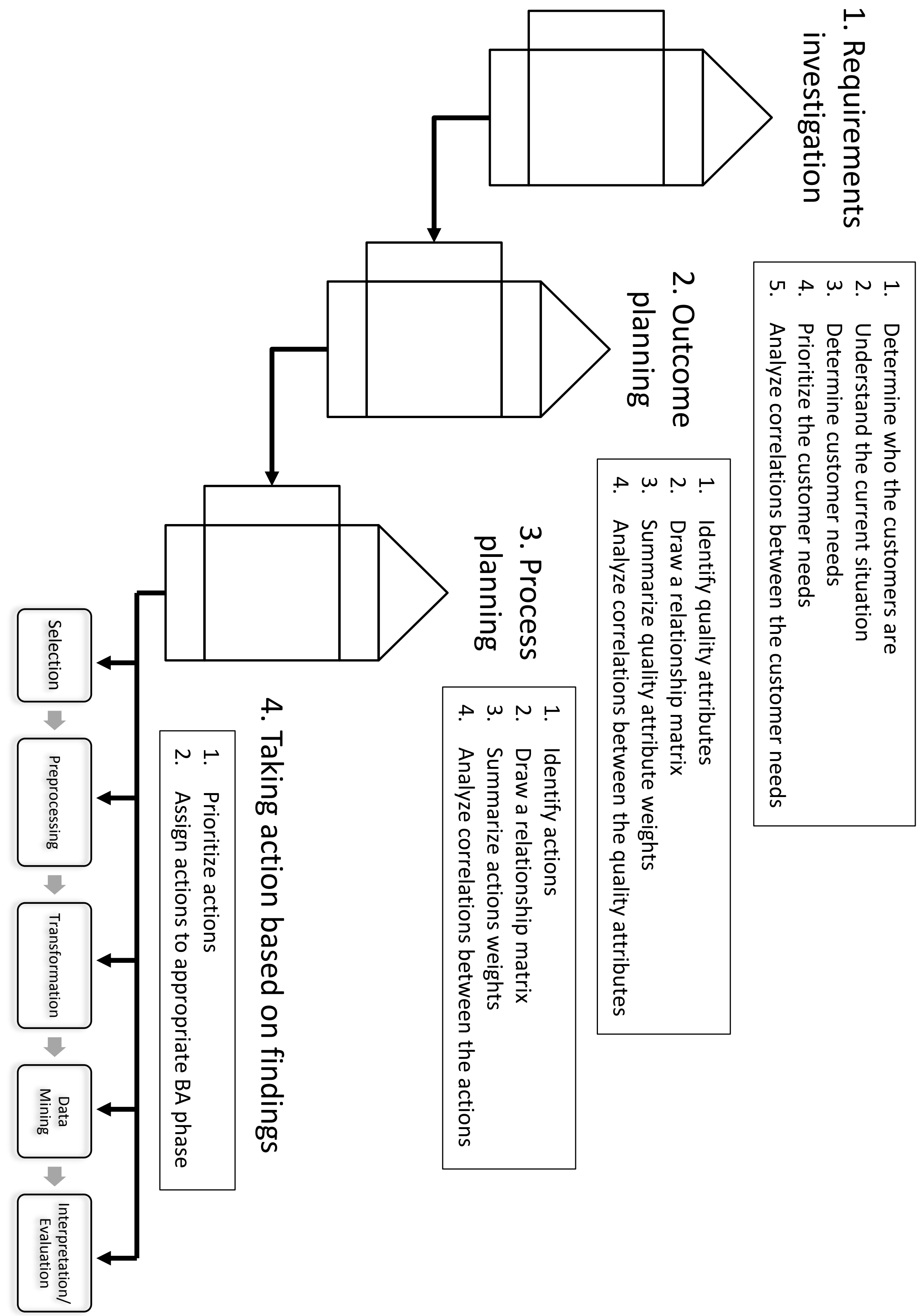


Figure 36 General QFD Methodology

The first stage, the requirement investigation, consists of five steps.

1. Determine who the customers to the BA process are. If their contribution is believed to be unequal they can be ranked using appropriate dimensions or a generic method presented in the theory chapter.
2. Understand the current situation. This can be done through informal conversations with experienced personnel or more formal interviews with customers.
3. Determine customer needs. Interviews are a good research method for this although associated with some subjectivity in the codification process. Validating the needs through member checks is then recommended. If there are many needs they can be grouped using the AIM method.
4. Prioritize customer needs. Map each customer with the requirement he or she has required. If the customers have been ranked then let the ranking influence the prioritization.
5. Analyze the correlations. Fill out the roof of the HoQ and analyze the correlations. Be extra careful if you find negative correlations.

The second stage, the outcome planning, consists of four steps.

1. Identify quality attributes. This can be done through brainstorming but needs to be anchored in the business. Therefore preferably include a business representative in this step. The quality attributes should be nouns that if present fulfills, partly or fully, one or several customer requirement(s).
2. Draw a relationship matrix. Map the quality attributes with the customer needs. Chose a rating scale that reflects your purpose and inform everyone involved in rating about the chosen scale.
3. Summarize quality attribute weights. Multiply the rating of each relationship with the weight of that customer requirement and sum them up for each quality attribute in accordance with the following equation:

$$
\begin{aligned}
&Weight\ of\ quality\ attribute\ i \\
&= relationship\ between\ customer\ requirement\ 1\ and\ quality\ attribute\ i \\
&\times weight\ of\ customer\ requirement\ 1 + \cdots \\
&+ relationship\ between\ customer\ requirement\ n\ and\ quality\ attribute\ i \\
&\times weight\ of\ customer\ requirement\ n
\end{aligned}
$$

4. Analyze correlations. Fill out the roof of the HoQ and analyze the correlations. Be extra careful if you find negative correlations.

The third stage, process planning, consists of four steps

1. Identify actions. This can be done through brainstorming but needs to be anchored in the business. Therefore preferably include a business representative in this step. The actions should be verbs that if executed presents one or several quality attribute(s) partly or fully.
2. Drawing a relationship matrix. Map the actions with the quality attributes. Chose a rating scale that reflects your purpose and inform everyone involved in rating about the chosen scale.
3. Summarize actions weights. Multiply the rating of each relationship with the weight of that quality attribute and sum them up for each action in accordance with the following equation:

$$
\begin{aligned}
&Weight\ of\ action\ j \\
&\quad = relationship\ between\ quality\ attribute\ 1\ and\ action\ j \\
&\quad \times weight\ of\ quality\ attribute\ 1 + \cdots \\
&\quad + relationship\ between\ quality\ attribute\ n\ and\ action\ j \\
&\quad \times weight\ of\ quality\ attribute\ n
\end{aligned}
$$

4. Analyze correlations. Fill out the roof of the HoQ and analyze the correlations. Be extra careful if you find negative correlations.

The fourth stage, taking action based on findings, consists of two steps.

1. Prioritize actions. Sort the actions in order of their weights with the highest weight first.
2. Assign actions to appropriate BA phase. Divide the actions into the BA phase where they should be executed. Include the ranking of each action. The total weight of each BA phase can also be calculated as an input to resource allocation.

4.8. Supplements to QM´s support of BA

In this section the framework presented in in the theory synthesis will be revisited and each phase of the BA process discussed. The aim is to supplement the framework with the findings from the case study to show how QM principles, practices and techniques can support BA.

4.8.1. Selection

In the selection phase the customer needs are identified in order to define the goal of the KDD process. The phase also includes providing a data set based on the process goal to focus and perform other phases of the KDD process (Fayyad, 1996). In the selection phase the suggested practices and techniques were used to support BA as suggested in the theoretical synthesis. Previous sections (4.3 to 4.6) show the outcome of this process. Aside from the techniques suggested, stratification was also found helpful in this phase as the customers could be divided into roles or sections for further understanding.

As suggested in the previous section there are more ways than those used in the case study in which quality management can support BA. One of these is the categorization of customers into different roles. By categorizing customers according to Lengnick-Halls (1996) framework a greater understanding of the customer needs can be gained. In the case study the managers could for example have been seen as buyers while the specialists could be seen as users which could give insights to how the different customer roles should be satisfied. It could also be important to identify which customers are co-producers, which in the case study would be those performing any analysis on their own, and it might even be in the interest of an analyst to convert customers into being co-producers which in turn would let more people be committed supporting the quality management principle.

QFD was used as a practice for collecting and translating customer needs into actions. Many of the quality attributes and actions are connected to the following phases in the BA process. By not only collecting the needs but also translating them, QFD is able to support more of the phases in BA. This is further explained under each phase.

Another practice to support the BA process is the Kano model. By categorizing the needs as basic, expected or attractive needs the needs can be weighted differently based on the relationship with customer (dis-)satisfaction. A column in the second HoQ could then be added as a supplement to be included in the overall weighting of needs; such a framework is suggested by Matzler and Hintlerhuber (1998). During this study the categorization of needs as basic, expected or attractive need had not been done. If the practice had been used this would probably result in a higher ranking of the requirement “reach certification agency requirements” as this is believed to be a basic need which in turn would explain why few customers mentioned it during the interviews as basic needs are rarely mentioned in interviews (Bergman & Klefsjö, 2011).

4.8.2. Preprocessing

The preprocessing phase can be divided into the sub steps data cleaning, removing noise from data and handling missing data (Fayyad, 1996). Focus on customer needs is the QM principle that relates to the objective of this phase. Based on the customer needs the noises and the data that is missed in the data set should be identified and handled. During the study it was also noticed that top management commitment can provide support to the preprocessing phase by allocating resources needed to run different sub steps in preprocessing. This shows another link between the QM principles and BA.

By adopting a process view on each phase the internal customers for the preprocessing phase can be identified. Since a focus on customers is a principle in quality management and according to Bergman and Klefsjö (2011) lead to higher quality, the preprocessing phase would benefit from collecting the voice of the customer. One way of doing this in practice would be talking to the people who are the customers of preprocessed data in the transformation phase. The division of customers, based on roles, could therefore also be a beneficial technique to use as it facilitates customer orientation and a focus on customers (Lengnick-Hall, 1996).

4.8.3. Transformation

In the transformation phase the number of variables is reduced to those that are relevant to the customer needs. (Fayyad, 1996). Focus on customer needs and basing decisions on fact are the QM principles that closely relates to the objective of this phase. In order to reduce the number of variables and focus on the relevant ones the analyst need to know the prioritization of the variables requested. This decision should be based on the facts gained through customer ranking and requirement prioritization in the selection phase.

The second and third HoQ resulted in a number of quality attributes and actions to be taken. Some of these are related to the work performed in the transformation phase. The quality attributes ”correlation analysis” and ”variation analysis” will result in different requirements on the reduction of variables. Since the transformation phase has to accommodate the following phases the quality attributes and actions related to these phases will affect the work in the transformation phase.

The high ranking of the quality attributes “variation analysis” and “descriptive statistical information” also puts requirements on the transformation phase. An analyst working in this phase needs to prepare the data in order for this type of analysis to be made. These are further examples of how the results of QFD can be used in practice in a BA process.

The AIM technique is also useful when reducing the number of variables. In this case study the AIM method was used in the selection phase when customer needs and quality attributes were grouped together. A similar use of the techniques could be considered here.

Just as in the preprocessing phase the transformation phase can be viewed as a process on its own with specific customers. These customers would mainly be those people involved in the following steps as they use the output of the transformation phase. Identifying the customers, establishing which role they have and collecting the voice of the customer would enable the transformation phase to produce an end result that analysts in the next step desire, hence contributing to a higher quality analysis.

4.8.4. Data mining

During the data mining phase several activities are performed such as selecting data mining method based on the goals of KDD and exploratory analysis (Fayyad, 1996).

Aside from the use of customer centric techniques such as collecting the voice of the customer and considering customer roles, the data mining phase can find much support in QM techniques. The seven management tools, as well as many of the seven improvement tools can be used to support data mining in a broader sense just as explained in the theory synthesis.

In the case study many of the quality attributes and actions were related to the data mining phase. A couple of examples are “Correlation analysis” and “Variation analysis”. Again the extensive work with QFD in the selection phase provides benefits in future phases. These quality attributes and actions can work as checklists for the analysts performing the analysis. A practical example of this use could be the fulfillment of the requirement “proper graphical presentation”. This requirement is clearly linked to the data mining phase and by having this information emphasis can be put on fulfilling the requirement and facilitate higher customer satisfaction. There are a number of measures the analysts can take to accommodate this requirement (Few, 2005 ; Tufte, 2009; Marchses and Banissi, 2013). One practical solution would be to remove excess ink (Tufte, 2009) and limit the information displayed to what really adds value (Few, 2005).

4.8.5. Interpretation/Evaluation

The interpretation/evaluation phase includes interpreting the patterns and other information derived from the previous steps as well as evaluating the BA process (Fayyad, 1996).

As the last phase in the process (within the scope of this study) the interpretation/evaluation phase benefits from the efforts made in the previous phases. Therefore the support QFD and the associated techniques can give to the interpretation/evaluation phase is by supporting the previous phases in ways that facilitates interpretation and evaluation. An example of this from the case is to provide good graphical presentation and to provide customized reports.

Finally, as with the previous phases, a process orientation in the interpretation/evaluation phase gives advantages when fulfilling the customer needs (Bergman & Klefsjö, 2011). Therefore the voice of the customer and customer roles are QM techniques that are applicable to this phase as well.

4.8.6. Update of the framework

Based on these learnings from the case study the framework suggested in the theoretical synthesis can be updated with more practices and techniques (Figure 37).

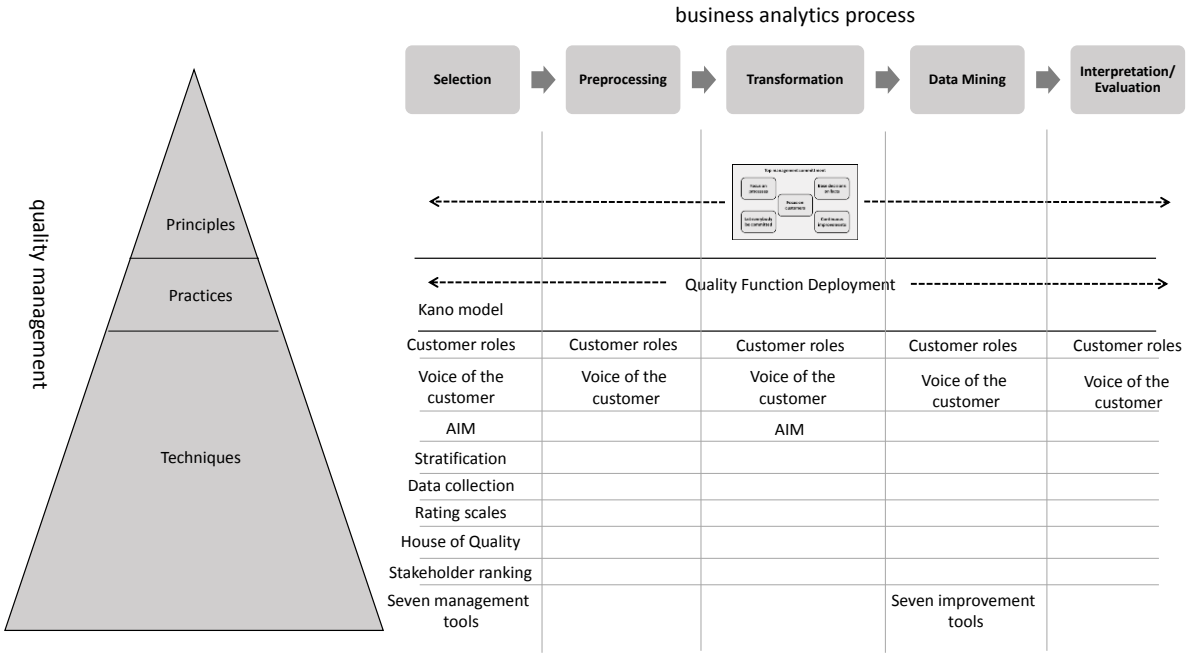


Figure 37 Final framework for integrating QM and BA

This framework show that QFD as a QM practice and its associated techniques can support different phases in the BA process. The framework also shows that some QM techniques are more applicable in some BA phases than in others. The AIM and stratification for example can facilitate the transformation phase, but the techniques are less applicable to when interpreting the data and evaluating the process.

5. Discussions and conclusion

This chapter will discuss the findings and research study, as well as provide suggestions for future research and finally present the conclusion.

5.1. Discussions

Regarding the three areas of IT, analytics, and business knowledge as the factors that affect the organizational framework of business analytics; it is emphasized that the analytics is needed to be integrated to the organizational operations and implementing the BA actions need to be supported by IT infrastructure of the organization (Grossman & Siegel, 2014 ; Saxena & Srinivasan, 2013). Since the operations, processes capabilities, and IT infrastructure are different from organization to organization, it can be realized that although the suggested methodology and related steps in this research are applicable for other organizations, but the sub- steps could be different and obviously one would have to define different quality attributes and actions for each organization.

The location of BA in the organizational structure involves issues related to the centralization and decentralization. When BA is centralized, it includes a group of analytics experts with a high focus on the BA function but the challenge of such a structure is that the analysts are far from other functions that they support and this makes it difficult to understand the other functions' processes and their needs. On the other hand, in the case of decentralization of BA, a group of analysts can be placed in different business functions which make it easier to collaborate but the advantage of resource focus is missed (Grossman & Siegel, 2014). However, regarding this issue some ideas are proposed by different researchers. For example, Grossman and Siegel (2014) introduce the hybrid approach as a third model. According to the hybrid model, a big data center can be set up where an analytical scientist is placed while the other analysts are distributed throughout the different functions with access to the big data center. The virtual department is another idea by Laursen and Thorlund (2010) which is proposed for small and medium size organizations where the BA team is responsible for coordination between organizational strategy and business analytics. However, the location of BA in the organization is an issue that needs to be investigated with emphasis on the organizations size, capabilities and business strategies.

The skills and competencies required by an analysts is another important factor to consider in BA. The business competencies, technical understanding and method competencies are three areas of required knowledge emphasized by Laursen and Thorlund (2010). This is well related to the key roles of analysts introduced by Davenport et al. (2001); database administrator, business analyst and data modeler, decision maker, and outcome manager. However this wide range of required competencies becomes more challenging when integrating QM and BA. The question is then to what extent it is possible for one person to have BA competencies together with QM skills and knowledge. In addition, although the Chief Data Officer (CDO) is a new role established by leading organizations to continuously improve their data policies a recent survey over 500 global companies reveals that the majority of them still have not fully learned how to manage big data at the corporate level (Lee et al., 2014).

Big data is a huge trend as explained in the theoretical framework. As the definition of what constitutes big data is debated (Loshin, 2013) it is hard to determine if the test results in this case is big data or not. Therefore the study was conducted without classifying the data. However, a study treating the test results as big data might come up with other results since different phases of BA such as data collection and data processing are influenced by the amount of data (Helland, 2010).

Although the two concepts QM and BA fit well with each other as explained in section 3.3, some conflicts between them can be identified. When using BA on a process over a longer time, techniques such as control charts are applicable and trend analysis can be made. These techniques, however, require a stable process (Oakland, 2008). When a change is introduced the stability is temporarily

disturbed and the process should be viewed as a new process requiring new samples in order to draw any conclusions based on the data (Oakland, 2008). Therefore, introducing changes makes the work with BA more difficult. On the other hand the QM principle of continuous improvements emphasize that "There is always a way to get improved quality using less resources" (Bergman & Klefsjö, 2011:45) which would lead to an endless stream of changes to the process. A conflict between the two concepts is therefore identified from literature and the trade-off needs to be understood. Basing decisions on facts is another QM principle which, as explained earlier, is supported by BA since BA produces information that can be used as facts in decision making. When there are many changes in the process the quality of this information can be questioned. If the decision makers still treats the information as facts despite the questionable quality of it, this could lead to faulty decisions. MacAfee and Brynjolfsson (2012) emphasize that human insights are still needed within BA.

When interpreting the information in the interpretation/evaluation phase there is an obvious need to be objective. If the analyst is looking for a specific pattern the chances of finding it is increased through the use of confirmation bias (Kahneman, 2011). The customer focus is according to Dean and Bowen (1994) the most important QM principle and requires all organizational entities to work with it. There is therefore a risk for a bias analysis if the customer wants to find something else than what the data is suggesting. An example could be when the data is used to verify a product update that has taken more time than expected. The customer (in this case the product developer) could then want the analysis to conclude that a product update was successful and a customer focused analyst could then be tempted to draw that conclusion too making the analysis biased and therefore incorrect.

The suggested QFD process has been explained in the context of this case study. This methodology has been applied to Volvo GTT PE but the methodology's applicability to other companies is yet to be tested. There are some special conditions that require further discussion. One of these is when a new test is introduced. The step of understanding the current situation can then focus more on the attitude towards the new tests as that is what constitutes the current situation when no test is run. In this case study all customers and suppliers were internal. In a situation where customers are external the sensitivity of the information distributed needs to be considered. This is not unique for BA processes. According to Davenport et al. (2001) analytics can save the company large sums of money and since analytics require data, then data is valuable and should be protected. In this case one of the suggested actions was to include more variables in the database. If the supplier of data is external instead of internal, as in this case, these actions would be harder to pursue as the choice of data is outside company control.

5.2. Conclusion

This thesis have two research questions that have been answered in this report. The answers are summarized below.

RQ1: How can quality management principles support the business analytics process?

In general, BA and QM has a mutually supportive relationship and, as explained in section 3.3, all QM principles facilitates work in the BA process while BA supports several of the QM principles. BA can for example facilitate basing decisions on facts which is one of the corner stones in QM. Figure 37 in section 4.8.6 explains the relationship more and also shows how the practices and techniques fit into the BA process.

Despite the mutually supportive relationship between QM and BA there are some potential conflicts between the two that the organization should be aware of and take into consideration during implementation. These are outlined in the discussion (section 5.1) and include QM's emphasis on constant improvements and BA's requirement of a stable process.

RQ2: How can quality management practices and techniques support the business analytics process?

Figure 37 in section 4.8.6 also summarize the support that QM practices and techniques can offer the BA process. In this case study a customized version of QFD is used as a primary practice to support the BA process. The customized version is explained by the figure in section 4.7 (Figure 36). This proposed methodology consists of four main stages with different steps that are needed to be done in order to move from one stage to another. Although the steps are applicable to other cases the differences in organizational capabilities and processes might lead to different sub-steps from company to company.

5.3. Future research

This study has investigated the use of some QM practices and techniques. The other applicable practices and techniques to support different phases of BA process need to be investigated by future research.

After analyzing the data there is a need to communicate it throughout the organization. Some of the actions derived from this study are related to how the information should be received which raises the question of how information should be communicated effectively. This is an area for future research.

This study was delimited from the phases related to decision making in the BA process. Although the importance of converting data to information and knowledge is great the benefits would be limited if it is not used. Therefore the success of the proposed methodology and framework presented in this thesis is highly dependent on future research on data driven decision making.

This study has looked into BA processes and chose the KDD as representative for BA processes. Holsapple, Lee-Post and Pakaths (2014) BAF presents another perspective on BA which could be considered more holistic. Taking this holistic view may affect the findings which is why we recommend future studies to be made with the BAF as a basis.

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Appendices

Appendix A – Interview guide managers

- The thesis is related to Business Analytics and the purpose is to give guidelines on how companies should convert data to communicable information effectively. We have therefore developed two research questions that reflect the focus areas of this thesis.
- Introducing CoP / Hot test
  CoP test is performed on the engines in order to measure and test mainly the emissions since the emissions are needed to be in accordance with the legal requirements. The parameters that are currently measured at Skövde are Nox, CO, PM, HC, etc. In addition, some performance parameters such as power, torque, fueling, etc. 0,2% of the engines are CoP tested .
  Hot test is a performance test of the engines and the parameters such as power, torque, fuel, etc are measured. 10% of 13L engines and 100% of 16L engines are tested.
- Purpose on the interview and method
  The purpose of this interview is mainly to get information about your needs and expectations regarding both current situation and desired future of the output of the process of converting data to communicable information. We have identified the different customers to this project and will in an initial step have interviews with you in the reference group. The idea is that you will represent your section and give general insights to what your section requires. We can then follow up with interviews with specialists in every section for their specific needs.
- With your permission the interviews will be recorded. No anonymity is promised but should you want to change any answer after the interview by contacting us you have one week to do so. If you found the questions unclear just let us explain that. If you need to visualize some explanations you can use the board available here.

<u>Interview with reference group</u>

- Please describe your section.
- What is your role in the product development process?
- Here is the process that we found in the management system, is this an updated version? Could you explain the process for us?
- Does your section use the CoP and Hot test results in this process?

  If yes:
    - How does your section use that?
    - Why does your section use it?
    - Where in the process does your section use it?
    - Who uses the test results in your section?
    - When and how often do they use it?
    - How do you personally get the test results? Through what channel do you receive it?
    - What are the main parameters that you personally look at?
    - What decisions do you personally make based on the results? (be specific)
    - Could your section use the test results in ways that you are not currently using it?
    - What would you benefit from using the test results in that way?

- Where in the process could the test results be used?
- What persons that are not currently using the test results could benefit from using it?
- Would you benefit from using the test results more often/seldom or at other times in relation to what you do now?
- Could other parameters be of interest to you personally in the future?
- Could you personally base decisions on the test results that you are not currently basing on it?

If No:

- Why are you not currently using it?
- Could your section use the test results in ways that you are not currently using it?
- What would your section benefit from using the test results in that way?
- Where in the process could the test results be used?
- What persons that are not currently using the test results could benefit from using it?
- When and how often should it be used?
- What parameters could be of interest to you personally in the future?
- Could you personally base decisions on the test results that you are not currently basing on it?

- How much impact does the test results have on product development at your section?
- *Information could be bar charts, control charts, averages and variance while knowledge is the understanding you get when you interpret the information*. Which of these two is most in line with what you personally want in terms of the content of the CoP and Hot test results?
- If information: What type of information do you personally need? What knowledge could you personally get from this information?
- If Knowledge: What type of knowledge would you personally like to have? Is there any specific information that you personally think could contribute to get this knowledge?
- Do you have the skills required to do the analysis yourselves at your section?
- To what extent is it possible for people out of your section to interpret the information and its effect on your process?

Appendix B – Interview guide specialists

- The thesis is related to Business Analytics and the purpose is to give guidelines on how companies should convert data to communicable information effectively. We have therefore developed two research questions that reflect the focus areas of this thesis.
- Introducing Cop / Hot test
  CoP test is performed on the engines in order to measure and test mainly the emissions since the emissions are needed to be in accordance with the legal requirements. The parameters that are currently measured at Skövde are Nox, CO, PM, HC, etc . In addition, some performance parameters such as power, torque, fueling, etc. 0,2% of the engines are CoP tested .
  Hot test is a performance test of the engines and the parameters such as power, torque, fuel, etc are measured. 10% of 13L engines and 100% of 16L engines are tested.
- Purpose on the interview and method
  The purpose of this interview is to get information about your personal needs and expectations, as a specialist, regarding both current situation and desired future situation of the output of the process of converting data to communicable information.
- With your permission the interviews will be recorded. No anonymity is promised but should you want to change any answer after the interview a summary will be sent to you for approval. If you found the questions unclear just let us explain that. If you need to visualize some explanations you can use the board available here.

<u>Interview with specialists</u>

- What is your role in the product development process and what activities do you perform?
- Is this the process you work in? What is your role in this process?
- Do you personally use the CoP and Hot test results in this process?

  If yes:
    - How do you personally use that?
    - Why do you personally use it?
    - Where in the process do you personally use it?
    - When and how often do you personally use it?
    - How do you personally get the test results? Through what channel do you receive it?
    - What are the main parameters that you personally look at?
    - What decisions do you personally make based on the results? (be specific)
    - Could you personally use the test results in ways that you are not currently using it?
    - What would you benefit from using the test results in that way?
    - Where in the process could the test results also be used?
    - Would you benefit from using the test results more often/seldom or at other times in relation to what you do now?
    - Could other parameters be of interest to you personally in the future?
    - Could you personally base decisions on the test results that you are not currently basing on it?
    - Who else uses the test results in your section?

- What persons that are not currently using the test results could benefit from using it?

If No:

- Why are you not currently using it?
- Could you personally use the test results in ways that you are not currently using it?
- What would you personally benefit from using the test results in that way?
- Where in the process could you personally the test results?
- When and how often should it be used?
- What parameters could be of interest to you personally in the future?
- Could you personally base decisions on the test results that you are not currently basing on it?
- What persons that are not currently using the test results could benefit from using it?

- How much impact does the test results have on your personal activities?
- *Information could be bar charts, control charts, averages and variance while knowledge is the understanding you get when you interpret the information*. Which of these two is most in line with what you personally want in terms of the content of the CoP and Hot test results?
- If information: What type of information do you personally need? What knowledge could you personally get from this information?
- If Knowledge: What type of knowledge would you personally like to have? Is there any specific information that you personally think could contribute to get this knowledge?
- What type of skills and knowledge is required to do the data analysis that you do or will do?
- With these skills and knowledge in mind, should the analysis be made by you or someone else?