Selecting Business Intelligence Solutions using Requirements Engineering

An evaluation of existing methods and a design of a new method

Master's thesis in Computer science and engineering

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Abstract

Business Intelligence (BI) is a collection of processes, technologies, and tools that aims to provide organizational value by triggering actions and decisions through well-presented information extracted from company data. Existing BI solutions on the market can be used to present the information. There is, however, no guidance in how to select an existing BI solution but there are many approaches to requirements engineering (RE) in BI which aim to build a BI solution from scratch. Therefore, this research investigated if existing methods for RE in BI also could be useful for selecting an existing BI solution based on the requirements the methods produced. The experience from doing so was used to understand what an appropriate method to select a BI solution could be.

The results showed that the existing methods for RE in BI could be used but that they gave weak support in selecting an existing BI solution. Hence, there were more appropriate ways to select BI solutions that were recommended instead of the existing methods. Based on the lessons learned from applying existing methods in parallel and from studying BI solutions, a new method was designed with the purpose of selecting an existing BI solution. The new method consisted of five phases; a pre-study, feasibility study, market analysis, requirements elicitation, and BI solution selection (see Section 5.5). The new method was deemed to be a more appropriate way to select a BI solution than existing methods since it produced requirements and criteria in a hybrid approach that could be used to distinguish between BI solutions.

The research was carried out on a real case at a global manufacturing company with headquarters in Stockholm, Sweden during Spring 2019.

Keywords: requirements engineering, business intelligence, requirements elicitation, KPI, BI solution.

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Anna Carbell & Andreas Mann, Stockholm, May 2019

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1 Introduction

Data is becoming more relevant and abundant than ever before and businesses have started to rely more on data than on their own experience and intuition when it comes to decision-making [26]. Collecting data is not a problem, in fact, both the amount and kinds of data that is collected are increasing rapidly every year. The challenge lies in finding the information that is actually useful in all that data, a challenge that paved the way for the field of business intelligence (BI).

BI is a collection of processes, technologies, and tools that aims to provide organizational value by triggering actions and decisions through well-presented information extracted from company data [26, 12]. In simpler terms, BI is a way to use business data to make better decisions. With the help of BI, an organization can understand the performance of its operations and gain value in terms of finances, productivity, trust, and risk mitigation. BI has shown to have a meaningful and positive effect both on companies' innovation efforts and their competitive advantages [12]. This makes the incorporation of BI solutions into organizations an important area to address. There exist BI solutions on the market that allow companies to access their internal data sources and then present the relevant data found in them in a way that allows managers to make informed decisions.

In existing research, there was a lack of specific methods for selecting existing BI solutions but several methods for requirements engineering (RE) in BI that were used for designing and implementing new BI solutions from scratch existed. This made it interesting to investigate such RE in BI methods to find out what an appropriate method for a BI solution selection could be.

1.1 Problem definition

In this research, three existing RE in BI methods were applied in parallel to produce requirements to use in a BI solution selection. These methods were the BI implementation life cycle [33], data mining in business intelligence (DM-BI) requirements elicitation [6], and the business intelligence model (BIM) [21]. Neither of these methods nor any other methods found in the literature review provided guidance in selecting a suitable BI solution based on requirements.

Therefore, this study aimed at evaluating if existing methods for RE in BI could produce requirements for selecting a BI solution. From the lessons learned of applying these methods in parallel, a new method for selecting a BI solution was designed. To evaluate the existing methods and the new method, the researchers applied the existing methods to a real case in an industrial setting at a manufacturing company and evaluated the new method with a BI steering group at the case company (the case company is described in Section 1.3).

The practical need for this research was justified by observed problems in industry expressed by the case company. They had a need for selecting an adequate BI solution that satisfied their specific needs. The company also expressed problems with how reporting was handled within the organization. This led to a lot of manual work without any value contribution since the reports were not good enough to neither base decisions on nor understand the current situation. The company did not lack data but rather the capabilities to leverage it through BI.

1.2 Research questions

The aim of this research was to investigate if BI solutions can be selected based on requirements produced by existing elicitation and modeling methods, and to investigate what an appropriate method for selecting a BI solution would be. In this study, three methods were therefore applied to support the elicitation of requirements; the BI implementation life cycle [33], DM-BI requirements elicitation [6], and the BIM [21]. To fulfill the purpose of this research, the following research questions (RQs) guided the researchers:

RQ1: Do existing RE methods for BI support selecting BI solutions?

The purpose of this RQ was to evaluate the three methods to conclude if the produced requirements provided sufficient support in selecting existing BI solutions. To answer RQ1, the elements of each applied method that either produced or supported the production of requirements were identified and employed. The output was then used to make a selection.

RQ2: What is an appropriate method for selecting an existing BI solution?

RQ2 formed the design problem of this study (see Chapter 4 for details on the design science process) where the answer to this question was the new method for selecting an existing BI solution. The lessons learned from answering RQ1 were used to answer RQ2.

1.3 Case company description

The case company in this researchwas a large manufacturing company in the forestry industry with several divisions and multiple production mills globally within each division. The company had 26 000 employees in over 30 countries and an operational earnings before interest and taxes (EBIT) of EUR 1.3 billion. The company had headquarters in Sweden and Finland. This research was conducted within one of the company's divisions which produced cardboard. This division had five production mills, four situated in Europe and one in Asia.

During the course of this research, a BI steering group at the company supported the researchers in their work. This steering group consisted of eight people with representatives from controlling, business information office (IT), operations development, and business development. They assisted both in validating the output from applying the existing methods and in evaluating and validating the new method.

1.4 Scope and delimitation

In order for this research to be finished on time with the given resources, the study had to delimit the scope to one division and one specific department, the Operations department, because of the organization's size and that Operations had a need this suited the research.

While there were other methods available for RE in BI, only three were considered in this research (BI implementation life cycle [33], DM-BI requirements elicitation [6] and BIM [21]). Justification for why these methods were chosen can be found in Section 4.1. This enabled future research to consider a wider variety and greater number of methods in their evaluation, see Section 6.3.

In design science, the produced design artifact, which in this research was the new method, should be tested and improved in several iterations [40]. However, due to the time constraint of this research, no further iterations of the new method were possible and it was up to future research to iterate the new method further.

1.5 Research contribution

A purpose of this study was to evaluate methods for RE in BI to support the selection process of adequate BI solutions by applying the methods to a BI development project in a large industrial organization. The research community benefited from this because they received a greater understanding of the RE methods as used in practice and could use that knowledge to further develop them. They also benefited by understanding how the existing methods could be useful for purposes other than their intended purposes.

The other purpose was to investigate what an appropriate method for a BI solution selection could be, which resulted in a new method presented in Section 5.5. This was useful for companies undertaking BI development projects who were experiencing insufficient data handling and reporting, and were in need of selecting a BI solution to mitigate this problem. Further, the research community could use this research to expand on the lessons learned and the new method by applying and improving them in an iterative manner.

1.6 Thesis structure

Following the introduction of this thesis is a chapter on background information, Chapter 2, concerning the topics of this thesis. This information is helpful for readers' understanding in the rest of the thesis. After the background chapter follows a chapter on related work, Chapter 3, which describes the methods that were applied in this research but also methods that were related to the research topic but were not applied. In Chapter 4 , Method, an in-depth description of how this research was conducted is presented. The results and findings from conducting research as described in the Method chapter is presented in Chapter 5. Following that, Chapter 6 discusses the findings from Chapter 5 as well as recommendations for future research within this field. Lastly, Chapter 7 presents the the conclusions of this research.

2
Background

This chapter describes the technologies and concepts that relate to the subject of this research. It begins with a description of BI and relevant technologies associated to it followed by a definition and an explanation of key performance indicators (KPIs). Finishing off the chapter is a section on RE.

2.1 Business Intelligence

As businesses are generating data at increasing speed, in an increasing number of types, and in larger quantities, abilities to leverage that data become increasingly important [26, 9]. In fact, being able to analyze data (i.e. Business Analytics or BI) has been noted as one of the four major technology trends of this decade [9].

Academic literature provides many definitions of BI. Öykü et al. [23] present it as both technical and organizational elements that are leveraged for presenting historical information to support analysis for better decision-making leading to improved organizational performance. Chen et al. [9] break it down further and describe BI as techniques, technologies, systems, practices, methodologies, and applications used to analyze critical data and understand an organization's business. Babu [2] is in line with the definitions by Chen et al. [9] but provides a more abstract description calling it a procedure for processing large amounts of data and presenting it in high-level reports that show the core information from that data. Popovič et al. [36] make a distinction between BI and business intelligence systems (BIS). They see BI as the *ability* of an organization to reason, plan, make predictions, solve problems, think abstractly, innovate, and learn to increase organizational knowledge and make informed decisions to reach organizational goals. BIS is defined as the information an organization has stored and how it is connected to software tools that allow decision-makers to analyze information and make decisions. All descriptions emphasize the role of BI being to improve decision-making by basing decisions on timely, useful, and correct information. This allows organizations to reduce decisions based on intuition rather than information, as well as it enhances communication across the organization, helps organizations respond more quickly to changes, and supports them in prioritizing their efforts [2, 26].

Although it is increasing in usage in all sectors, value through BI has been most prominent in sectors such as wholesale, retail, and finance [23]. The data they leverage in order to gain value from BI is usually stored in various ways such as in data warehouses (DW), data marts, and in online analytical processing (OLAP) cubes. As data can come from different sources, BI solutions need to support the collection of data from a heterogeneous group of data sources and, they also need to support the demands of more than one user type [2]. The integration of different systems and data sources often proves a challenge for organizations taking on BI efforts [23]. Popovič et al. [36] emphasize the need of solving data integration issues (bad data quality, lack of IT integration skills, data transformation issues etc.) before committing fully to a BI implementation.

To achieve success with BI endeavors, they need to be interdisciplinary and include not only IT and those with analytical skill, but also those with knowledge of the business and its domain as well as those with communication skills [9]. Öykü et al. [23] identify *flexibility* and *user access* as key capabilities for BI success. Flexibility means that a system for BI, i.e. a BI solution, must be compatible with the existing tools and applications in an organization. An inflexible system is expected to increase costs and complexity. User access relates to the information and access that different roles in the organization need and should have. Some organizations opt for complete transparency while others are more restrictive of what information is available to whom. Also, someone working close to operations will probably need more detailed information in contrast to someone in high-level management. Further, Öykü et al. [23] saw that *data quality* was not as critical as flexibility and user access when it comes to BI success. Data only needs to be of "good enough" quality and efforts to improve it further risk impacting more important capabilities.

Popovič et al. [36] investigated information quality further. They found that increased information quality leads to an increase in information usage. But they also found that organizations with good analytical decision-making cultures could leverage information even when it was not of the best quality. Hence it is organizations with low levels of analytical decision-making cultures that can achieve the most value from improving information quality. In addition to their findings on information quality, Popovič et al. [36] also indicate a need for BI to focus on the needs of knowledge workers more than on the quality of access to information. To do this, managerial concepts should be incorporated into the BI process.

2.2 Key performance indicators

KPIs are measures that help managers take actions to improve an organization's performance [34]. These are tied to an organization's critical success factors. The *key* in KPIs means that they are key to the specific organization and *performance* means that they should assist in improving performance. KPIs reveal the gaps that occur between actual performance and the planned performance and by doing so, they can assist in identifying problems as well as correcting those problems [8]. Feedback is necessary for any system to achieve success and KPIs offer the feedback that is necessary within an organization in order to reach success in their performance. Parmenter [34] describes the seven characteristics that a KPI should have. They are/have *non-financial*, going deeper than a financial result; *timely*, reported continuously on daily or at minimum weekly basis; *CEO focused*, holds the attention of top management; *simple*, should indicate necessary actions; *team-based*, should be able to be derived from a specific unit's efforts; *a significant impact*, closely tied to critical success factors; *a limited "dark side"*, should not cause undesirable behavior.

The team-based aspect of a KPI means that it should be tied to a team or a cluster of teams that are working closely together [34]. This creates clarity and ownership, something that is emphasized by Chae [8] who says that assigning roles and responsibilities for KPIs is important for them to work in practice. Further, for any performance management (such as a KPI) to work, it requires incentives from top management as well as a culture that favors measurements in the organization [8]. Such a culture includes an organization that clearly understands its KPIs and where all employees feel that they grasp the importance and meaning of KPIs [34].

2.3 Requirements engineering

RE is defined as a subset of systems engineering, thereby present in all engineering practices and not only software engineering [11]. RE includes activities such as discovering (elicitation), analyzing, communicating, and managing requirements. It also includes validation, making sure that requirements represent stakeholders' needs, and verification, making sure that a finished system conforms to specified requirements. A requirement, in turn, is something that describes functional or design characteristics, or constraints of a product or process. A requirement is easy to understand, testable or measurable, and must be necessary. Discovering requirements, referred to as requirements elicitation, usually employs methods originating from social sciences [41]. That being the case means that it is important for a requirements engineer to have good communication skills. Such is especially the case when conducting interviews for elicitation. If conducted well, interviews support the majority of elicitation phases; understanding the domain, identifying sources of requirements, analyzing the stakeholders, selecting techniques and approaches, and eliciting the requirements.

3

Related work

This chapter describes previous work in RE and BI related to the purpose of this study. The chapter first describes general approaches to RE followed by more BI-specific approaches. The more general are presented in Section 3.1 and the ones adapted to BI are presented in Section 3.2. A few goal modelling approaches are presented, some that are more general and some that have been adapted to BI. Further, the methods and approaches that are BI-specific include life cycles for BI implementation, requirements elicitation in information and data mining, and privacy RE. In this research, only three of the presented approaches in this chapter were adopted. The justification for the methods that were chosen can be found in Section 4.1.

3.1 General RE approaches

Lausen [24] presents a general approach to RE and suggests a Requirements template that takes a problem-oriented approach to elicit, specify and validate requirements. The purpose of the template is to describe what a system should do, what it should be used for and what problems it should reduce. It can be used to specify a customer's needs with the purpose of delivering the specification to potential suppliers to understand if their systems are compatible with the needs. This approach by Lausen [24] is not specific for BI and focuses on many different aspects of RE which makes it helpful for newcomers in the RE field. It was considered in this research because it was described in detail in terms of execution with a clear output (a requirements specification).

The User Requirements Notation (URN) is a modeling language used in the field of RE. It aims at eliciting, analyzing, specifying and validating requirements for systems and processes [1]. The URN connects the 'what', 'how' and 'why' dimensions in a model to help explain different scenarios to stakeholders. The language combines two languages; the Use Case Maps (UCM) notation and the Goal-oriented Requirement Language (GRL). UCM helps in describing architectures and scenarios while GRL supports the modeling of actors and their intentions. URN has been extended and revised by many authors [1]. One such extension was to include KPIs in order to better align processes and goals [37].

Another goal-oriented RE approach is presented by Letier and Lamsweerde [25] who suggest that software specifications should be derived from system goals. Goals are objectives that a system (software) must satisfy and they range from high-level business concerns to low-level specific software functionality. In the research by Letier and Lamsweerde [25] they utilize the KAOS framework for goal-oriented requirements engineering to derive a system specification. To identify goals they suggest a top-down goal refinement approach by asking “how” questions. To understand what requirements are necessary to satisfy these goals, a bottom-up goal abstraction approach is recommended where “why” questions are asked. From these, different patterns are used to derive requirements for the model i.e. how different components in the model are to be connected. From these requirements, a specification of a system can be generated.

3.2 BI-specific approaches

Olexová [33] proposes a BI implementation life cycle which describes six phases a BI implementation project should progress through for successful implementation. The life cycle ranges from problem definition to maintenance of the BI solution. The purpose of the initial phase, problem definition, is to identify the current problem situation and how it produces a need for a BI solution but also to determine the scope and the objectives of the BI project. The feasibility study, phase two, examines the feasibility of the BI implementation project in terms of technical, economic and organizational feasibility. This includes ensuring that the organization has the capabilities needed for BI in terms of collecting, processing, and presenting data. The requirements engineering phase, the third phase, focus on collecting information about KPIs such as what data is needed to calculate the KPIs and how to calculate different measures. The fourth phase, the design phase, specifies the system design while the implementation phase, phase five, refers to building the new system. The last phase then focuses on maintenance in terms of correcting errors and modifying the system to meet the requirements.

A previous take on a BI implementation life cycle was done by Gangadharan and Sundaravalli [15]. Similar to Olexová [33], they emphasize the importance of evaluating KPIs in order to understand business drivers and information requirements. However, the life cycle as described by Gangadharan and Sundaravalli [15] begins with extracting information requirements by evaluating KPIs. They further suggest a phase comprised of understanding what BI is, why the organization would want to implement it, and what benefits can be expected, as a precondition to starting BI implementation projects. Lists of metrics describing the necessity of BI in an organization, aspects to consider before the implementation of BI, challenges that organizations often face when implementing BI, and indicators of BI infrastructure completeness and adequacy are described to aid practitioners in their implementation of BI.

A method for requirements elicitation and documentation for data mining in BI (DM-BI) is presented by Britos et al. [6]. The method describes a number of requirement problems that can be solved by making sure that certain concepts are derived and describes what information is necessary for successful requirements elicitation. It is comprised of a five-step process; understand the project's domain, know the project's data domain, understand the project's scope, identify the human resources needed, and select the correct tool. Understanding the project's domain relates to establishing communication channels among stakeholders. Knowing the data domain relates to establishing the project's requirements. Understanding the project scope relates to achieving project objectives and expectations. Identifying human resources needed relates to understanding restrictions, roles, and responsibilities for the specific human resources that are needed for the project. Lastly, selecting a tool is done with the help of the information acquired in the previous phases. The process also puts emphasis on making sure that there is no confusion in the language used between DM-BI groups and the party that is sponsoring the effort. This is something that is further emphasized in later work [29].

Mansilla et al. [29] propose a process for collecting requirements in information mining projects. The process is divided into three phases that are conducted prior to modeling, evaluating and deploying the information mining project. The first phase focus on understanding the language that is used in the organization and the output of the phase is a list of users to be interviewed and use case models. The second phase is to document concepts from business processes and how different business processes are related to each other. The output is a map of different concepts from business processes and their relations. The final phase decides what information mining processes can be employed to solve problems in the organization's business processes. The output of the final phase is a list of problems and an information mining process to be applied, and not requirements.

The business intelligence model (BIM) is a modeling language that translates the often data-oriented nature of BI into concepts such as business objectives, threats, and opportunities [21]. The benefit of this business model language approach is that data easily can be interpreted in terms of overall operation goals which managers can use to base decisions on since it borrows concepts from business-oriented languages and frameworks. The output of the BIM is a model, and hence not actual requirements. However, BIM models have been used as design blueprints for BI systems which suggest that requirements can be derived from it [3].

Burnay et al. [7] present a framework for RE in BI which aims to translate stakeholder expectations into BI requirements and how they can be operationalized in system specifications. The framework is goal-oriented, meaning that it aims to understand and analyze business goals to build a BI system that meets stakeholders' needs and expectations. It uses a graphical approach to model requirements with different entities of which some are borrowed from other similar goal-oriented approaches [39, 18, 21]. These entities are elements such as sources, schemas, fields, and indicators, and a requirement can require many different entities to be satisfied.

Chiasera et al. [10] write about approaches to privacy RE and how they relate to BI. The research does not explicitly describe a method for RE but rather discusses the importance of privacy in a data-intensive field such as BI. They describe how privacy can be specified on data at the moment that the data is provided by setting privacy constraints at the source level, at the warehouse level, and on report level. They state multiple ways for setting privacy constraints at the source level but does not describe an actual method for doing so. They instead suggest that modeling languages can be used or intensional associations between data and metadata. Defining privacy requirements at the warehouse level instead of the source level requires an understanding of data warehouse structures. One benefit of specifying privacy in the warehouse is that it is less complex since only the data that is extracted to the warehouse needs privacy specifications. Similar to RE at the source level, there is no expressed method for doing this. This also applies to RE on report level where the privacy constraints are set for the data presented in the actual reports.

3.3 Summary of related work

There are many methods and approaches to RE, both in BI and non domain-specific. Some are more detailed in describing how they should be used and what output they should produce while others are more abstract and discuss RE rather than giving a specific process. None of the methods or approaches are specifically designed to choose existing BI solutions, something that was an expressed need in industry and therefore needed further investigation.

4
Method

This section describes and argues for the research approach used to address the RQs of this study presented in Section 1.2. The research follows the design science methodology where the aim is to design and develop an artifact to study and evaluate in a specific context [40, 20]. The aim of design science is to both contribute to the social context in which the artifact is applied by solving a problem, and to the knowledge context by answering so-called knowledge questions which refine the knowledge context through iterations of the artifact [40].

The study was carried out in five phases set by the research team, see Figure 4.1. The rationale for breaking down the project into several phases was to make a design process that was easy to follow, evaluate, and replicate.

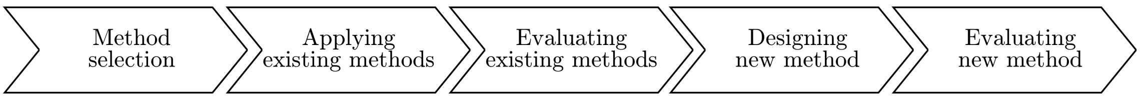

Figure 4.1: The five phases of the project and the order of which they were carried out.

The first phase, method selection, involved a thorough review of existing research literature (see Chapter 3) that aimed at finding the most suitable methods for the project. The selected existing RE in BI methods were then analyzed to ensure full understanding by the researchers. In the second phase, these methods were applied, where data was collected and used as input to produce requirements for the BI solution selection. This phase was the most time-consuming and comprehensive part of the project since it both concerned data collection and application of the methods. The third phase then focused on the analysis of the selected methods that were used to extract requirements. The purpose of the analysis was to identify lessons learned from applying the methods which were used as input into the design of the new method. In addition to this, the produced requirements from the three methods were validated and prioritized by the project steering group who consisted of case company employees. The fourth step was the design of the new method, i.e. the selection method for BI solutions, which namely was an empirical result of the prior three phases of the project. Lastly, the designed method was then evaluated in an interactive workshop together with the steering group of the project who gave feedback on the new method. Because of the extensive time required in the second phase of the design process, the researchers did not have time to do further iterations of evaluating and improving the artifact as is suggested in design science [40].

4.1 Method selection

The aim of the method selection phase was to select a number of existing RE methods suitable for BI from the approaches/methods presented in Chapter 3. To find relevant related work of existing methods, searches in the search engines Google Scholar and Scopus were made using key phrases such as ‘business intelligence requirements engineering’, ‘business intelligence requirements elicitation’, and ‘business intelligence implementation’. When selecting methods, the researchers focused on finding related work that was relevant for the field of RE, was published in recent years, had connections to BI (or was suitable for BI), and was easy to understand (e.g. a stated process or method for how to apply in practice). The researchers also looked for a diversity in the existing methods to see what lessons could be learned from different approaches to RE in BI. Due to the limited time, only three methods were selected and future research should consider a broader scope of methods/approaches. A summary of the verdict of the related work can be seen in Table 4.1. From the related work, the three methods that were selected to be applied in this research were the BI implementation life cycle [33], DM-BI requirements elicitation [6], and BIM [21]. Justification for the method selection is presented below.

The BI implementation life cycle [33] was utilized in this research (see Table 4.1) since it had been applied to a real case which made it intuitive and easy to understand. Hence, the output from each phase of the life cycle could be derived which was believed to support the design of the data collection in this study. The method also emphasized KPIs which made it further suitable to apply to the case company who expressed problems with their KPI reporting, and since KPIs are core elements in BI [19, 30]. It was therefore interesting to investigate whether the BI implementation life cycle could be useful for producing requirements based on KPIs for selecting among existing BI solutions.

DM-BI requirements elicitation by Britos et. al [6] was considered to be well suited for this research since the method aimed at producing requirements and since the publication of the method was well cited (63 citations). Further, it aimed to produce requirements specifically for the purpose of selecting a solution, an aim that was similar to a core part of this research. The format in which the method specifies and presents requirements was believed to be well suited for presenting requirements to the case company, and thus to enhance the validation process.

Applying goal modeling in this research was justified by previous work stating that such approaches were useful in requirements specification [10]. Therefore, one goal modeling language, the BIM [21] was adapted. The reasons for adapting the BIM were several. It was a significantly different approach to the other two adopted in this study [33, 6], allowing the researchers to gain an additional dimension to their lessons learned. It was a well-cited (123 citations) approach that has also been applied in practice [3]. The BIM was developed from a business perspective which made it more suitable than other goal-oriented approaches mentioned in Chapter 3 since the steering group at the company consisted of top-level management. In order for them to validate the output of this research, it had to be presented in an understandable format. Since the researchers wanted variation in the methods applied, no other goal-oriented approaches were adopted.

The related work that was not applied in this research was rejected either because it was not as current as other approaches, not considered useful specifically for the domain of BI, or not as complete and/or intuitive as selected methods, see Table 4.1.

Table 4.1: A summary of the selected and rejected related work.

Author	Method/Approach	Verdict
Lauesen[24]	Requirements template	Not BI-specific
Olexová[33]	BI implementation life cycle	BI-specific, intuitive, related to KPIs
Gangadharan & Sandaravalli[15]	BI life cycle	Not a recent publication
Britos et al.[6]	DM-BI requirements elicitation	BI-specific, purpose is selecting a solution, well cited
Mansilla et al.[29]	Requirements elicitation in information mining	Unclear process and output
Horkoff et al.[21]	Business intelligence model (BIM)	Method variety, well cited, suitable for management
Burnay et al.[7]	RE in BI framework	Few citations, too similar to BIM
Amyot et al.[1]	User requirements notation (URN)	Not BI-specific
Letier and Lamsweerde[25]	System goals requirements specification	Not BI-specific
Chiasera et al.[10]	Privacy requirements engineering	Too technical and no stated process.

4.2 Applying existing methods

In this phase of the research process the selected existing RE in BI methods were applied in parallel; the BI implementation life cycle [33], DM-BI requirements elicitation [6], and the BIM [21]. They were applied in parallel since their way of collecting data was carried out in the same way, namely through interviews and document analysis, and because time constraints did not allow them to be applied sequentially. The section begins with a description of how data was collected to be used as input in the methods and is then followed by an explanation of each method's execution.

4.2.1 Data collection

Semi-structured interviews were used as the main data source since none of the selected methods explicitly described how input data was collected but indicate that interviews are used [33, 6, 21]. Interviewing is an efficient way for researchers to understand the needs of an organization [5] and thereby gather necessary input data for the RE in BI methods applied in this study. This is also supported by Zowghi and Coulin [41] who state that interviews can support all phases of requirements elicitation. Semi-structured interviews is further an easy way to explore and understand the organization and the industry as a whole since interviews enhance the ability to derive insights together with important stakeholders as the project progresses [5]. In addition to interviews, document analysis was used which is also indicated by Olexová [33] as a useful way of collecting input data.

All data collected through interviews and documents was used as input into the three RE in BI methods, see Figure 4.3, Figure 4.4, and Figure 4.5. There was no guidance in what questions to ask or what areas to investigate when collecting data from the methods. Therefore, the researchers designed their interview templates (see Appendix A) based on the expected output from studying the methods since examples of output were given in the methods. Examples of output are risks, economic feasibility, goals, and objectives; all of which were examples of different output from different phases in the methods. All collected data was coded, structured and categorized as described in Section 4.2.2.

The semi-structured interviews were conducted in two rounds since input data for the three methods was to be found at different levels in the organization. Therefore, two interview templates were designed for different purposes; the first focusing more on collecting input data for the BI implementation life cycle and DM-BI requirements elicitation, and the second focusing more on collecting input data for the BIM, see interview templates in Appendix A. The interview template for the first round aimed at understanding the problem as well as needs, wishes, and objectives of the project. It further focused on risks, obstacles, constraints, and how information was transferred within the organization. The second then focused on overall goals, internal and external risks/obstacles, potential constraints, and what must be fulfilled in the organization to satisfy goals. Both interview templates included a number of questions that gave room for the interviewees' own interpretations so that they could provide answers based on those [4, 5].

Because of the different focuses of the two interview rounds, the interviewees differed between them. The first interview round required information from mills and middle management who worked more hands on with reporting, while the second round needed information from top management who explicitly could state the strategy and goals of the division. Table 4.2 and Table 4.3 list all interviews conducted in the the first and second interview round respectively. They specify the roles of the interviewees and the interviews' index. The column *Location* indicates where in the organization the interviewees belonged to; either division or mill level (mills are numbered 1-4). Results presented in Chapter 5 that originate from interviews refer to the interview indices in Table 4.2 and Table 4.3 to provide a clear chain of evidence.

Table 4.2: A summary of all interviews conducted in the first interview round. Each interview is assigned an index, a description of the interviewee's role, and a location.

Index	Interviewee role	Location
1	Head of Operations Controlling	Division
2	Business Information Officer	Division
3	Business Information Officer, Business Line Controller, VP Controlling	Division
4	Business Information Officer	Division
5	Mill Senior Specialist Local Applications	Mill #3
6	Operations Controller	Division
7	Director Operations Development, Quality and Operations Developer, Manager Local Application Services	Mill #1
8	Mill Controller	Mill #1
9	Head of Operations Controlling, Director Operations Developer	Division
10	Mill Controller, Operations Developer	Mill #2
11	Operations Developer, Senior Specialist Local Applications	Mill #2
12	Mill Controller	Mill #4
13	Production Manager, Production Controller	Mill #3

14	Senior Specialist Local Applications	Mill #3
15	Finance Manager and Mill Controller	Mill #3

As can be seen in Table 4.2 a total of 15 interviews were held in the first round with people from functions within controlling, business information office (IT), local applications (IT), production management and operations development. These were considered to be important stakeholders since they worked either directly or indirectly with reporting, and were primary users of the BI solution that was to be selected.

Table 4.3: A summary of all interviews conducted in the second interview round. Each interview is assigned an index, a description of the interviewee's role, and a location.

Index	Interviewee role	Location
16	Head of Operations Controlling	Division
17	SVP Operations	Division
18	SVP Controlling, Strategy and IT	Division

In the second round, three interviews were held in total with all relevant executives on division level. The interviewees were top managers within the Operations division who were responsible for the strategic planning for the division within the functions controlling and IT, as well as accountable for issues that typically concerned goals, threats and financials. Document analysis was further used to understand KPIs (as a part of the BI implementation life cycle) but also to provide input for the BIM from strategy documents.

4.2.2 Qualitative data analysis

Since a large amount of data was collected in the research project, it had to be analyzed in a structured way. Analysis of interview data is commonly done in three phases; data reduction, data recognition, and data representation [14]. *Data reduction* is the initial phase where data is distilled to find key elements and findings from it. In the *data reorganization* phase the researchers code and categorize the data according to themes found in it. In the final *data representation* phase, stories are developed that carry the main ideas of the analysis along with evidence to support it.

In this study, all interviews were summarized and key points were extracted after each interview. This can be seen as the data reduction phase [14] of the research, which was conducted continuously as interviews were conducted. The reasoning for doing data reduction directly after interviews was that the researchers assumed that learnings could be lost if the initial processing of the data was not done while the data was fresh in mind. Further, each set of interview notes was prefaced with a description of the setting, interviewee, and the purpose of the interview to give context to the data.

The next step was to code the interview data to find patterns in the data and perhaps reasons for those patterns' appearances [38]. In this research, the coding method used was *descriptive coding* as it is a generic and useful method for qualitative data analysis that is suitable for novice qualitative researchers. The coding process is conceptualized in Figure 4.2.

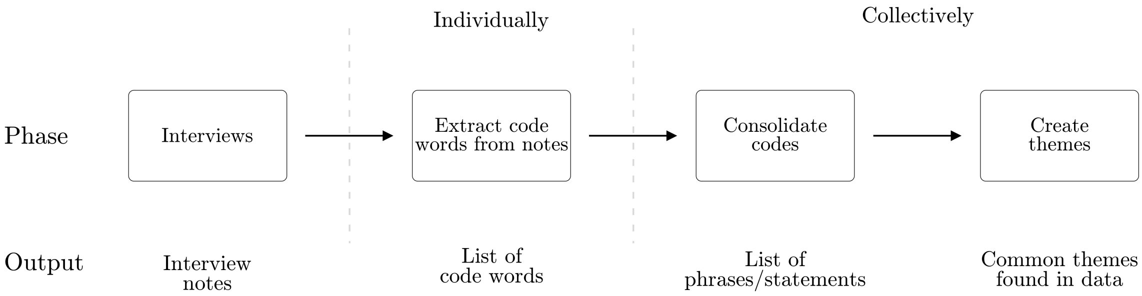

Figure 4.2: The process for coding interview notes into research data. Codes were firstly produced separately and then collectively summarized into a list of phrases/statements before being categorized into themes.

The first cycle of coding as described by Saldaña [38] resulted in a list of code words. Coding was done separately by both researchers which allowed for multiple points of view that could complement and be compared against each other. The code words were then utilized in a data representation step [14] in which the code words collectively were translated into a list of phrases/statements. This enhanced the requirement elicitation since the phrases/statements either could be used as input in some of the RE in BI methods or directly be translated into a requirement in other RE in BI methods. The codes were then categorized based on identified themes to organize them in a more structured way, see Appendix B. Lastly, columns for interview sources and count (number of unique interview sources) were added to provide support for each claim/finding/statement, giving a clear chain of evidence. New themes were identified for the second interview round that focused more on strategy and goals planning. The processes for deriving those themes were identical as for the first round. A complete representation of consolidated codes can be found in Appendix B. Since the interviews were designed for producing the needed input to the methods, the codes logically materialized in a way that allowed for them to be used easily and directly in the methods.

Document analysis was done similarly to the analysis of interview data. The documents analyzed were coded according to themes. The themes were predefined based on the expected output from the different methods' phases that required document analysis. The parts of the research that required document analysis were the requirements engineering phase in the BI implementation life cycle [33] and the BIM [21]. See themes from document analysis in Appendix B.

4.2.3 BI implementation life cycle

As described in Chapter 3, Olexová [33] proposes a process in six phases for successful BI implementation. The life cycle as a whole was outside of the scope of this research since the purpose of this research was to produce requirements and not design and implement a BI solution. The last three phases were therefore deemed to lie outside of the project scope but would be natural next steps for the organization at which the research was applied. The three initial phases (problem definition, feasibility study and requirements engineering) were however useful in producing requirements in this research. Figure 4.3 shows how the method was applied in this research.

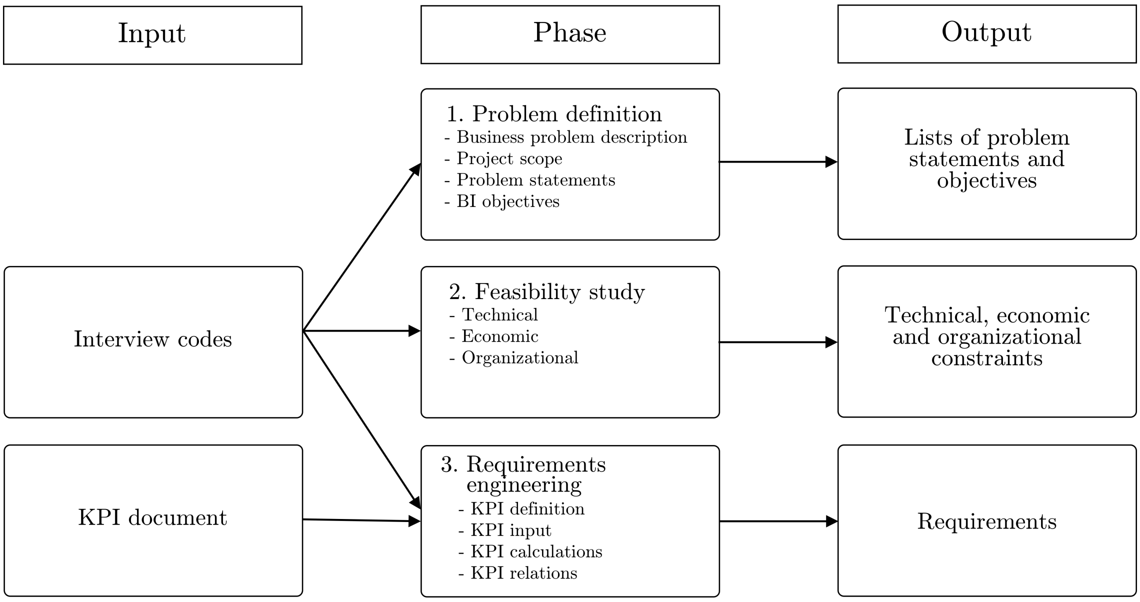

Figure 4.3: A schematic process of the BI implementation life cycle method, what data was used as input in each of the phases, and what each of the phases produced as output.

As can be seen in Figure 4.3, interview codes were used as input in all phases while KPI documents provided input data for the third step. The outcome from the three phases were lists of problem statements and objectives (see result in Section 5.1.1), feasibility in terms of technical, economic, and organizational constraints (see result in Section 5.1.2) and a list of requirements (result in Section 5.1.3). Each phase is described in more detail below.

The initial step of the BI implementation life cycle, *problem definition*, was to set the scope of the project and define the initial description of the business problem [33]. This was done in collaboration with the company through interviews to ensure that the scope did neither become too wide nor too niched. To do this, the first interview round focused on understanding the problem the organization was facing and what they wanted to achieve with a BI solution. The outcome from this process was a number of problem statements which described the current situation, a direction and/or limitations for the project and some general objectives for the BI solution based on the initial description of the business problem. When defining this, it was important to consider the limited time frame of this project.

To generate problem statements and objectives, the coded interview data was analyzed by the researches and those that could be identified as either problems or objectives were presented to the steering group (presented in Section 1.3). A workshop was held with the project steering group to validate the accuracy of the findings. All participants were asked to comment on each problem statement and objective (see Appendix C) to verify the correctness of it and prioritize it based on the participants' interests and needs. Those that were prioritized from Appendix C are presented in Section 5.1.1. Thereafter, each prioritized problem statement was mapped to one or more objectives to make sure that it was covered.

The next step, the *feasibility study*, examined the feasibility of the project in terms of technical, economic, and organizational factors. To determine the technical feasibility, IT functions at both division and mills were interviewed to ensure that their systems were compatible with a potential BI solution. To decide the economic feasibility, managers were interviewed to provide answers on possible constraints that prevented them from using any BI solutions. The purpose was to find evidence of any budget restrictions or cultural issues that might restrain the organization from using a specific BI solution. The organizational feasibility was derived from interviews.

Another part of the feasibility study was to select a BI solution. The selection in this study was done after all requirements had been produced from the RE in BI methods. The purpose of this research was to produce requirements to use in a solution selection. Therefore, the selection was not made in this phase but instead after the requirements engineering phase.

For the third step of the BI implementation cycle, *requirements engineering*, Olexová [33] proposes a comprehensive analysis of KPIs. The KPI analysis should include definitions, calculations, input data and how the KPI affect or influence other KPIs that measure company performance. It should further include a specification of the intended report users and report periodicity for KPI reports. This study was delimited to the Operations division and thereby the Operations' KPIs. Olexová [33] does not state how to go from KPI information to requirements. In this case, the organization had detailed KPI documents that contained all the necessary information that was needed according to the method. The KPI documents were analyzed by the researchers to identify the exact input data and what data was needed for the different calculations and measures. Interviews with mill controllers, IT and managers were further necessary to identify report users, periodicity and the KPIs effect on other KPIs.

To produce actual requirements from the KPI analysis, information on the form specified by Olexova [33], i.e. KPI definition, needed input data, how they are calculated, and how they relate to other KPIs, was first summarized. The summaries can be found in Appendix C. From these KPI summaries, requirements were identified individually by the researchers and then discussed among the researchers to allow for multiple points of view. The requirements were produced based on the needs for calculations, the different report users and the periodicity of reports. It was important to also consider the findings from the prior steps since they laid the foundation for the third step and provided more descriptive insights about the problem situation as a whole. The produced requirements is presented in Section 5.1.3.

4.2.4 DM-BI requirements elicitation

The DM-BI requirements elicitation method by Britos et al. [6] presents a five-step process, where only the two first steps were needed to produce requirements. Therefore, only these two steps; *understand the project's domain* and *know the project's data domain* were applied in this research. The three following steps in DM-BI requirements elicitation were not applied because they neither improved the requirements from the first two steps nor produced new requirements.

The purpose of the initial step, *understand the project's domain*, is to establish communication channels and define common abbreviations and acronyms related to the project [6]. The second step, *know the project's data domain*, aims at establishing the project's requirements in terms of requirement goals (RGs), requirement restrictions (RRs), requirement risks and contingencies (RCs) and requirement result suppositions (RSs) [6]. Figure 4.4 presents the input for each of the steps applied from DM-BI, and the output from them.

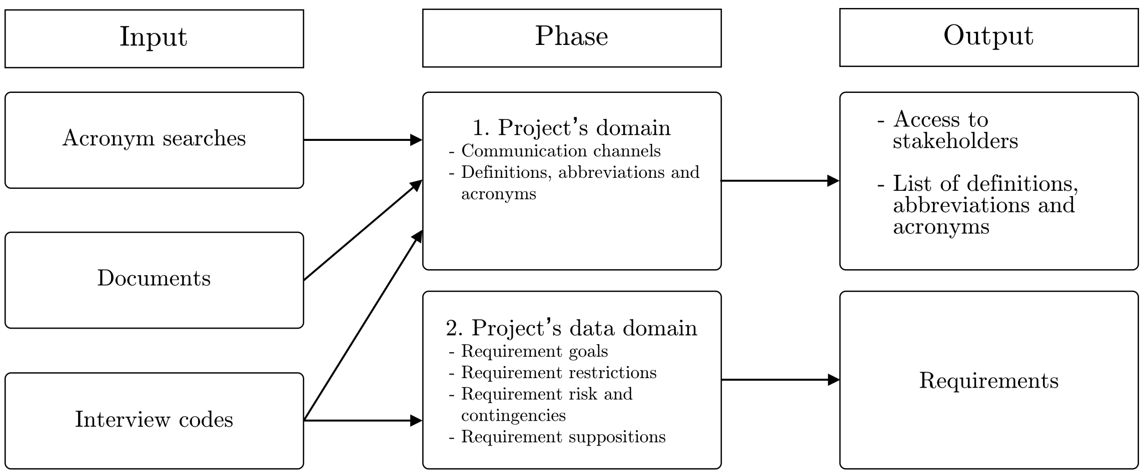

Figure 4.4: A schematic process of the DM-BI requirements elicitation method and what data was used as input in each of the phases, and what each of the phases produced as output.

Figure 4.4 shows that acronym searches, documents, and interview codes were used as input in the first step of the process, resulting in a list of definitions, abbreviations, and acronyms. The first step also secured communication channels with key stakeholders. To produce requirements in the second step, interview codes were used as data input for RGs, RRs, RCs, and RSs. *Acronym searches* in the figure refer to searches in search engines by the researchers to understand abbreviations used within the organization. These were identified, defined, and verified by the researchers together with the key stakeholders who had to confirm that the researchers had understood the concepts correctly. *Documents* here does not refer to document analysis but instead means that internal documents were studied to find definitions for specific terms, acronyms, and abbreviations. *Interview codes* are described in Figure 4.2.

Definitions, abbreviations, and acronyms were defined in the initial step. The result from this first step is presented in Appendix D. The coded data from the first interview round, acronym searches and document analysis laid the foundation for the project domain.

The second step, *know the project's data domain*, established RGs, RRs, RCs and RSs. RGs can be translated into objectives that are criteria for evaluation of the BI solution to be implemented; RRs define restrictions that might hinder or limit the RGs to be achieved; RCs identify the risks of the RGs and how these can be mitigated; and RSs are assumptions of what has to be either available or fulfilled in order to satisfy the RGs. This implied that all RRs, RCs, and RSs had an impact on and related to the RGs.

To specify the requirements, Britos et al. [6] suggest that the four above requirement dimensions are structured in tables and interlinked with one another. Each RG is thereby related to a number of RRs, RCs, and RSs. The templates for the requirement tables, see Section 5.2.2, were uniquely designed for this research for improved readability. The design was based on examples provided in the research by Britos et al. [6]. Each row in the tables is considered to be a requirement. To produce the requirements (formulated as RGs, RRs, RCs, and RSs), the interview codes were analyzed by the researchers, individually and then collectively, to allow for different points of view. Those that were identified as goals (objectives) were included in the RGs template. The template specifies unique requirements indices, requirement goal descriptions, and the interview sources that supported the statement. For the other three requirement dimensions; RRs, RCs, and RSs, requirements were derived from interview codes or based on the researchers' judgments. Each requirement within any of these three dimensions was supposed to relate to a requirement goal in the RG table. The principle of linking requirements together is presented in Figure 5.1. The template for these dimensions includes unique requirements indices, requirements descriptions and how they relate to RGs. See the result in Section 5.2.2. Since the interviews were formulated with the purpose of extracting the input data needed for the methods, the resulting codes could be designated to a specific requirement dimension. The interview codes were reformulated to be full sentences for the purpose of making them easier to read. The relations between RRs, RCs, and RSs to RGs could be derived intuitively by the researchers.

4.2.5 Business intelligence model

The process of building the BIM model and extracting requirements from it is shown in Figure 4.5. The process began with coding data from the second interview round from which the model could be built. The model was then validated with the interviewees from the second interview round. Lastly, requirements were extracted using patterns described later in this section.

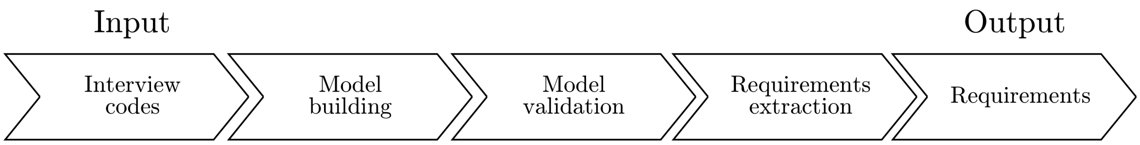

Figure 4.5: The process for producing requirements from the BIM.

BIM is, as mentioned in Chapter 3, a modeling language that translates data into business objectives, threats, and opportunities. The purpose of the BIM methodology is to create a conceptual strategic model of the organization [3]. The concepts of the BIM are goals, situations, processes, domain assumptions and indicators, which are connected by either a refinement (relation) or influence [3, 21, 22], see Figure 4.6. Refinements are links (represented with solid lines in the model) that are defined as AND or OR, while influences are dashed lines marked with weights that define the strength/weakness of the influence one component has on another component. These are described in further detail below as each component and their links are presented.

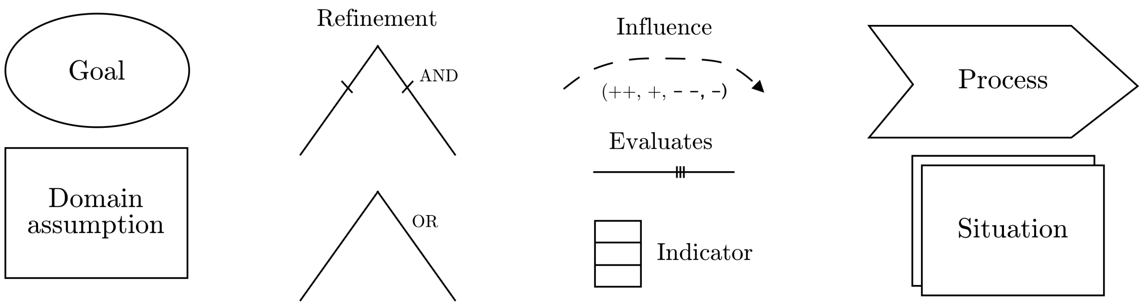

Figure 4.6: The components of the BIM.

Goals can be translated into business objectives and can be broken down into subgoals which have to be satisfied to reach the overall goal. Goals that are OR-refined can be satisfied by each of its subgoals, i.e. in multiple ways, while an AND-refinement indicates that all subgoals must be satisfied in order for the overall goal to be fulfilled [21]. A goal break-down can also be divided into a *process* which achieves the goal under the circumstances that its *domain assumption* is true (properties required to satisfy a goal). Processes and domain assumptions were identified from document analysis and interview codes, see the interview template in Appendix A.

Indicators are associated with goals and processes. Goals give the "why" dimension and processes give the "what" dimension to indicators [21, 3]. In this research, the indicators could directly be derived from the KPI documents and included in the model.

Situations refer to internal and external factors that either have favorable (represented with '+') or unfavorable (represented with '-') influence on the satisfaction of a goal. Situations should impact business objectives, i.e. organizational situations [22]. In this research, situations were identified from document analysis and interview codes. Documentation that was analyzed were activity plans, goal plans, and strategy documents. The *influences* (dashed lines) between the components are marked with weighted qualitative values to indicate whether their impact was '++' (strong positive), '+' (weak positive), '- -' (strong negative), or '-' (weak negative) [21]. Influences were described by the interviewees, which according to Barone et al. [3] is suitable since they can be regarded as domain experts. In the modeling as described by Horkoff et al. [21] influences can also be probabilistic, which defines the probability of goal satisfaction. These were however not included in this research since it would require a comprehensive market analysis which was beyond the scope and delimitations of this research.

Modelling

To build the model, a "bottom-up"-approach was used where indicators and processes were starting-points from which goals were extracted [21]. To extract the goals the interviews in the second round focused more on long-term strategic issues as well as on the interdependencies among KPIs in order to derive what processes and domain assumptions that were necessary to satisfy the goals. The researchers identified the main targets from the company's strategy. One was set as the main goal that formed the origin of the model. OR-refined subgoals were then derived based on the document analysis. These subgoals were then in turn further broken down into either two subgoals or a process and a domain assumption. Following that, indicators could be connected to the goals they assessed and situations could be connected to the goals and domain assumptions they influenced.

While the BI implementation life cycle and DM-BI could derive requirements directly from interview codes and document analysis, the BIM derived a model from that data instead. From the resulting model, there was no intuitive way to directly produce requirements as done with other methods. Because of this, the researchers had to develop a structured approach to extracting requirements from that model. Literature exist that describes how goal models (i* goal models specifically) can be translated into textual requirements [28]. This was done by applying patterns that take a concept or a dependency/relationship in an i* model and translates it into a textual requirement on a standardized form. Maiden et al. [28] developed a Strategic Dependency (SD) model, which is a type of i* model, that contains a network of actors and how they depend on each other. From this model, the patterns applied generated textual requirements from the dependencies that for example could look like the functional requirement: *FR: The actor 'A' shall receive the resource 'R'* *from the actor 'B'*. Using this pattern approach on an i* model generated at least one functional requirement per element in the model [32].

Model validation
In this research, a similar approach was taken inspired by Maiden et al. [28]. The first step was to validate the BIM, something that should be done before trying to extract textual requirements from it [32]. The model was validated by all stakeholders from the second interview round. In order to validate the model, the researchers first explained the BIM language and how the model should be read. The executives could thereafter comment on the accuracy and validity of the model. Once validated, the researchers applied a set of patterns to extract textual requirements form the BIM.

Requirements extraction
Goals in i* models are easy to translate into requirements as they are expressed as goals for the system [27]. In the BIM however, the goals are business oriented, e.g. *increase sales*, which made it harder to directly translate them into textual requirements. The goals from the BIM were in this research, therefore, translated into requirements on the data that needed to be available to present progress in that goal. For example, if the goal was to *increase sales*, then the BI solution needed to have access to sales data. Two other patterns were applied to goals as well; the first indicated that trends for the 'goal' data should be able to be presented and the second indicated that target data for the 'goal' should also be available alongside data on actual performance.

As for relationships in the BIM model, different patterns were used. If a goal had been broken down into separate subgoals, textual requirements on the dependency between goal and subgoal were extracted. For example, if data relating to the parent goal was presented, then a BI solution should allow a user to separate that data into the data that was related to the subgoals. Examples of this can be seen in Figure 4.7.

Processes in the BIM were not translated into requirements. The reasoning behind this was that processes to reach goals are part of an organization's strategic plans and not something that a BI solution can support. For example, a process like *develop a new technology* could not in a reasonable way be translated into a requirement for a BI solution by the researchers.

Domain assumptions in the BIM model were handled in two ways. If the domain assumption existed as a sub-component of a goal, the domain assumption was translated similarly to how goals were translated, i.e. a requirement stating what data was needed to represent that domain assumption. Domain assumptions relating to a process were not translated into requirements as they were conditional statements that had to be true for that process to be plausible. As such, this had more to do with strategic planning than reporting through a BI solution. Like goals and domain assumptions, situations in the BIM were translated into data requirements.

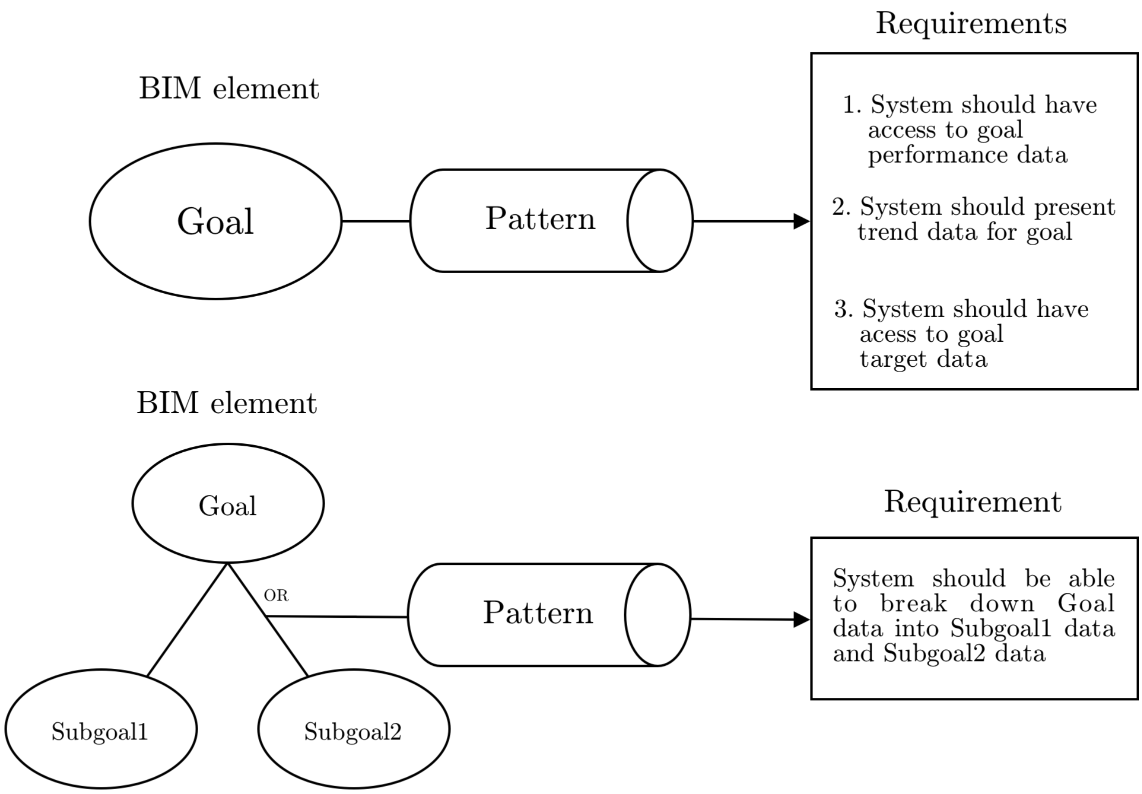

Figure 4.7: Examples of patterns applied to the BIM elements to produce requirements.

Influences in BIM did not explain a strictly quantifiable relation between the concepts they connected. Therefore, they could not be translated into requirements as dependencies between goals and subgoals. Instead they were translated into requirements related to scenario-building with a BI solution. For example, if the goal to *reduce cost* had a weak positive (+) influence on the goal *maintain gross margin*, the requirement would read *changes in cost data shall impose a change in gross margin data of magnitude 'X'* where 'X' would vary depending on the strength of the influence. In this research 'X' is replaced by the strength of the influence (++, +, - -, -).

4.3 Evaluating existing methods

After having finished applying the RE in BI methods, the results (i.e. requirements) were studied. Based on the RQs formulated in Section 1.2, the analysis of the methods was done from two perspectives. First, the requirements produced were validated in order to see how well they supported selecting a BI solution. The second perspective was to derive lessons learned from applying the methods in parallel.

4.3.1 Requirements validation and prioritization

Before proceeding to the BI solution selection, the researchers had to validate the generated requirements with the company to make sure that the selection was based on actual needs. To do this, all requirements produced from the three methods were presented to them during a meeting. The members of the steering group could during the meeting either accept or reject the requirements.

After validating the requirements, the accepted requirements were prioritized in a grading survey which was sent out to the steering group members who filled it in individually. The accepted requirements were graded by all members of the steering group on a scale from 1 to 5. A grade of 1 signified that the requirements had low priority for that particular stakeholder while a grade of 5 indicated a high priority. When all members of the steering group had filled out the survey, averages of grades for every requirements were calculated. These averages were used to determine what requirements should be considered when selecting a BI solution. Requirements with an average grade above 3.0 were used in the selection. This criteria was set to make sure that only requirements that were deemed important by stakeholders were used in the selection.

4.3.2 BI solution selection

The resulting requirements from the validation and prioritization were then used to compare and select among existing BI solutions. To be able to check if the produced requirements could be met by existing BI solutions, the solutions' product specifications were analyzed along with peer reviews to get users' perspective of the solutions as well. To select BI solutions to analyze, the market was scanned with help of Gartner's peer insights review [17]. It included several reviews by peers who recently had undertaken BI implementation projects and provided their thoughts on the implementation and deployment of the BI solutions, and the BI solution itself. Therefore, it was considered to be a reliable source.

The peer review reports cover over 90 different existing BI solutions that have been compared and rated by users. To reduce the number of BI solutions to include in this study, three criteria were set by the researchers; i) only reviews from the last 12 months, since newer versions from BI solution vendors were frequently released, ii) at least 200 peer reviewers were necessary to find credible proof of its value, and iii) reviews written by peers at companies that were similar to the case company in terms of turnover. See the result of applying these criteria in Section 5.4.2

To determine if the resulting BI solutions met the requirements produced from applying the different RE in BI methods, an evaluation template was set up. The template listed all requirements (by their indices) with one column for each of the resulting BI solutions. If a requirement was applicable and fulfilled by a specific solution, the researchers marked the cell for that requirement row with an 'X', see Table 5.12. If a requirement was not applicable, it was marked with 'N/A'. This was done after studying specifications and peer reviews of the BI solutions.

4.3.3 Lessons learned

After the three methods had been applied, the researchers analyzed the whole process of applying them in parallel based on the researchers their own experiences. Peffers et al. [35] suggest that researchers can validate or evaluate their research through ad hoc arguments, which is why the assessment was based on the researcher's experience from applying them in parallel. As a first step, the researchers had to individually state their impressions and lessons learned from applying the methods in parallel. To enhance the evaluation process, questions like *"What outcome was most valuable?"*, *"Was anything missing in the process?"* and, *"Could anything have been improved or done differently?"* was written down to guide the researchers in their assessment. These questions were derived from the RQs to support the researchers in both evaluating the process of applying three existing methods in parallel, but also to support the design of the new method. Each lesson learned was then written down individually on a post-it and thereafter presented to the other researcher. If there was a disagreement in a lesson learned, it was discussed and validated to be either accepted, rejected or reformulated. By doing so, multiple points of view were taken into account in the evaluation and validation process. Finally, the lessons learned were categorized according to themes that could be identified as they were presented among the researchers, see the result in Section 5.4.3.

4.4 Designing new method

To design a new method the researchers drew inspiration from multiple sources, see Figure 4.8. The lessons learned from applying existing methods in parallel were assessed to see which elements of the methods were useful and for what purposes their were useful for based on the researchers' experiences. Lessons learned within the theme *Additions* (see Table 5.13) could directly be included as elements in the new method. The elements within the other themes with an output that were deemed useful were also considered in the design of the new method.

After deciding what elements from existing methods to include, the researchers identified knowledge gaps, step two in Figure 4.8. These knowledge gaps were pieces of information that would have improved the quality of the recommendation of a BI solution. These are presented in Appendix G as a suggestion for future applications of the new method to aid in data collection. These were also included as an appendix to the new method to support future application. To identify these knowledge gaps the researchers assessed the lessons learned and analyzed peer reviews and product specifications of BI solutions on the market. This was done to be able to give guidance in what information is necessary to gather to produce requirements that better fulfill the purpose of selecting a BI solution.

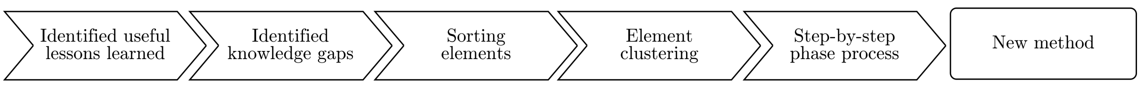

Figure 4.8: The design process for developing the new method.

Thirdly, when all elements of the new method had been identified, the order in which they should be addressed was determined. The researchers set up a timeline on which they placed all the elements according to a logical order of execution. For example, requirements need to be formulated before making a selection. After having placed the elements in chronological order, the elements were clustered (step four in Figure 4.8) into separate phases to improve readability and usability, similar to the existing methods that were applied in this research. The elements were clustered based on their outcomes, e.g. elements producing feasibility criteria could be included in the same phase.

Lastly, to justify the new method and make it understandable and actionable, the researchers answered three questions per phase; *why* is this phase necessary, *what* is this phase producing, and *how* is this phase done. This resulted in the new method as seen in Figure 4.8.

4.5 Evaluating new method

To evaluate the new method a workshop was held with the project steering group (presented in Section 1.3). In the workshop the following questions were asked:

1. Can you understand the method?
2. Can you understand the purpose of the method?
3. Would the organization be able to use this method?
4. How long do you estimate that the suggested method will take to complete?
5. Can the steering group asses the requirements elicitation concepts from Appendix G?
    (a) If not, who can?
6. For each phase, is it clear what is supposed to be input and output?
7. For each phase, is anything missing?
8. For each phase, is anything redundant?
9. Are there any phases that are missing or redundant?
10. Would the outcome have been different if this method had been used?

The questions were derived from the researchers' experience of studying and applying the three existing methods. For example, Q6 was derived from the lessons learned from studying the existing methods which not explicitly described the input needed for each phase. The purpose of the questions was to understand how the steering group perceived the method as a whole as well as the phases individually. By doing so, they could indicate how they could benefit from the method but also how it could be improved to serve their needs better.

The steering group were asked because they were the ones who had responsibility for the BI effort at the company and therefore were representatives of a potential BI team at another company that are planning on applying the new method. The steering group were also BI advisors over the course of this research which provided them with insights in the project which allowed them to give more detailed feedback.

5

Results

The chapter begins with the results from the three applied methods starting with the BI implementation life-cycle, followed by DM-BI requirements elicitation, and then BIM. Following that, results from the validation workshop, where requirements produced from the methods were validated and prioritized, are presented together with the results from the solution selection and lessons learned from applying the methods in parallel. Lastly, the developed new method for RE when selecting an existing BI solution is presented followed by the results from the evaluation of it.

5.1 BI implementation life-cycle

The results from following the BI implementation life cycle by Olexová [33] are presented according to the method's phases.

5.1.1 Problem definition

The problem definition phase described the initial business problem and the scope as well as produced problem statements and objectives.

Initial description of the business problem
Data from the first interview round provided information for the initial description of the business problem. There was no standardized or unified reporting culture in the company which led to mill-specific reports designed for individual mill's needs. This caused problems on division level in the organization as information from mills was incoherent. This made it hard to assess an overview picture of how the organization was performing. When managers inquired about the state of operations at mills they received answers and static reports that were not comparable to each other. Further, information was not delivered in a timely manner. When information regarding deviations in performance reached division-level managers, there was a risk that the cause of the deviation had occurred a long time ahead. Investigating deviations and what caused them was not possible with the information provided on division-level.

Project scope
The scope of this project, resulting from the problem definition phase in the BI implementation life-cycle, concerned the internal reporting and follow-up of KPIs that were central for Operations and represented Operation's performance. This

in turn, made the KPIs significant for both mill and division management as they indicated production losses, quality measures, and financial results. The project was undertaken by one of the organization's divisions and concerned only the Operations department. The division had five mills of which four were included in this project. These four mills were all located in Europe.

Problem statements

Initially, 15 separate problem statements were formulated based on the interview codes, all of which were supported by at least two interview sources. A condensed list of the six prioritized problem statements from the validation workshop (see Appendix C) is shown in Table 5.1. The problems were expressed by the interviewees in the Source column. The indexes in the Source column refer to Table 4.2. For a complete list of problem statements, see Appendix C.

Table 5.1: A summary of all confirmed and prioritized problem statements with information about who claimed or supported the problem statement (interview source).

#	Problem	Interview source
1	Information transparency	3, 6, 7, 10, 13, 14, 15
2	Large manual reporting workload	3, 4, 5, 7, 8, 9, 11, 13, 15
3	Inconsistent reporting	1, 2, 3, 8, 9, 15
4	Unclear report ownership	1, 2, 5, 10, 11, 12, 13, 14
5	Unclear data ownership	1, 2, 5, 10, 11, 12, 13, 14
6	No clarity in information needs	3, 7, 9, 10, 11, 13, 15
7	Data validation	3, 7, 9, 11, 12, 14, 15

The problem statement confirmed by most interviewees, nine in total, was the amount of manual work that was required in tasks connected to reporting (problem statement 2). This manual work included manual preparation of data by extracting data to excel sheets and in turn sending those sheets as static reports to division-level management. It also included work required to adjust underlying logic in existing reporting systems. Whenever changes in KPI definitions occurred, manual work to correct the definitions in the existing reporting systems was required for every report that measured that specific KPI. Another source of manual work was the building of reports either in excel sheets or other existing systems. This was due to the fact that reports were very niched to specific use cases which meant that many reports were created, often without a clear definition of the value it should deliver.

The problem statements expressed second to most times, eight in total, was problem statement 4 and 5; *unclear report ownership* and *unclear data ownership*. As stated above, many reports were created for niche use cases. These rarely had clear owners which meant that no one had the responsibility to make sure that reports held the information that the recipients of the reports needed and that there was no assigned owner for making sure that the information was correct. It also meant that there were no report specification or management of report specifications as no one had ownership of that responsibility. The issue with data ownership related to the fact that no one was responsible for making sure that the data provided to the reports was correct and valid. This meant that even if the reports themselves were designed well they would not be reliable since the underlying data had not been validated.

Problem statement 1, *information transparency*, indicated that there were issues with the accessibility of information in the organization. Information concerning the Operations KPIs was not distributed to all functions of the organization to a satisfactory degree. Access to the information in a digestible format was limited to users with licenses to software used for visualization of information. This led to some functions, such as machine operators and some decision-makers, not being able to understand the current situation of Operations performance which in turn made it hard to do improvement efforts.

Inconsistent reporting (problem statement 3) was a problem mainly expressed by interviewees on division level. To get a clear picture of how the division as a whole was performing and to be able to benchmark and compare mills, information from all mills had to be somewhat standardized. All mills sent information to division level on different formats making it hard for division management to compare and benchmark.

Related to problem statement 3 was problem statement 6, *no clarity in information needs*. One of the underlying reasons to inconsistent reporting from mills was the lack of a specification from the division in terms of what information was needed for the KPIs. Mills expressed that they probably did not lack data to generate the needed information but rather that they did not know what information was needed.

Problem statement 7, *data validation*, specified the issue of having data of low quality. Low quality data in this case referred to data about incidents/events that did not have an incident code specified, i.e. the data was said to be uncoded. This data was collected in real-time by production machines and was coded both automatically and manually by machine operators. Therefore, the data used to present the Operations KPIs could be categorized as uncoded (which was considered to be low quality data). This meant that the root causes to the KPI figures were unknown and efforts to mitigate them could not be initiated. Further, the quality of the data risked being compromised with all the manual extraction of data from different existing systems. This could lead to the wrong data ending up in reports and thereby compromising the quality and integrity of that report.

Objectives

Objectives for the BI project were also produced from the interview codes. The objectives confirmed in the validation workshop are presented in Table 5.2. For a list of all objectives, i.e. objectives before prioritizing and scoping down in the workshop, see Appendix C. In Table 5.2 the column *Relation to problem statement* shows the problem statement that the objective aimed to solve. As can be seen in the table, all problem statements related to at least one objective.

Table 5.2: A summary of all confirmed objectives with information about who claimed or supported the problem statement (interview source).

#	**Objective**	**Interview source**	**Relation to problem statement**
1	Reporting should improve Operations performance	1, 5, 8, 9, 10, 13, 15	Problem statement 1
2	Visualize data to identify situation	1, 5, 6, 9, 10, 13, 14, 15	Problem statement 1
3	Visualize data to perform root cause analysis	6, 9, 10, 13, 14, 15	Problem statement 1
4	Specification of report detail needs	5, 6, 7, 11, 13, 14, 15	Problem statement 6, Problem statement 3
5	Reduce manual reporting work	3, 4, 5, 7, 8, 9, 11, 13, 15	Problem statement 2
6	Transparent information-sharing	3, 6, 7, 10, 13, 14, 15	Problem statement 1
7	Prioritize improvement efforts based on reports	6, 8, 9, 10, 13, 15	Problem statement 7
8	Ownership structures	1, 2, 5, 10, 11, 12, 13, 14	Problem statement 4, Problem statement 5, Problem statement 7
9	User-friendly reporting systems	1, 7, 10, 11, 12, 13, 14	Problem statement 2

The purpose of reporting in a BI solution was to improve performance in day-to-day operations so that costs could be reduced and profits increased. This was expressed in objective 1 which indicated that a BI solution should support reporting primarily for mill management and operators, and not division management. Thereby it was connected to the problem of lack of information transparency, since reporting should support all levels in the organization.

Objective 2 also mitigated the lack of information transparency and stated that data should be visualized so that employees could easily understand the current Operations performance situation. This meant clean and easily interpreted interfaces that could be used efficiently by shop floor employees as well as division and mill management.

Objective 3 further mitigated the lack of information transparency and stated that data should be visualized so that one could derive why the current operations performance situation is what it is, i.e. root cause analysis. This connects to objective 7, *prioritize improvement efforts based on reports.* By being able to understand what incidents were causing the biggest problem in production, mill management and operations developers could make better decisions regarding where to put in efforts for biggest return.

Project objective 4 indicated the need for a specification of information needs from all levels of the organization. Reporting through a BI solution should support appropriate information presentation at all organization levels. This objective tied to problem statement 6 and 3, *no clarity in information needs* and *inconsistent reporting.*

Reporting should be able to be automated to a great extent in terms of data preparation, data extraction, and report building. It should also allow multiple stakeholders with different information needs to find their desired information in the same reports. This was formulated as objective 5, *reduce manual reporting work*, which logically tied to problem statement 2.

Objective 6 related to problem statement 1, *information transparency*, and indicated that information should be accessible throughout the organization vertically. This meant that information about one mill should be available from the shop floor employees of that mill up to division management. The organization expressed a need for a BI solution that could be accessed from multiple platforms. For example, shop floor employees needed to be able to use mobile devices to access reports. There was no expressed need for horizontal information transparency between mills regarding specific mill's information.

The organization needed defined structures for ownership to make sure that reports contained the right data and that the data was correct. This to ensure that no decisions were based on wrongful information. This was expressed in objective 7 which was defined to mitigate problem statement 4 and 5.

Objective 8, *user-friendly reporting systems*, implied that since the BI solution was intended to be used by several functions with varying IT capabilities, the BI solution needed to be easy and intuitive to use so that it did not put an additional burden on IT support departments. This objective should mitigate problem statement 2 as the previously used inflexible systems resulted in a large manual workload.

5.1.2 Feasibility study

The technical feasibility of a BI solution was derived from interviews. No single mill had a data warehouse for the purpose of extracting data about the different Operations KPI. However, the organization had a large amount of data available. This made certain BI solutions less suitable as a BI solution needed to be able to connect to a multitude of data sources if it were to be used without needing investments in data warehouses and OLAP cubes. The organization had wishes of developing necessary data warehouses and OLAP cubes in the future. Until then, they wanted to leverage BI solutions that could present their data without having those data sources in place. The feasibility study further showed that there were no major constraints in the current IT infrastructure on neither division nor mill level. All mills but one used the same production system to collect production data. The mill not using that system collected and stored their data in a similar way making all mills comparable. All data that was necessary to calculate the KPIs that the BI solution should present could be collected with the current infrastructure. However, data could not directly be used in reports but required cleaning, reformatting, and restructuring before. This depended on the IT human resources available which was somewhat constrained. Other than that, the key IT employees saw no constraints from a technical point of view.

As for economic feasibility, top management had not set any budget for a BI solution but were not reluctant to implement a solution if it was proven useful. However, this did make cost something to consider closely as purchasing or subscribing to a BI solution would imply that funds had to be taken from another budget post.

The third aspect of the feasibility study, organizational feasibility, revealed that there were no big obstacles from an organizational point of view. All interviewees conveyed positive attitudes and expressed needs for a BI solution. Some interviewees warned that large organizations might display aspects of change aversion but this was not seen as a threat to feasibility considering the positive attitude towards the project both on mill and division level. A possible threat to the feasibility of adopting a division-wide BI solution was that mills were quite independent and found their own ways of working which made it harder to standardize. This put emphasis on the need for an increased information sharing culture among all mills in the division.

The feasibility study further showed that the company had large investments in an Azure technology stack by Microsoft. The subscriptions they had allowed them to use Microsoft's BI solution Power BI without adding to their subscription fees. Employees at the company were also familiar with the interfaces of Microsoft software. This implied that the organizational and economic feasibility was biased towards choosing that solution.

5.1.3 Requirements engineering

As stated in Section 4.2.3, KPI documents were analyzed to extract requirements. The document analysis was done as described in Section 4.2.2 and resulted in KPI summaries, see Appendix C. From these summarized KPI descriptions requirements were extracted, see Table 5.3.

Table 5.3: Requirements produced based on the summarized KPI documents in Appendix C.

Index	Requirement
R1	Should support performing basic arithmetic (addition, subtraction, division, multiplication)
R2	Simulate how changes in a KPI affect values in other KPIs
R3	Availability on multiple platforms, i.e. mobile and desktop
R4	Reports must be accessible to all users
R5	Should support filtering data for different time bases (e.g. days, months, years)
R6	Should support filtering data for detail level (e.g. see only total KPI figures or details in underlying data)
R7	Should support external and internal reporting
R8	Reports should be available online
R9	Visualize actual performance against target performance

The requirements engineering phase resulted in nine requirements. R1 was based on the calculations that were described in the KPI documents. These needed to be supported in the BI solution. R2 was based on the effect that a KPI had on other KPIs in order to get a clear understanding of the organization as a whole. R3-R6 were based on the variety of users of a new BI solution. These users worked in different functions with different access to devices, with different needs of information and different frequency needs. R7-R9 were derived directly from the KPI documents.

5.2 DM-BI requirements elicitation

This section presents the results from the two phases applied in the DM-BI requirements elicitation.

5.2.1 Understand the project's domain

Initially, communication channels were set up which consisted of a steering group with representatives from controlling, business information office (IT), operations development, and business development, see Section 1.3. Communication within the group was done in person and over Skype. Members of the steering group had an extensive network in the organization which allowed access to other key stakeholders within the division. Meetings and interviews with mill representatives were done both on-site at mills and via Skype.

Definitions, acronyms, and abbreviations related to the domain of the project were derived and documented. Some examples are shown in Table 5.4. See Appendix D for a complete list of definitions, acronyms, and abbreviations.

Table 5.4: Examples of definitions, acronyms and abbreviations.

Definition, acronym, or abbreviation	Description
Data	Anything that can be processed into information
Information	Processed data that are understandable and can be acted upon
Trend analysis	Visualize historical data in a manner so that patterns can be identified to increase the understanding of operations performance
Operations performance	A measure of the organization's overall Operations performance in terms of speed, quality, financials and actuals measured against targets
Operations data	Data about the operational performance registered by the board machines and manually coded by operators

5.2.2 Know the project's data domain

Requirements were produced in four dimensions; RGs, RRs, RCs, and RSs as described by Britos et al. [6]. The resulting requirements for each dimension are presented below.

Requirement goals (RG)
Table 5.5-5.8 present requirements specified on the form proposed in DM-BI requirements elicitation [6]; *requirement goals* (Table 5.5), *requirement restrictions* (Table 5.6), *requirement risks and contingencies* (Table 5.7), and *requirement results suppositions* (Table 5.8). The RGs presented in Table 5.5 were derived from the interview codes and their source interviews can be found in the *Source* column.

Table 5.5: Requirement goals describing the objectives of a requirement, i.e. what the proposed BI solution should be able to meet.

Index	Goal	Source
RG1	Allow for trend analysis of historical Operations performance	1, 6, 9, 13
RG2	Daily updating of Operations data	7, 11, 13, 14, 15
RG3	Data can originate from a heterogeneous group of data sources	5, 7, 10, 11, 12
RG4	Visualize current state of Operations performance	1, 5, 6, 9, 10, 13, 14, 15
RG5	Performing root cause analysis	6, 9, 10, 13, 14, 15
RG6	Presenting actual performance against target performance	8, 9, 10, 13, 14, 15
RG7	Dynamic and interactive reporting	3, 7, 9, 10, 11, 13, 14, 15
RG8	Cost plan within budget constraints	3, 7, 10, 11
RG9	User friendliness	1, 7, 10, 11, 12, 13, 14
RG10	Provide information transparently to the organization	3, 6, 7, 9, 10, 11, 13, 14, 15
RG11	Formatting and calculating data in reports	3
RG12	Searching for BI solution support	10, 11, 12, 13, 14, 15
RG13	Model scenarios for decision support	6, 7, 8, 9, 10
RG14	Providing appropriate access rights	3, 4, 5, 6, 7, 10, 11, 13, 14

RG10, *Provide information transparently to the organization*, was expressed by nine of the interviewees. This requirement highlighted the fact that information generally was inaccessible for many functions in the organization and was usually only available to those who had licenses to the systems for data visualization that the organization used previously. Transparent information did not indicate complete accessibility throughout the entire organization, i.e. both horizontally, vertically, and across divisions. This was why RG14, *Providing appropriate access rights*, was also supported by many interviewees.

Requirement goals RG1, RG4, RG5, and RG6 related to how data and information should be able to be presented in the reports in a BI solution. Information needs were varying across the organization and some stakeholders needed only a visualization of the current situation while others needed the ability to perform root cause analysis to improve Operations performance.

RG2 and RG3 described requirements relating to how data was accessed. The existing storage solutions that the organization had required that data could be extracted from different sources, i.e. there was no data warehouse on mill level that allowed for easy extraction of data that satisfied all reporting needs. To support reporting in a BI solution, the proposed BI solution needed to be able to extract data from the organization's different data sources. It was also considered important that the data was available at least on a daily basis.

As described in Section 4.2.4, the requirements in each requirement dimension (RGs, RRs, RCs and RSs) related to each other, see an example in Figure 5.1.

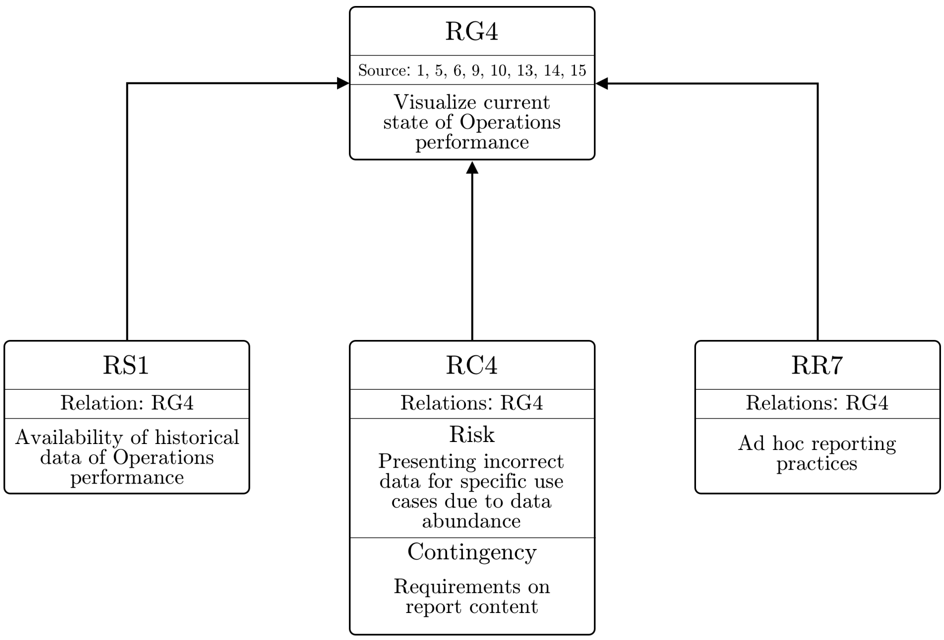

Figure 5.1: An illustration of how requirements within the requirement dimensions related to each other.

As can be seen in Figure 5.1, RR7 (*Ad hoc reporting practices*), RC4 (risk *Presenting incorrect data for specific use cases due to data abundance* and contingency *Requirements on report content*), and RS1 (*Availability of historical data of Operations performance*) related to RG4, (*Visualize current state of Operations performance*).

Achieving the goals in Table 5.5 was somewhat restricted. These restrictions were connected to the goal(s) they restricted in the *Relation* column in Table 5.6.

Requirement restrictions (RR)
Table 5.6 holds the restrictions that related to the goals in Table 5.5. The relation to RGs for requirement restrictions is shown in the *Relation* column.

Table 5.6: Requirement restrictions describe concepts that limited the ability to reach the requirement goals in Table 5.5

Index	Restriction	Relation
RR1	Available employee hours	RG1, RG2
RR2	Inflexible current systems	RG1, RG6, RG7
RR3	Heterogeneous data sources update frequency	RG2
RR4	Data sources' processing capacity	RG2
RR5	IT human resources	RG3
RR6	Organizational competence	RG4, RG5, RG6, RG7, RG9, RG12, RG13
RR7	Ad hoc reporting practices	RG4
RR8	Amount of uncoded Operations data	RG5
RR8	Separate data sources	RG6
RR9	Budget	RG8
RR10	Current cloud service provider	RG8
RR11	Access rights	RG10, RG14
RR12	Available information channels	RG10
RR13	Software licenses	RG10

As can be seen in Table 5.6, RG2, *Daily updating of Operations data*, was restricted by RR3, *Heterogeneous data sources update frequency.* The most common restriction, *Organization competence*, RR6 related to seven of the requirement goals which indicated that the restrictions for a BI solution related more to organizational issues than technical or economic ones. However, restrictions in technical and economic terms were expressed as well, e.g. in RR4 and RR9 respectively.

Requirement risks & contingencies (RC)
Table 5.7 presents the requirement risks & contingencies (RC) and how these related to the requirement goals.

Table 5.7: Requirement risks & contingencies describe risks related to achieving the requirement goals in Table 5.5 along with contingency plans to mitigate those risks.

Index	Risk	Contingency	Relation
RC1	Bad data quality	Assign ownership of data quality	RG1, RG2, RG4, RG5, RG6, R10, RG11, RG12
RC2	Ambiguous data presentation	Develop best practices for data presentation	RG1, RG2, RG4, RG5, RG6, RG11
RC3	Inconsistency in data from different sources	Ensure data documentation	RG3, RG6
RC4	Presenting incorrect data for specific use cases due to data abundance	Requirements on report content	RG4
RC5	Analysis paralysis	Reports on sufficient detail level	RG5
RC6	Budget restricts selecting optimal solutions	Highlight potential cost savings opportunities	RG8
RC7	Confidential information leakage	Communicate data policies within the organization	RG10
RC8	Incorrect calculations	KPI definitions	RG11
RC9	Using inaccurate information	Use proven and reliable sources for support	RG12
RC10	Restricts information transparency	Communicate information policies within the organization	RG14

As can be seen in Table 5.7, many RGs related to the risk of *Bad data quality* (RC1). The suggestion to mitigate this was to *Assign ownership of data quality*, something that was expressed by many interviewees. In doing so, the responsibility of making sure that data was correct and of good quality lied with a specific group or person which would reduce the risk for ambiguity.

RC2, *Ambiguous data presentation*, meant that if the possibility to present data was made available to many different functions, there would be a risk of reports being developed that were ambiguous due to bad practice in report building or not being aware of the information needs for that report. To mitigate this, best practices were to be developed to which report builders could turn for inspiration and guidance in building reports that were clear in what information to present.

Another risk was that of *Confidential information leakage*, RC7. Increased transparency within the organization could lead to information being spread outside of the organization, e.g. in sales and/or customer meetings. To mitigate this risk, which was related to RG10, policies on how information and data should be used were to be communicated organization-wide, e.g. during company-wide calls that were held quarterly.

Requirement result suppositions (RS)
Table 5.8 presents a list of statements all of which had to be true and/or achieved, i.e. RSs, in order for the BI solution to satisfy the set requirements.

Table 5.8: Requirement result suppositions for requirement goals in Table 5.5 indicates what had to be in place in order for RGs to be achieved.

Index	Supposition	Relation
RS1	Availability of historical data of Operations performance	RG1, RG2, RG4, RG6, RG13
RS2	Organizational best practices for data presentation	RG1, RG4, RG5, RG6
RS3	Competence in working with the organization's different data sources	RG3
RS4	Data coded according to specified incident codes	RG5
RS5	Availability of target data	RG6, RG13
RS6	Clear and unambiguous definitions	RG5, RG6, RG11
RS7	Specification of information detail needs for different organization levels	RG7
RS8	A decided budget for new system investments	RG8

RS9	Mapping of users of the new system	RG9
RS10	Organization-wide access to reading reports	RG10
RS11	Devices for information presentation	RG10
RS12	Internal knowledge-sharing culture	RG12
RS13	Vibrant and accessible support communities	RG12
RS14	Policies for access rights	RG14

RS6, *Clear and unambiguous definitions*, was vital since it laid the foundation for specifying what information was needed in a report, e.g. for a KPI. A clear definition allowed for less work to prepare the needed data and in deciding how to present it. This relates to RS2, *Organizational best practices for data presentation*, which allowed for the correct information ensured from RS6 to be presented in a way that was easy to interpret and base decisions on.

As expressed for the other requirement dimensions in Table 5.5-5.7, there were not many requirements that related to technical aspects. This was also the case for suppositions which put focus on making sure that organizational, and some economic, suppositions were confirmed. RS4, *Data coded according to specified incident codes*, related to organizational aspects because it was dependent on operators coding data correctly. It was however also technical as it depended on the existing system's available incident codes that could be assigned to incidents/events.

5.3 Business intelligence model

Figure 5.2 shows the validated BIM model. For a description of the different elements in the model, see Section 4.2.5. The model shows goals from the Operations department such as *Improve Operations performance*, *Reduce net fixed costs*, *Improve safety*, and *Improve customer satisfaction*. The goal *Improve Operations performance* was set as the origin of the model and broken down into sub-goals since this research primarily concerned Operations performance.

Requirements were extracted from the model in Figure 5.2 by applying the patterns described in Section 4.2.5. Applying these patterns resulted in 70 requirements based on goals, refinements, domain assumptions, situations, and influences. An excerpt of the requirements can be found in Table 5.9. The full list of requirements can be found in Appendix E. Applying the patterns worked in the majority of the cases, but some elements were not directly translatable into textual requirements. An example of such was the situation *Adoption of Lean practices*. This situation could not adequately be translated into a requirement with the specified patterns since there was no available data that could measure that situation.

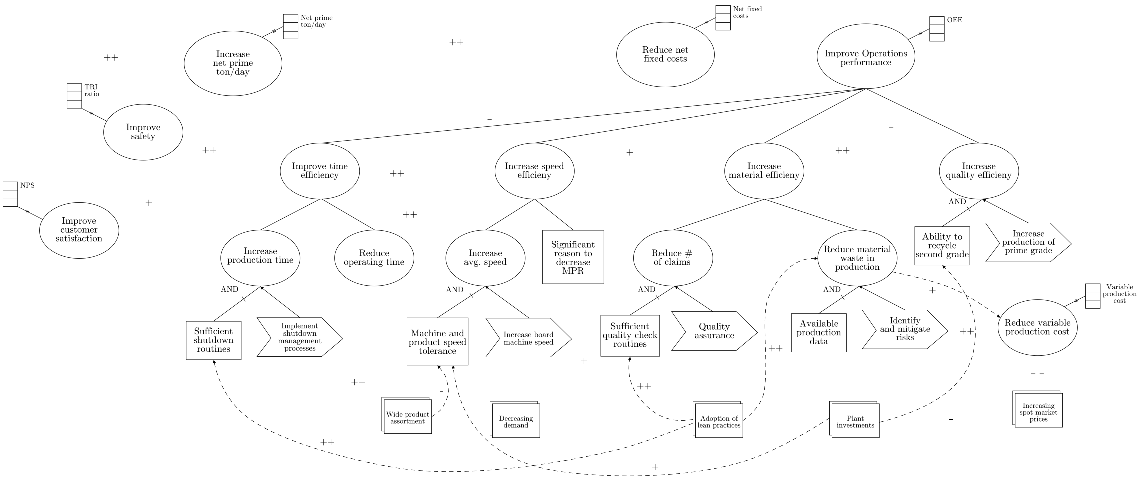

Figure 5.2: The model produced using the BIM language. See Appendix E for a figure with higher resolution.

Influences that were connected to domain assumptions that in turn were part of a refinement of a goal together with a process (see goal *Increase production time* and its refinements in Figure 5.2) were also not translated into textual requirements. For example, the influence of the situation *Wide product assortment* on the domain assumption *Machine and product speed tolerance* could not be translated into a textual requirement per the pattern described in Section 4.2.5.

Examples of the requirements that were able to be extracted from the BIM using the patterns are presented in Table 5.9. All produced requirements from the BIM are presented in Appendix E. The table holds an index to be able to reference the requirement, the actual requirement produced by applying the pattern, and the type of concept that the requirement originated from.

Table 5.9: Some examples of the produced requirements from the BIM.

Index	Requirement	Entity
B37	System should have access to OEE data	Goal
B38	System should be able to visualize trends of OEE development	Goal
B39	System should have access to target data for OEE	Goal
B46	System should have access to MPR data	Domain assumption

B47	System should be able to visualize trends of MPR development	Domain assumption
B48	System should have access to target data for MPR	Domain assumption
B49	System should be able to break down OEE data into quality efficiency data, material efficiency data, speed efficiency data, and time efficiency data	Refinement
B54	System should be able to access demand data	Situation
B63	Changes in production time shall impose a change in net fixed cost by a magnitude of (++)	Influence

Goals in the BIM were represented in three textual requirements each. An example of this was the goal *Improve Operations performance* which was translated into requirements B37-B39. Applying the patterns to this goal resulted in these three requirements; *System should have access to OEE data*, *System should be able to visualize trends of OEE development*, and *System should have access to target data for OEE.* The domain assumption *Significant reason to decrease MPR*, which was not connected to a process, was represented in requirements B46-B48 and followed the same structure as for goals. The refinement of the goal *Improve operations performance* into its subgoals was represented by requirement B49. The situation *Decreasing demand* was represented in the requirement B54. The influence between *Increase production time* and *Reduce net fixed costs* was represented in requirement B63.

5.4 Analysis of methods

This section describes the results from the requirements validation and prioritization process and the lessons learned from the experience of applying the RE in BI methods. This included assessing whether or not the generated requirements reflected the needs of the organization and if the produced requirements were useful for a BI solution selection.

5.4.1 Requirements validation and prioritization

The discussion in which the steering group validated the produced requirements resulted in all requirements from all methods being validated. This meant that the grading survey (see Section 4.3.1) that was then sent out to the steering group included all produced requirements from the three methods since all were accepted. The output from the grading survey was a list containing the validated requirements with an average grade. As described in Section 4.3.1, the requirements with an average grade above 3.0 were used in the selection. These are presented in Table 5.10. For a full list of all average grades per requirement, see Appendix F.

Table 5.10: A summary of the requirements with an average grade above 3.0.

Index	Avg grade (1-5)	Index	Avg grade (1-5)
RS12	5	RG8	4
BA	5	RR6	4
R8	4.8	RR7	4
RG2	4.8	RC1	4
RG10	4.8	RC5	4
RS1	4.8	RC8	4
RS7	4.8	RS4	4
BB	4.8	RS5	4
BD	4.8	RS10	4
R5	4.5	R1	3.8
R6	4.5	R2	3.8
RG1	4.5	RR2	3.8
RG4	4.5	RR5	3.8
RG6	4.5	RR8	3.8
BC	4.5	RC2	3.8
R3	4.3	RC10	3.8
R4	4.3	RS2	3.8
RG11	4.3	RC3	3.5
RC4	4.3	RG13	3.3
RS6	4.3	RR11	3.3
RS14	4.3	RR12	3.3
R9	4	RC9	3.3
RG5	4	RS11	3.3
RG8	4		

As mentioned in Section 5.3, the BIM produced 70 requirements. 52 out of these 70 received an average grade above 3.0 and were therefore considered in the BI solution selection in Section 5.4.2. Because of the patterns applied to produce requirements, many requirements were on the same format, e.g. System should have access to OEE data (B37) and System should have access to MPR data (B46). All requirements on the same format received the same average grade in the grading survey (e.g. B37 and B46 both received an average grade of 4.0). To increase readability in Table 5.10 and Table 5.12, requirements on the same format from the BIM with the same average grade were merged. These are BA, BB, BC, and BD in Table 5.10 and Table 5.12. See the requirements that were merged and their format in Table 5.11.

Table 5.11: The requirements that were merged in order to improve readability in the thesis.

Merged requirement	**Requirements**	**Format**
BA	B1, B4, B7, B10, B13, B16, B19, B22, B25, B28, B31, B34, B37, B40, B43, B46	The system should have access to 'Goal' and 'Domain assumption' data
BB	B2, B5, B8, B11, B14, B17, B20, B23, B26, B29, B32, B35, B38, B41, B44, B47	The system should be able to visualize trends of 'Goal and domain assumption development
BC	B3, B6, B9, B12, B15, B18, B21, B24, B27, B30, B33, B36, B39, B42, B45, B48	The system should be able to have access to target data for 'Goal' and 'Domain assumption'
BD	B49-B52	The system should be able to break down 'Goal' data into 'Subgoal' data

5.4.2 BI solution selection

All requirements with an average grade above 3.0 were compared against existing BI solutions, as described in Section 4.3.1. The searches for BI solutions from Gartner's peer insights review with the set criteria from section 4.3.2 resulted in three BI solutions; Microsoft Power BI (751 reviews), Tableau (506 reviews), and QlikView (253 reviews). These three BI solutions were checked against the prioritized requirements in Table 5.12. An 'X' meant that the BI solution satisfied the requirement in the Index column while 'N/A' meant that the requirement was not applicable to be evaluated in terms of the solution.

Table 5.12: The result from selecting among BI solutions.

Index	**Average grade (1-5)**	**Power BI**	**Tableau**	**QlikView**
RS12	5	N/A	N/A	N/A
BA	5	X	X	X
R8	4.8	X	X	X
RG2	4.8	N/A	N/A	N/A
RG10	4.8	X	X	X

Table 5.12: The result from selecting among BI solutions.

Index	Average grade (1-5)	Power BI	Tableau	QlikView
RS1	4.8	X	X	X
RS7	4.8	N/A	N/A	N/A
BB	4.8	X	X	X
BD	4.8	X	X	X
R5	4.5	X	X	X
R6	4.5	X	X	X
RG1	4.5	X	X	X
RG4	4.5	X	X	X
RG6	4.5	X	X	X
BC	4.5	X	X	X
R3	4.3	X	X	
R4	4.3	X	X	X
RG11	4.3	X	X	X
RC4	4.3	N/A	N/A	N/A
RS6	4.3	N/A	N/A	N/A
RS14	4.3	N/A	N/A	N/A
R9	4	X	X	X
RG5	4	X	X	X
RG8	4	N/A	N/A	N/A
RR6	4	N/A	N/A	N/A
RR7	4	N/A	N/A	N/A
RC1	4	N/A	N/A	N/A
RC5	4	N/A	N/A	N/A
RC8	4	N/A	N/A	N/A
RS4	4	N/A	N/A	N/A
RS5	4	X	X	X
RS10	4	X	X	X
R1	3.8	X	X	X
R2	3.8	X	X	X
RR2	3.8	N/A	N/A	N/A
RR5	3.8	N/A	N/A	N/A
RR8	3.8	N/A	N/A	N/A
RC2	3.8	N/A	N/A	N/A
RC10	3.8	N/A	N/A	N/A
RS2	3.8	N/A	N/A	N/A
RC3	3.5	N/A	N/A	N/A

Table 5.12: The result from selecting among BI solutions.

Index	Average grade (1-5)	Power BI	Tableau	QlikView
RG13	3.3	X	X	X
RR11	3.3	X	X	X
RR12	3.3	N/A	N/A	N/A
RC9	3.3	N/A	N/A	N/A
RS11	3.3	N/A	N/A	N/A

The results from comparing prioritized requirements against BI solutions did not provide indication of a superior solution. Many of the requirements were not applicable ('N/A') to compare against the BI solution since they were not requirements for an actual BI solution but rather organizational requirements for BI success. Those requirements that could be checked against the BI solutions were fulfilled ('X') by all solutions, except for R3 which only Power BI and Tableau fulfilled. The solutions that were studied were obviously very similar in terms of what they offered in functionality. Based on the result from Table 5.12, Power BI or Tableau were the recommendations.

5.4.3 Lessons learned

Table 5.13 presents the lessons learned from the experience of applying the existing methods in practice. These were categorized according to appropriate themes that arose after having produced the findings (lessons learned). *Requirements* described lessons learned that related to eliciting and specifying requirements. *Usefulness* described lessons learned that stated what purpose the different steps in the RE in BI methods were useful for. *Risk* described the risks that were related to applying the different methods, in parallel and also potentially by themselves. *Improvements* were lessons learned that related to what could be improved in the process of producing requirements that can be used in selecting a BI solution. *Additions* described lessons learned where the researchers felt the need for additional steps and processes to produce adequate requirements for BI solution selection. If a lesson learned was specific to one of the methods, it is explicitly stated in the table. Otherwise, the lesson learned was derived from the combined experience of applying all three methods in parallel.

Table 5.13: Lessons learned from applying the three existing methods in parallel.

Theme	Finding
Requirement	Coding interview data provided good input for producing requirements.

	Generated requirements revealed company maturity level for BI and interview design flaws since the information received from interviews was not necessarily connected to a BI solution selection. KPI documents were useful to understand data requirements. Generated requirements were not useful to choose a BI solution. Breaking down requirements in dimensions in DM-BI requirements elicitation boosted comprehension and understanding of the company's problems and needs. Low BI maturity had an influence in producing requirements that were not useful in the selection. Defining problem statements and objectives in the BI implementation life-cycle supported and guided the formulation of requirements well. Hard to have standardized patterns that describe how to go from components to requirements in BIM. Produced requirements relates more to organizational matters and requirements on an OLAP cube rather than requirements for a BI solution.
Usefulness	Defining problem statements and objectives in the BI implementation life-cycle helped in finding a 'common ground' among stakeholders and to set goals and expectations for the project. Defining problem statements and objectives in the BI implementation life-cycle was useful to understand the 'why', i.e. the root cause, of a need. Validating problem statements and project objectives with stakeholders revealed information inconsistencies, tendencies of company politics, and conflicting views. Documenting definitions, abbreviations, and acronyms in the DM-BI requirements elicitation helped to understand the company and its operations which boosted communication. However, apart from that it was a superfluous artefact that was not revisited. The BIM was useful for comprehension of company goals. The BIM was useful for stimulating discussion regarding how to achieve goals.

Risks	The methods required a lot of judgmental skills from the researchers. Lack of maturity in BI can compromise the validity of the requirements produced. Stakeholders prioritized their own interests and they could be conflicting. Managers may mask selfish interests and not be transparent with their motives. Terminology in the results from methods (such as domain assumptions, suppositions etc.) is not intuitive for the company to understand.
Improvements	The meta-model (patterns) for extracting requirements from BIM should be more robust in order to produce adequate requirements. Using criteria from the feasibility study in the BI implementation life-cycle would have given a better foundation to select an existing BI solution. Should have more thoroughly defined domain terminology beforehand to make interviews early on more comprehensive. In the BIM, the goals were too generic to break down to only one process that should be able to satisfy the goal.
Additions	Need for an initial stakeholder mapping that reveals all stakeholders necessary for the project to understand how extensively a BI solution will be used. Need for mapping out organizational resources and capabilities to understand the ease of adopting a BI solution. Need for an understanding of what information is needed to produce adequate requirements for a BI solution (and through this design an interview template that is more useful in providing less generic answers). Need for understanding the organizational BI maturity beforehand. Need for understanding the IT infrastructure and the organizational structures.

5.5 Designing new method

The design process resulted in a method consisting of five phases; pre-study, feasibility study, market analysis, requirements elicitation, and BI solution selection, see Figure 5.3. The method was designed as described in Section 4.4.

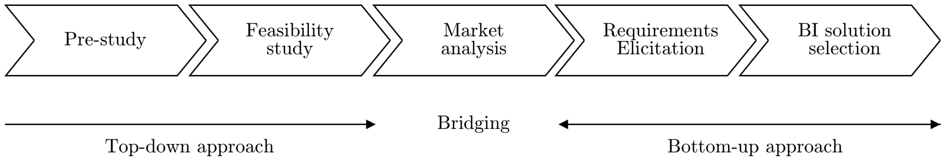

Figure 5.3: The phases of the new method and the approaches for each phase.

The proposed method takes a hybrid approach to the selection by studying both the organization and existing solutions' capabilities. By studying the organization, the BI project team will understand the BI maturity of the company which is important to understand the comprehensiveness and effort required for the project. It will also reveal what constraints exist within the organization as well as provide an understanding of what problems the BI solution should solve for that specific organization. To complement this top-down approach which originates from the organization's needs, a bottom-up approach originating in existing BI solutions is also suggested to improve the selection process. The inclusion of a bottom-up approach was based on the lessons learned in Table 5.13. By studying solutions, the organization will better understand the differences between existing solutions in terms of their functionality and capabilities. From this, the BI project team and the organization can understand what information is needed to make a selection.

To guide the BI project team, Figure 5.4 shows what input is needed for the different phases to produce their expected output. In the first two phases, there is no defined input because it could not be generalized to be applicable in every specific case. The purpose of these phases is to gain an understanding of the BI project. All phases are described in more detail below describing the purpose, input, output, and execution of the phases.

5.5.1 Pre-study

The purpose of the pre-study is to reveal the organization's BI maturity, its needs in BI, and establish common terminology to be used within the scope of the project. Understanding an organization's BI maturity is important for the rest of the process as it will affect how following phases are performed. If an organization has low BI maturity, phases two and three will be more comprehensive as the organization has less understanding of the capabilities and functionality of a BI solution and therefore need to spend time to understand both their own limitations and capabilities in BI as well as the solutions. In addition, the requirements produced in the fourth phase will be more generic and the organization will have to rely more on the judgement of experts than on their own intuition.

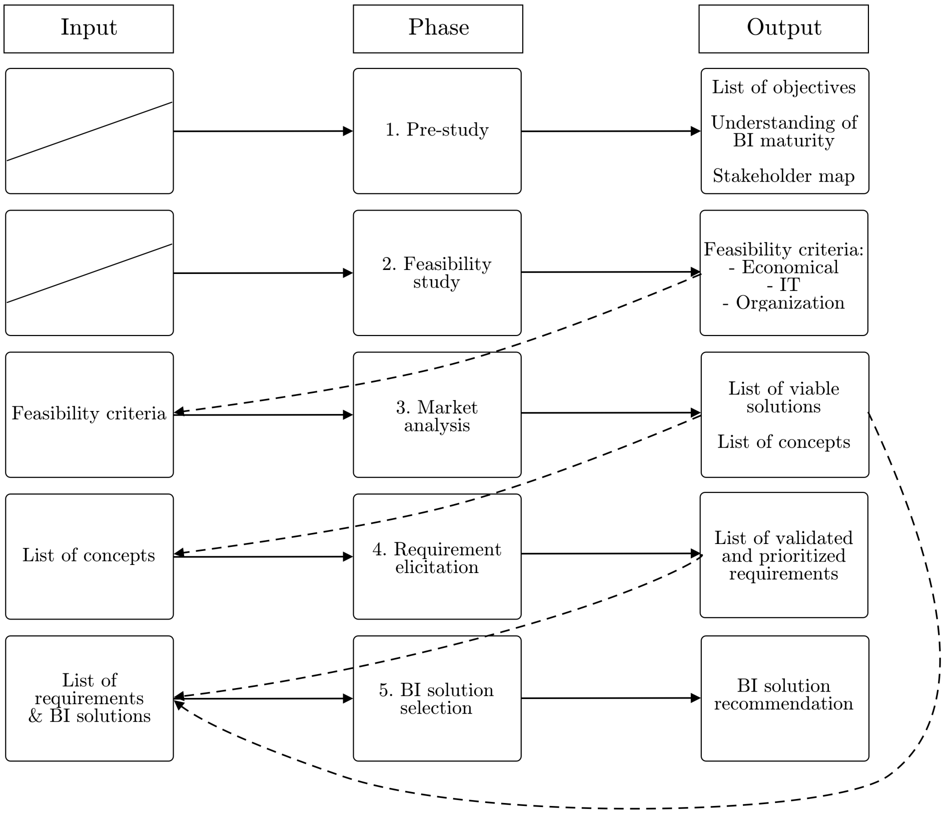

Figure 5.4: A schema of the input and output from each phase and how the output from some phases are used as input in other phases.

By clearly defining and validating the needs for a BI solution, the effort of acquiring one can be justified. Practitioners should include stakeholders from different functions and different levels within the organization when validating needs to make sure that they can be satisfied by a BI solution.

The following steps are a recommendation for how to achieve the goals of the pre-study:

- Identify primary users of a BI solution and the key stakeholders for the project.
- Let the stakeholders express their needs in terms of reporting, information transparency, and information use. Also assess stakeholders understanding of BI by asking questions like ‘have you worked with BI solutions before?’, ‘what do you know about the capabilities of BI?’, and ‘what are your expectations of implementing a BI solution?’. In doing so, the BI project team can grasp the BI maturity and plan accordingly in the following steps.
- In the case of low BI maturity, educate the stakeholders in BI and explain what can be expected and what capabilities and functionalities BI and a BI solution can offer.
- To mitigate risk of self-interests, validate stakeholders’ and primary users’ needs preferably in a workshop format where they can discuss conflicting interests and find common ground.

The expected output from following these steps should be a list of objectives for the project that have been accepted and validated by stakeholders and primary users. These objectives will guide the project when going forward and can be used to verify project success. Data to produce this output can, for example, be collected either through interviews with stakeholders or in group/team meetings with stakeholders, i.e. forums where stakeholders can communicate.

5.5.2 Feasibility study

The purpose of the feasibility study is to investigate and understand the feasibility of implementing a BI solution in the organization. The feasibility is studied from an economic, IT, and organizational perspective as these are areas that affect the choice of a BI solution. Investigating feasibility is important because without it, an organization runs the risk of acquiring a BI solution that is too expensive, incompatible with existing IT infrastructure and resources, and/or not usable by the organization's employees.

Economic feasibility refers to the budget the organization has available for acquiring a BI solution. If this is not available, the economic feasibility study will serve to initiate budget discussions as it is not recommended progressing forward without having any budgetary constraints.

IT feasibility refers to understanding the IT infrastructure in the organization. This includes what systems, servers, and software are used to store, process, analyze, and access data. It also includes understanding what IT human resources are available and where they are located, i.e. both internally and externally.

Organizational feasibility refers to understanding what necessary competences exist in the organization. This relates to competence in using a BI solution or other software, competence in creating reports both in terms of content and presentation etc. This can indicate whether or not end-user trainings will be necessary after implementation. Investigating organizational feasibility could also reveal potential obstacles relating to company culture. Such obstacles could be aversion to change or aversion to ownership.

A recommended process for the feasibility study is:

- Identify what budget is available. If no budget has been assigned, decide on a budget if that decision power is available in the team or prepare a business case based on the initial phase to present to financial decision-makers.
- Identify all constraints in IT that might render a certain BI solution unviable. An example could be that a certain BI solution could not connect to the data sources in an organization.
- Identify all end users and map out their competence. Decide if extra training will be necessary.

The output of the feasibility study is a list of criteria used to screen the market.

5.5.3 Market analysis

The purpose of the market analysis is to scan the market for existing BI solutions suitable for the organization's needs to narrow down the amount of BI solutions to do a thorough comparison of. In doing so, the organization will understand what needs to be investigated in the requirements elicitation phase since they will have an understanding of the differences between the existing BI solutions. In the market analysis, the organization can filter out solutions that are not viable options based on the feasibility study. The market analysis could also in turn affect the feasibility study. For example, budget adjustments could be made if there are superior contenders that lie outside of the set budget.

In the market analysis, the BI project team needs to study the different solutions that are feasible (according to the feasibility study) to identify what they offer in functionality, how they differ, and what information the organization needs to be able to make a decision. It is also important to understand the completeness of the products out of the box, i.e. is full functionality available on purchase or are plugins necessary to meet the organization's needs. The time consumption and ease of deployment and implementation from peers' experiences should also be considered. From this, concepts to focus on when producing requirements can be identified which will aid in making an adequate selection. Concepts in the new method refer to areas to address in requirements elicitation which could be investigated in order to produce requirements that can be useful in a BI solution selection. Examples of concepts that have been processed into requirements can be seen in Table 5.14.

These are some steps that are recommended for a market analysis of BI solutions:

- Scan the market to find what BI solutions are available. The project team does not need to make any initial judgement of the solutions, rather it is positive to have more options to investigate.
- The BI solutions should then be screened against the feasibility criteria set up in the previous phase. This means that the different solutions are checked in terms of e.g. budget, data source compatibility, and current software. This should result in a filtered list of BI solutions that can be studied and compared against the requirements produced in the coming phase.
- Read specifications and reviews of the remaining BI solutions to identify concepts which will aid in producing requirements that can be used to make a selection of a BI solution. Examples of concepts and how they can be used to produce requirements can be seen in Table 5.14. This should result in a list of concepts from which requirements can be produced (see suggested concepts in Appendix G).

The expected output from the market analysis is a list of BI solutions that are feasible and can be evaluated in the BI solution selection phase and a list of concepts that can aid the requirements elicitation.

5.5.4 Requirements elicitation

The purpose of the requirements elicitation phase is to produce requirements that can be used to distinguish between BI solutions from the market analysis. To do this, the BI project team needs to find out what requirements the organization has in terms of implementation, usage of the solution, searching for support etc. In order to find this, it is recommended to interview primary users and stakeholders. The BI project team should design their interview templates based on the list of concepts from the Market analysis phase. Some suggested concepts to investigate can be found in Appendix G. Examples of how requirements can be produced are presented in Table 5.14.

Table 5.14: Some examples of concepts and questions that can be used or asked to produce requirements.

Concept	Question	Requirement
Deployment time	When must the BI solution be up and running?	Deployment should not take over 6 months
Customization	Are there any needs for customizations?	BI solution should allow a GUI with the organization's colors
Language support	For what languages do you need support?	BI solution should offer interfaces and support in the following languages...
Data source connectors	From how many and what type of data sources will the BI solution access data from?	BI solution should be able to connect to the following types of data sources...
Making predictions	Do you have a need to model future scenarios?	The BI solution should be able to create scenarios for the future

To provide input to the requirements process, the BI project team should code the interview data, see Section 4.2.2, and base the codes on concepts such as those in Appendix G. This allows the team to easily structure data from all interviews so that the data easily can be translated into requirements.

The process of eliciting requirements and preparing to do so could follow the following steps:

- Design an interview template that can be used to provide answers about the concepts and information that is needed to make a selection, see examples in Table 5.14.
- Conduct interviews with primary users and stakeholders.
- Code interview data as suggested above and translate them into requirements.

- Validate and prioritize the requirements with stakeholders and primary users. This could be done in a workshop format and/or with surveys. Validating the requirements means both ensuring that they represent actual stakeholder needs but also that they can solved by a BI solution. This is to avoid having non-applicable requirements in the selection.The purpose of prioritizing is to assess the most important requirements that a BI solution should satisfy.
- Clearly indicate what requirements are 'must-haves', i.e. cannot be compromised and need to be fulfilled by the BI solution.

The expected output is a list of validated and prioritized requirements that can be used in selecting among the BI solutions that are feasible.

5.5.5 BI solution selection

The purpose of this phase is to select the BI solution that best meet the organization's requirements. In doing so, the organization has done a thorough scan of available solutions and chosen the one that is appropriate, scalable, within budget, usable by the organization, compatible with existing systems, and holds desired capabilities and functionality. When this phase is finished, the organization can begin work on implementing the system and integrating it with already existing systems.

In order to make a selection, the organization could do as follow:

- List all validated and prioritized requirements together with all the BI solutions from the market analysis. In each BI solution column, mark if that solution satisfies the requirement. See example in Table 5.12.
- Based on the results, make an assessment of which BI solution is best for the organization. An example assessment would be to weigh requirements by their grade which would result in every solution having a final score to base the decision upon.

The output of the final phase should be a recommendation for a suitable BI solution(s) that the organization can start to implement.

5.6 Evaluating new method

The results from the evaluation workshop of the new method that was held with the steering group can be seen in Appendix H. A summary of the feedback is presented in Table 5.15. The results are presented according to the workshop layout (see Section 4.5), i.e. summarized answers to each question are presented separately.

Table 5.15: Summarized results from the evaluation workshop.

Question	**Comment**
Can you understand the method?	The general consensus was that the method could easily be understood and that understandability was supported by method figures. Some concerns about the size of the methods were raised.
Can you understand the purpose of the method?	The main purpose was perceived to be the selection of a BI solution however it was also perceived as a method for assessing BI maturity.
Would the organization be able to use this method?	The workshop revealed that the organization would probably be able to use the method. However, it was emphasized that it would not be possible for one person to perform it single-handedly and would require a team of varying competences.
How long do you estimate that the suggested method will take to complete?	The steering group expressed that it was hard to estimate and the given estimates ranged from 3 months up to 3 years. Many emphasized that urgency would greatly affect the time.
Can the steering group asses the requirements elicitation concepts from Appendix G? If not, who can?	Further indicated that there would be a need of a cross-functional team to both understand all concepts but also to answer them. They believed that this competence could be found within the organization.
For each phase, is it clear what is supposed to be input and output?	No one stated that they did not understand what input and output was expected. This was supported by the method figure. The "Understanding BI maturity" was difficult for some to grasp.

For each phase, is anything missing?	Some practical guidance in what functions in a company to include and guidance in where to find BI solutions.
For each phase, is anything redundant?	The usefulness of the objectives was the only element that was questioned.
Are there any phases that are missing or redundant?	Nothing was missing and there also was not anything that was deemed to be useless. However, there were concerns about the time-consumption of applying the method in full and some suggested that a selection perhaps could be made after the feasibility study to save time.
Would the outcome have been different if this method had been used?	Mixed answers, but all emphasized that the recommendation would have been more robust if produced by the new method.

Table 5.15 shows that the overall impression of the new method was good. There were some comments that indicated that clarifications and/or modifications were needed. These are discussed in Chapter 6.

6
Discussion

This chapter begins with a discussion related to the research questions of this thesis in order to answer them. Thereafter, a discussion about recommended future work is presented. The discussion chapter is finished with a section discussing the threats to validity of this research.

6.1 Do existing RE methods for BI support selecting BI solutions (RQ1)?

This research showed some evidence that existing methods could be used in a BI solution selection but gave weak support in doing so. Therefore, it was interesting to analyze how useful the produced requirements from all methods were when selecting a BI solution. When discussing the usefulness of requirements, the researchers here refer to how well requirements worked in distinguishing between different BI solutions in the selection. A requirement that was not useful was a requirement that was so generic that it was plausible to believe that all BI solutions on the market could satisfy it, i.e. a very basic requirement such as RG1, *Allow for trend analysis of historical Operations performance.*

In the DM-BI requirements elicitation method, requirements were produced in four dimension; RGs, RRs, RCs, and RSs. As shown in Table 5.12, 6 out of 7 prioritized RRs were not applicable (N/A), i.e. they could not be assessed in the solution selection and, therefore, did not provide any support in the recommendation. The BI solution selection also showed that 9 out of 9 prioritized RCs were N/A. Further, it showed that 7 out of 10 prioritized RSs were N/A. These results suggested that this was due to them being organizational issues that could not be solved by a BI solution. Hence, the RR, RC, and RS dimensions of requirements did not provide support for the actual selection. However, this was not conclusive evidence that the method (DM-BI requirements elicitation) as a whole was not useful for a BI solution selection because, as can be seen in Table 5.12, 7 out of 9 prioritized RGs were applicable in the selection (meaning they could be marked with an 'X' in Table 5.12). Seeing as the other requirement dimensions supported RGs, as shown in Figure 5.1, it is not reasonable to disregard the usefulness of RRs, RCs, and RSs. Their usefulness did not lie in the actual selection but rather they helped in identifying what could affect the BI solution when it was in use. For example, if the BI solution was to be implemented and used, *Bad data quality/Assign ownership of data quality* (RC1) was something that needed to be addressed to actually leverage the

BI solution. Hence, the DM-BI requirements elicitation showed potential usefulness for the case company beyond a selection. For example it indicated how to mitigate risks (RCs), what needed to be in place for BI success (RSs), and what limitations (RRs) the company might have in implementation and usage of the BI solution.

While 7 out of 9 prioritized RGs (i.e. RGs with an average grade above 3.0) were applicable, only 3 out of the 14 total produced RGs (*Data can originate from a heterogeneous group of data sources, Cost plan within budget constraints,* and *Searching for BI solution support*) were actually deemed useful for a BI solution selection by the researchers. Further, only 2 of those 3 were applicable in this case and they were not prioritized by the steering group. This in the end meant that 0 out of the total 14 RGs were applicable, prioritized, and useful for a selection, i.e. the requirements that were useful for distinguishing between BI solutions were not prioritized by the steering group. If no prioritization had been made, there might have been better support for selecting a BI solution.

From the BI implementation life cycle there are findings that both support and refute RQ1. Supporting evidence for RQ1 can be seen in that 8 out of 9 requirements produced in the BI implementation life cycle were prioritized and all eight of those were applicable in the solution selection. The support was, however, not very strong seeing as only 2 out of 9 requirements were applicable, prioritized, and useful for a selection. These were R3 (*Availability on multiple platforms, i.e. mobile and desktop*) and R4 (*Reports must be accessible to all users*). However, R3 was the only requirement that that was not satisfied by all three BI solutions as seen in Table 5.12. Hence, this was the requirement that the entire recommendation was based on. This indicated that in this case, there was support for selecting a BI solution. This did not make R3 a superior requirement, rather it was probably a coincidence that the selection could be made based on this requirement. Since this was the case, the selection was not very robust.

An interesting finding was that all prioritized requirements produced from the BI implementation life cycle were applicable in the selection. On the other hand, only two out of these requirements were useful for selecting a solution which implied that a BI-oriented requirement is not necessarily useful in a BI solution selection. This finding provokes the discussion of whether or not a method that produces BI-oriented requirements is needed for a BI solution selection or if any generic and non domain-specific approach will do. See further discussion in Section 6.3.2.

In the BI implementation life cycle, the requirements were produced by studying KPIs. These were applicable in the selection but the majority were not useful for distinguishing between BI solutions, i.e. not useful for a selection. Therefore, it would be interesting to investigate if the produced output from the two initial phases (problem definition and feasibility study) could have supported the selection better. As suggested by the lessons learned in 5.4.3, using criteria from the feasibility study would have given more guidance in the selection. The feasibility study showed that the company had a Microsoft Azure technology stack which presumably would have resulted in the recommendation only being Power BI (which is also by Microsoft). The validated objectives in Section 5.1.1 could probably also guide the selection since 6 out of 9 were deemed useful by the researchers when assessing a BI solution. For example, Objective 6 stressed the need for platform flexibility which related to R3 which was the only requirement that the recommendation could be based on. This is further evidence that existing methods support a selection and that other output than requirements, such as feasibility criteria, can be useful for a BI solution selection. Hence, including additional output, and not only requirements, in the selection could have made the selection more robust.

The BIM produced the most requirements for the selection, 70 in total. 52 of those were prioritized by the steering group and all 52 were applicable in the selection. Based on these numbers alone, this method supported the selection the most. However, after assessing the usefulness of the requirements, zero were deemed useful by the researchers which rather indicated that it did not support the selection. It was hard to attribute this assessment to the BIM though, as the requirements produced were heavily dependent on the applied patterns described in Section 4.2.5 which was further supported by the lessons learned in Table 5.13. This is discussed further in threats to validity in Section 6.4 as the patterns were not a part of the BIM. Therefore, no conclusive evidence was found either for or against RQ1 in terms of the BIM.

From the discussion in this section, some conclusions could be drawn about RQ1, 'Do existing methods for RE in BI support selecting BI solutions?'. Based on the requirements produced by the three RE in BI methods, a recommendation could be made, i.e. they supported the selection of a BI solution. However, it was only one requirement from one method that the selection was based on which made the recommendation very weak. Hence, existing methods could be used to support a BI solution selection but the support will not be very strong. Therefore, existing methods can be used but are not recommended to be used when making a BI solution selection. Without applying the methods in other cases, it is difficult to assess their usefulness beyond this case. This together with the lessons learned suggest that there are more suitable ways to select a BI solution which is discussed in Section 6.2.

6.2 What is an appropriate method for selecting an existing BI solution (RQ2)?

In order to answer RQ2, a new method was designed, based on the lessons learned, and evaluated. See a summary of the new methods phases, input, and output in Figure 5.4. The discussion in the section above showed that only 2 out of 98 prioritized requirements were useful and applicable. This called for a more appropriate method to produce requirements for selecting a BI solution. The new method, therefore, included a more thorough feasibility study and a bottom-up approach to requirements elicitation. The new method was evaluated with the steering group (see Section 5.6) to help in identifying if the new method was appropriate or what modifications would be needed to make it appropriate.

The new method was deemed intuitive and easy to understand by the organization and when asked if they could execute it in-house with their own resources the answer was positive. However, the steering group emphasized the need for a cross-functional team when executing the method and that allocating such a team could be hard to do in practice even though it sounds plausible in theory. This was interesting because in agile organizations, cross-functional teams are very common and have worked successfully in delivering value [31]. This indicated that the case company did not have much experience with working in agile ways which was reasonable since the case company was not a software company but a traditional manufacturing company. The evaluation of the new method further showed that there were concerns about the time required to execute the method. Time estimates expressed by the steering group ranged from three months up to three years which is not a sensible amount of time for just selecting a solution. Seeing as selecting a solution is only a part of a bigger project, i.e. there is also implementation and deployment necessary, the method in its entirety was perhaps not the most appropriate way. The large expected time consumption was addressed by suggested improvements to the new method which are discussed in later paragraphs. However, the steering group believed that the predicted outcome of the new method, had it been applied, would be better than the recommendation given from applying the existing methods in this research.

An obvious issue that needed to be addressed was the fact that only 2 out of 98 requirements were actually useful in the BI solution selection in this research. One major reason for this was the BI maturity of the case company. This was evident from some of the expressed requirements (those that were marked with ‘N/A’ in Table 5.12) at the company which could not be met by a BI solution alone. Further, the three requirements (RS12, BA, and R8) that received the highest average grade in the prioritization (see Table 5.10) were either not useful or applicable in the selection. This indicated that case company did not know what was necessary for a solution selection but also that they did not know what BI could provide. Therefore, a mapping of a company’s BI maturity was included in the new method to ensure that the organization is equipped for the effort before starting. By doing so, it was believed that the amount of applicable and useful requirements would be large enough to make a robust selection.

According to the evaluation workshop and the solution selection, it was evident that existing BI solutions were very similar, see Section 5.4.2. It is reasonable to believe that this is due to the fact that BI solutions on the market are developed to fit any organization and thereby are very similar in terms of their functionality. Despite this, when the researchers studied BI solutions there were some obvious differences such as cost, support functions, and deployment time (see Appendix G). This suggested that requirements should be produced to address these differences, where a bottom-up approach was seen as an appropriate way of doing so. Another evidence that supported this was that the requirements produced from the existing methods that were deemed useful in the selection could all have been produced from the requirements elicitation concepts presented in Appendix G.

This further led to a discussion about what an appropriate requirement was. The discussion in Section 6.1 showed that the requirements that were useful for a BI solution selection were not specific to BI, i.e. they could have been used in solution selections in other domains than BI (e.g. *Availability on multiple platforms, i.e. mobile and desktop* is applicable both inside and outside the field of BI). This was also shown by the requirements produced by the concepts presented in Table 5.14 which led to the conclusion that when selecting a BI solution with the help of requirements, the requirements do not have to be BI-oriented. There was no evidence in this research that suggested that there was anything wrong with having BI-oriented requirements, i.e. it could not be concluded if requirements should exclusively be BI-oriented or not. What could be concluded was that R3, the requirement that the selection was based on, was not BI-oriented.

According to lessons learned and the discussion above, a more thorough feasibility study is appropriate to support a selection. Therefore, the new method suggested that the feasibility study should produce feasibility criteria that can be compared against BI solutions. The researchers had intended for the feasibility study to result in criteria that could filter BI solutions on the market to have a shorter list of BI solutions to compare against requirements, i.e. fewer alternatives to choose among. However, the steering group stated that a selection probably could be based on a feasibility study alone (see Appendix H), i.e. without the requirements elicitation phase. This implies that the first three phases of the new method (see Figure 5.3) could be an appropriate method to use when making a BI solution selection. This would also address the feedback given on the new method regarding time consumption since the last two phases would not be necessary.

According to the findings it could be concluded that a thorough feasibility study could be an appropriate way to select a BI solution. However, it was not clear from the findings, because the new method had not been applied in practice yet, that there was a guarantee that a feasibility study would result in a selection. In the case that a feasibility study is not enough when applying the method in practice, the requirements elicitation phase, which takes a bottom-up approach, could be an appropriate addition (at the cost of taking extra time) to make a BI solution selection. This indicates that the new method could be an appropriate method to select a BI solution. The call to investigate this further is discussed in Section 6.3.

6.3 Future research

This section presents suggested future research related to this research.

6.3.1 Iterations of the new method

Section 6.2 concluded that the new method could be an appropriate method for a BI solution selection. However, this was based mainly on an evaluation of said method which meant that it had yet to be implemented in practice. Therefore, iterations and further improvements are necessary which is also a key part of design science [40]. In future iterations of the method, there are some areas that needs to be considered further. It should be investigated if each phase with its input and output is useful in practice. This includes identifying if there are any phases that are redundant and if any of the phases need modification. It should further be investigated whether or not the feasibility study alone provides enough support to make a selection as discussed in Section 6.2.

An interesting finding to analyze in future iterations is the requirements elicitation concepts in Appendix G to see if they provide support in producing requirements to base a selection on. If evidence from doing so suggest that the requirements elicitation concepts in Appendix G are redundant compared to criteria produced in the feasibility study, it is plausible to believe that the requirements elicitation phase in the new method is superfluous. If so, the requirements elicitation phase would have to be replaced or revised.

The new method incorporated a prioritization process into the requirements elicitation phase as seen in Section 5.4.1. There was no evidence from applying existing methods that suggested that this was necessary or efficient. Therefore, this needs to be assessed in future research to see if such prioritization is necessary.

Finally, the new method should be applied in another context, e.g. another industry, country, and/or organization size, to see whether or not the new method is appropriate for contexts other than the context in this research. This is something that is also further discussed in the threats to validity in Section 6.4.

6.3.2 Application beyond BI

As suggested in Sections 6.1 and 6.2, there was not necessarily a need for BI-oriented requirements when selecting an existing BI solution. This questions whether it is then necessary to have a BI specific approach when making a selection. It is reasonable to assume that any generic RE method will work in any domain (such as BI) since generic RE methods are designed to be adaptable to any domain. From that reasoning, it could be concluded that there is not a critical need for specific RE methods in specific domains.

The need for domain-specific RE methods has been discussed previously in the health care industry where it was shown that health care RE methods could and had been applied successfully in domains other than health care [16]. From that discussion, it could be interpreted that the complexity of a domain, the criticality of the project (e.g. risk to human life or privacy risk), and how well versed the requirements engineers are in the specific domain, are more important factors to consider when selecting an RE method than the domain is. Therefore, there was reason to believe that the new method, which had BI-specific elements to is such as BI maturity, is applicable in domains other than BI. To investigate if this is the case, it is suggested that future research apply it in domains other than BI, i.e. not to select a BI solution but rather to select a solution in another domain, e.g. customer relationship management (CRM) solutions or enterprise resource planning (ERP) solutions.

6.4 Threats to validity

In this research, three categories of validity were addressed. The different threats were described in how they might have influenced the research and how the researchers mitigated them. The types of validity that are discussed are internal, construct, and external validity as explained by Feldt and Magazinius [13].

6.4.1 Construct validity

Construct validity refers to if the treatment and the outcome coincides with the causes and effects to be studied [13]. The fact that the existing methods were applied in parallel and not sequentially might have influenced their input and the quality of their output. The data that was analyzed for each method came from the same data set (interview codes) which meant that the same input was used to produce different output. This caused some output from different methods to be similar. For example, the RGs from DM-BI requirements elicitation [6] and the objectives from the BI implementation life cycle [33] were in some cases very similar as can be seen with RG10 from Table 5.5 and Objective 6 from Table 5.2. Thus, it was not obvious which method provided this information. To mitigate this threat, the researchers designed two interview templates. The first to collect data for the BI implementation life cycle and DM-BI requirements elicitation, and the second to collect data for the BIM. Thereby, the same data set was not used for all three methods, i.e. the BIM had a separate data set as input while the other two methods used the same. The interview templates were further designed with the methods' expected output in mind to make it easier to distinguish what input to use in what method, see Appendix A.

This research used descriptive coding as described in Section 4.2.2 to structure and interpret the interview data. The researchers did not use predefined themes based on expected output from the existing methods, e.g. RGs [6], problem statements [33], domain assumptions [21], which could have made it hard to distinguish what interview codes to use as input in the different methods. This was mitigated by the interview template design, as discussed above, but also by choosing methods that varied in output as described in Section 4.1, thereby making it easier to identify what interview codes to use where.

The BIM was not created with an intention of producing textual requirements. However, this was done in this research which could have affected the output derived from the BIM. To mitigate this, patterns that were inspired from producing requirements from other goal models were applied, see Section 4.2.5.

6.4.2 Internal validity

Internal validity looks at the causal relationship between effect on an outcome and the conduct in the research [13]. One observation on internal validity in this research is that the design science process should follow an iterative approach [40], that is, the produced artifact should be investigated, improved and further revised in a cyclic manner. This research, as previously stated, did not iterate the new method meaning that it had not proven to be useful in practice. To reduce the validity threat this caused, the new method was evaluated in a workshop with the steering group to assess its usefulness and where it could be improved. This was the effort that the time constraints of this research allowed which was why the researchers called for further iterations of the new method, see Section 6.3.1.

The case company might have been biased towards certain BI solutions that had already been tried out by some employees. This could have provided them with some basic competence in using that system which might have biased their opinions during interviews and thereby affecting the quality of the input to the different methods. This was mitigated by addressing the interviewees knowledge about BI (see Appendix A) to see if they had any previous experience with it. Only 3 out of 19 interviewees had previous experience in an existing BI solution, and that experience was minor.

As discussed in section 6.2, the BI maturity had effect on the findings in this research. To prevent this from affecting the design of the new method negatively, all interviewees were asked about their BI knowledge. Based on this, the researchers were aware of how the lessons learned, on which the new method was based on, had been influenced by the low BI maturity at the company and could take that into consideration when designing the new method.

6.4.3 External validity

External validity addresses whether or not the research would be valid in a context other than that in which it was applied [13]. This research was conducted within one specific context (see Section 1.3) which threatened its validity. There are some factors in this research that increases the external validity. The case company was a global manufacturing company with an organizational structure that can be seen in other industries. The company was not unique in terms of their BI capabilities or digitalization efforts, i.e. it could be seen as a generic manufacturing company. As such, the findings in this research should be valuable to other companies as well. The results in this research indicated many organizational issues which could mean that this research is only valuable in regions with similar organizational culture as in Sweden. However, the case company was a global company with operations in more than 30 countries, lowering this validity threat.

7
Conclusion

In this research, three existing RE in BI methods were applied to investigate if existing methods could be used to produce requirements for the purpose of selecting an existing BI solution. The methods were applied in a real case at a global manufacturing company. The applied methods were the BI-implementation life cycle [33], DM-BI requirements elicitation [6], and BIM [21]. The produced requirements from the methods were compared against three BI solutions on the market. The comparison resulted in two BI solutions being recommended, suggesting that existing methods could be used to select an existing solution. However, the recommendation was based on only one requirement which indicated that the recommendation made was very weak.

The lessons learned from applying existing methods were then used to design a new method that was believed to be a more appropriate way to select a BI solution since the existing methods resulted in a weak recommendation. The new method was evaluated with a steering group at the case company showing that it could be an appropriate method for selecting a BI solution. The evaluation workshop also revealed improvements to the new method that potentially could make it even more appropriate, but also that it was believed to be easy for a company to apply by themselves. This thesis, therefore, recommended future iterations of the new method to consider the suggested improvements and to see its usefulness in practice.

This research provided the research community with a new method for selecting an existing BI solution. With this, researchers and practitioners in industry can select solutions that are well suited to their needs as well as gain a good understanding of what they will need to do in order to leverage the benefits that BI solutions can offer. Existing methods for RE in BI were applied and evaluated which can provide insights in how to apply them in practice and what they are useful for. Further, this research also contributed interesting findings about the need for domain-specific approaches to RE, something that is suggested to be further investigated in the future.

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A

Appendix - Interview templates

This appendix presents the interview templates used in the interview rounds.

A.1 Interview template used in the first round

Intro

- Introduction of the project
- Introduction of the researchers
- Purpose and expectations of the interview

Questions

- What do you work with?
  - Your responsibilities
  - Who do you report to?
- What problems do you experience in your current way of working (with KPIs and reporting in general)?
  - Why is this a problem?
- Have there been any previous efforts to improve?
  - If so, what did they try to do?
  - Did it work? Why/why not?
- What do you know about BI in general?
- What do you need from a BI solution?
  - Why do you need it?
  - What needs to be in place in order for you to satisfy your needs?
- What risks and/or obstacles do you see with implementing a BI solution?
  - Any constraints?
- Where does data come from?
  - Do you design data cubes? If not, how are analyses executed?
- How is data transferred within the organization?
  - Do you see any constraints in your systems?
  - Do you see any potential improvements for transferring data?
- Suppose that a BI solution would be fully implemented, how would that affect your role and your way of working?
  - How do you believe it will affect on a company-level?
  - Do you think it is possible to implement organization-wide? Why/why not?
- Who is responsible for reporting and who is owning what data?

- What do they see as the main success factors with KPI reporting?
- Anything to add?

A.2 Interview template used in the second round

Intro

- Introduction of the project
- Introduction of the researchers
- Purpose and expectations of the interview

Questions

- What is the Operation department's mission?
  - Why is this your mission?
  - How will you achieve this mission?
- Which are the Operation department's overall goals?
  - Why are these your goals?
  - How do these goals relate to the goals of the corporation?
  - How do you measure these goals? (What processes?)
  - How will you achieve these goals?
  - Do you see any risks that will stop you from achieving these goals?
    * Internal risks/threats?
    * External risks/threats?
- Do you measure anything within the Operation department that is connected to your goals?
- Are any of your goals dependent on each other (both positively and negatively)?
  - Does any of your KPIs affect each other (positive/negative)?
- What needs to be in place in order for you to reach your goals?
- Are there any constraints in terms of organizational and/or economic factors?
- What do you see as the main success factors with KPI reporting? What would be a best case scenario?
- Are there any documents describing your goals and strategies that can be shared for internal use?
- Anything to add?

B

Appendix - Codes and themes

This appendix includes all codes and themes from the qualitative data analysis of both interviews and documents.

B.1 Codes and themes from interview round 1

Table B.1: Codes within the theme management.

Theme: Management	Interviewee source	Count
Set division goals	10	1
Mill management benefits	10	1
Detail needs for management	10, 6, 11, 11	4
Deciding KPI targets	8, 11, 9, 13	4
Management (pushes) follow up KPI targets	9, 13, 15	3
Reporting to increase profits and reduce costs	9, 8, 12, 13, 15	5

Table B.2: Codes within the theme production.

Theme: Production	Interviewee source	Count
Reporting prioritizes value-creation for mills	12, 9, 13, 15	4
Different production preconditions	10, 8, 13	3
External impact factors	10, 13	2
Improve operations performance	10, 5, 1, 8, 9, 13, 15	7

Operations' impact on profits	9	1
Work on preventive measures	9	1
Use report for daily production follow-up	15, 14, 13, 11, 7	5
Reporting leads to positive effect on OEE	11, 15	2

Table B.3: Codes within the theme data collection.

Theme: Data collection	**Interviewee source**	**Count**
Machine-specific coding	10, 11, 13	3
Manual coding	10, 11, 12, 9	4
Predefined code categories (unique)	10, 11	2
Predefined code categories (common)	10, 6	2
Manual data extraction	5, 1, 8, 9, 13	5
Data directly from multiple databases	5, 12, 11	3
Automated data coding	11, 12, 14	3
Manipulating data for report input	11, 14	2
Large amounts of data	7, 12, 9	3
Time-consuming data extraction	7, 9	2

Table B.4: Codes within the theme data quality.

Theme: Data quality	**Interviewee source**	**Count**
Uncoded data	10, 12, 9, 13	4
Insufficient coding definitions	10, 9, 6, 11	4
Data validation	3, 11, 12, 9, 7, 14, 15	7

Explanatory data naming	3	1
Manual manipulation/correction of data	11, 12, 13, 14	4
Data consistency among systems and servers	7, 12	2
Quality improves through feedback loop	9	1
Lack of insight in how underlying data is derived	14	1

Table B.5: Codes within the theme reporting needs.

Theme: Reporting needs	**Interviewee source**	**Count**
Visualize to identify situation	10, 5, 1, 6, 9, 13, 14, 15	8
Visualize for root cause analysis	10, 6, 9, 13, 14, 15	6
Report detail level	10, 3, 11, 7, 9, 13, 15	7
Visualize actuals against targets	10, 8, 13, 14, 15	5
Need of report best practices	10, 5, 3, 1, 9, 14	6
Real-time report updating	5, 1	2
Specification of report content	5, 1, 7, 6, 14, 13, 15	7
Manually consolidating mill reports	9	1
Visualize trends	6, 1, 13	3
Digital reporting	14	1
Specify data source on report	11, 14	2

Table B.6: Codes within the theme reporting situation.

Theme: Reporting situation	**Interviewee source**	**Count**
Long report lead times	13	1

Static reports	13, 14, 11	3
Manual reporting work	4, 3, 8, 11, 7, 9, 5, 13, 15	9
Mill-specific reporting	2, 3, 1, 9, 8, 15	6
Multiple reports per KPI	12, 13	2

Table B.7: Codes within the theme organization.

Theme: Organization	**Interviewee source**	**Count**
Expensive licenses restrict information access	10, 11, 7, 3	4
User friendliness	10, 11, 14	3
Awareness of machine uniqueness	10, 12	2
Lack of report ownership	10, 5, 2, 1, 11, 12, 12, 14	8
Reporting integrity	10, 13, 14	3
Improved reporting for time-savings	10, 9, 11, 13, 14, 15	6
Data ownership	4, 11, 12, 13, 14, 15	6
Company-wide reporting standards	2, 6, 8, 11, 9, 13, 15	7
Lack of IT resources/capabilities	13, 14	2
Lack of role structure, incidental work tasks	14, 11	2
Ownership clarity	15	1

Table B.8: Codes within the theme information & knowledge.

Theme: Information & Knowledge	**Interviewee source**	**Count**
Educate operators in coding data	10, 8, 11	3
Information transparency	10, 3, 6, 7, 13, 14, 15	7

Information frequency needs	10, 1, 12, 11, 13, 15	6
Support community for BI solution	10, 11, 14	3
Internal knowledge sharing for reporting	11, 15	2
Educating in systems	12, 13, 14	3

Table B.9: Codes within the theme culture.

Theme: Culture	**Interviewee source**	**Count**
Lack of unified reporting culture	1, 2, 9	3
Change aversion	2, 11, 14	3
Aversion to responsibility	11	1
Operators give low priority to coding	12	1
Creator feels responsibility	14	1
Adapt to peer's way of working	12	1
Department collaboration	14, 11	2

Table B.10: Codes within the theme IT.

Theme: IT	**Interviewee source**	**Count**
Data availability within organization	11, 9, 14, 13	4
Server workload	10, 14	2
Single data origin	10, 7, 12	3
Data consolidation (division reporting cube)	5, 4, 3, 11, 7, 9, 13	7
Lack of mill-level data warehouse	5, 4, 7, 14	4
Ability for formatting and calculating in tools	3	1
Optimized OLAP cubes	3, 5, 14, 13	4

No constraints for tool selection	3, 11	2
Cloud and local data	3, 1, 11, 7, 14	5
Similar capabilities among mill systems	6, 7, 9, 15	4
Time-consuming setup for report data sources	11, 5, 14	3
Current system inflexible and not user friendly	11, 7, 12, 1, 13, 14	6
Report overflow	13	1
Lack of goals target data in data source	13	1
Coding data flexibility	13	1
Resource intensive to create new reports	13	1
Scalability in data sources	14	1
Report platform accessibility	14, 11	2

Table B.11: Codes within the theme decision-making.

Theme: Decision-making	**Interviewee source**	**Count**
Sub-optimizations for cost savings	10, 8	2
Prioritize efforts	10, 6, 8, 9, 13, 15	6
Need for faster decisions based on data	10, 9, 6	3
Decisions to be made based on data	10, 13	2
Modelling scenarios	10, 6, 7, 9, 8	5
Investment decisions	6	1
Standardize to benchmark and compare	15	1

Table B.12: Codes within the theme governance.

Theme: Governance	Interviewee source	Count
Access rights to data	5, 3, 11, 13	4
Data source access via reports	3, 11	2
Policies for report distribution	3	1
Access rights to reports	6, 11	2

Table B.13: Codes within the theme KPI.

Theme: KPI	Interviewee source	Count
KPI naming variance	10, 13	2
Mill's interpretation of KPI definitions	10, 4, 2, 6, 7, 14, 13	7
KPI ownership (mill and division)	4	1
Common KPI definitions exist	1, 7, 13	3
Unclear/Insufficient KPI definitions	8, 7, 14, 13	4
KPI importance	13, 12, 15	3
Redefining KPI - adjustment of codes and RAPS	14	1

B.2 Codes and themes from interview round 2

Table B.14: Codes within the theme capabilities.

Theme: Capabilities	Interviewee source	Count
Realtime updating exists	17	1
Manual work	17	1
Lack of root cause understanding	18	1
Reduce involved people	16	1
Data availability	16, 17	2
Varying production preconditions	16	1

Table B.15: Codes within the theme culture.

Theme: Culture	Interviewee source	Count
Communicate culture change	17	1
Impatiance in change projects	17	1
Customer awareness	17	1
Informed decisions	17	1
Mill kingdoms	17	1

Table B.16: Codes within the theme financials.

Theme: Financials	Interviewee source	Count
Leverage asstets	17	1
Staff cost savings	17	1
Large fixed costs	18	1
Follow-up on product margins	18	1

Operations affect financial results	16, 17	2

Table B.17: Codes within the theme information sharing.

Theme: Information sharing	**Interviewee source**	**Count**
Inconsistent mill information	16	1
Hard to see top level goal progress in short term	17	1
Information frequency needs	16, 17, 18	3
Accurate and timely information	16, 17	2
Varying information needs	16, 18	2
Identify strengths	16	1
Situation assessment	17	1
Information availability	16	1
Communicating goals	17	1
Ease of giving feedback	17	1

Table B.18: Codes within the theme KPI.

Theme: KPI	**Interviewee source**	**Count**
Quality affects sales	16	1
Varying OEE targets	16	1
KPI consistency on top level	17	1
KPI variety on low detail level	17	1
Time efficiency affect safey	17	1
OEE importance	18	1
Safety importance	18	1
Some KPIs hard to quantify	18	1

Quality efficiency affect NPS	17, 18	2
Product assortment effect on OEE	16	1
Existing KPIs satisfy needs	17	1
NPS importance	18	1
Fixed cost effect OEE	18	1
Net fixed cost effect EBITDA	18	1

Table B.19: Codes within the theme Operation activities.

Theme: Operation activities	Interviewee source	Count
Automation efforts	18	1
Try to affect demand	18	1
Implement lean practices	17	1
Reduce shutdowns	17	1
Machine utilization	17	1
Reduce claims/returns	17	1
Solving problems permanently	17	1
Improved delivery	17	1

Table B.20: Codes within the theme Operation planning.

Theme: Operation planning	Interviewee source	Count
Forecast follow up	16, 18	2
Proactivity	16, 17	2
Trend analysis	16, 17	2
Prioritize efforts	17	1
KPI follow up	16, 18	2

Activity plans for goals	17	1

Table B.21: Codes within the theme organization.

Theme: Organization	**Interviewee source**	**Count**
Improve mill decision autonomy	17	1
standardization of reporting	18	1
Communicate to upper management	16	1
Assign responsibility/ownership	16, 17, 18	3
Sharing knowledge	16	1
Autonomous divisions	17	1
provide value to operations	16, 17	2

Table B.22: Codes within the theme reporting.

Theme: Reporting	**Interviewee source**	**Count**
Mill-specific reporting	16	1
Visualize progress and deviations	16	1
Root cause analysis	16, 17	2
Daily actuals vs targets	16, 17	2
Detail levels	16, 17, 18	3
Goal visualization	17	1
Automation of reporting	18	1
Information about planned stops	16	1

Table B.23: Codes within the theme risks.

Theme: Risks	Interviewee source	Count
Safety risks	17	1
External risks	17, 18	2
Dependency on demand	18	1
Raw material availability	17, 18	2
R&D to have good products	18	1
Risk of strike	18	1

Table B.24: Codes within the theme strategy.

Theme: Strategy	Interviewee source	Count
Change takes time	17	1
Avoid investments	17	1
Investment plan for 5y	17, 18	2
Invest in automation	18	1
Investments in pulp mills	18	1
Benchmarking (future use)	16	1
become market leaders	17	1
consistent quality	18	1
high service levels	18	1
loyal customers	18	1
expand measure areas	18	1
Goal plan	17	1
Aggressive targets	17	1
Management responsible for targets	18	1

B.3 Themes and documents from the document analysis

Table B.25: The themes from the requirements elicitation phase in the BI implementation life-cycle.

Themes	Document
KPI definition	KPI document
KPI calculations	KPI document
KPI input data	KPI document
Report users	KPI document
Periodicity	KPI document

Table B.26: The themes from document analysis used for the BIM.

Themes	Document
Goals	Strategy document
Domain assumptions	Strategy document
Situations	Strategy document
Processes	Strategy document
Indicators	Strategy document

C

Appendix - Problem statements, objectives and KPI summaries

This appendix contains problem statements, objectives and summaries of KPI documents that were used in the BI implementation life cycle.

C.1 Problem statements and objectives

Table C.1 present the problem statements and C.2 present the objectives that were generated from applying the method.

Table C.1: The derived problem statements from the first step of the BI implementation life-cycle.

Problem	Source	Description
Information Transparency	3, 6, 7, 10, 13, 14, 15	Information was not accessible throughout the organization leading to bad situation awareness
Large manual work-load	3, 4, 5, 7, 8, 9, 11, 13, 15	Preparing reports require manual ad hoc work both in extracting data but also in structuring that data.
Inconsistent reporting	1, 2, 3, 8, 9, 15	The inconsistency in reporting made it hard for decision-makers to understand, benchmark, and compare performance at the different mills.
Unclear report ownership	1, 2, 5, 10, 11, 12, 13, 14	The lack of report ownership meant that no one had the responsibility to make sure that the right people got the right information.
Unclear data ownership	1, 2, 5, 10, 11, 12, 13, 14	The lack of data ownership meant that no one had the responsibility to make sure that data was correct and validated.

No clarity in information needs	3, 7, 9, 10, 11, 13, 15	The unclarity in information needs and information flows often resulted in inadequate information at all levels in the organization.
Data validation	3, 7, 9, 11, 12, 14, 15	Manual data extraction and coding of incidents/event can lead to insufficient data quality.
Varying production preconditions at mills	8, 10, 14	Differing production preconditions leads to variance in OEE among mills.
Machine uniqueness	6, 9, 10, 11, 12, 13	Machines are to some extent unique which hinders standardization on a low detail level.
Reporting integrity	11, 14	Risk of data manipulation for distorting OEE.
Insufficient coding definitions	6, 9, 10, 11	Coding categories for incidents/events do not satisfy the OEE definition.
Lack of company-wide reporting standards	2, 6, 8, 9, 11, 13, 15	Leads to mill-specific reporting that cannot be benchmarked or compared.
People need information on different time intervals	1, 10, 11, 12, 13, 15	Need many different static reports to satisfy needs at different levels in the organization.
Lack of data warehouses	4, 5, 7, 14	Requires IT capabilities and resources that are limited.
KPI naming variance	10, 13	Variance in naming KPIs at mills can risk confusion.
Inflexible current systems	1, 7, 11, 12, 13, 14	Current systems require a lot of manual work and are very inflexible. This causes many static reports for reporting similar information.

Table C.2: The derived objectives from the first step in the BI implementation life-cycle.

Objective	Source	Description
Reporting should improve operations performance	1, 5, 8, 9, 10, 13, 15	The purpose of OEE reporting in a BI solution should be to improve performance so that costs can be reduced and profits increased.
Visualize data to identify situation	1, 5, 6, 9, 10, 13, 14, 15	Data should be visualized so that employees can easily understand the current operations performance situation.
Visualize data to perform root cause analysis	6, 9, 10, 13, 14, 15	Data should be visualized so that one can derive why the current operations performance situation is what it is.
Specification of report detail needs	5, 6, 7, 11, 13, 14, 15	Reporting through a BI solution should support appropriate information presentation at all organization levels.
Reduce manual reporting work	3, 4, 5, 7, 8, 9, 11, 13, 15	Reporting should be able to be automated to a great extent in terms of data preparation, data extraction, report building.
Transparent information-sharing	3, 6, 7, 10, 13, 14, 15	Reports should be available for internal use throughout the entire organization.
Prioritize improvement efforts based on reports	6, 8, 9, 10, 13, 15	Reporting should support decision-makers when deciding what efforts to make to improve operations performance and hence reduce costs and increase profits.
Ownership structures	1, 2, 5, 10, 11, 12, 13, 14	The organization needs defined structures for ownership to make sure that reports contain the right data and that the data is correct.
User-friendly systems	1, 7, 10, 11, 12, 13, 14	Adopted systems must be easy to use for all stakeholders with varying IT competence.
Reporting prioritize value-creation for mills	9, 12, 13, 15	It is significant that mills can benefit from the reporting efforts.

Use report for daily production follow-up	7, 11, 13, 14, 15	Necessary to improve Operations performance and act quickly and proactively.
Reporting actual performance against target performance	8, 10, 13, 14, 15	To see how well Operations perform against the targets that have been set together with division management.
Education in company systems	8, 10, 11, 12, 13, 14	In order to make sure that data is of good quality and information is correct and useful.
Division data warehouse and OLAP for Operations data	3, 4, 5, 7, 9, 11, 13, 14	This would allow for easy report creation on division level suited to management needs. “Self-service” BI.
KPI ownership	4	For making sure that KPI is correct and adequately reported to the division from mills.

C.2 Validation of problem statements and objectives

This section describes the process of validating problem and objective statements from the initial phase of the BI implementation life-cycle, i.e. the validation workshop.

Initially, the researchers presented all produced problem statements and objectives to the project steering group. The problems and objectives were derived from the coded interview data. To validate the statements the researchers went through and described the statements one by one, described where they originated from, and then the steering group could either accept or reject the statement. If a majority agreed on either accepting or rejecting, that action was taken.

Following that, all members of the steering group individually prioritized all statements. From this ranking, together with an assessment by the researchers, the resulting prioritized problem statements and objectives presented in the thesis were decided.

C.3 Input data for requirements engineering

The following section includes a description of the KPI definitions needed to produce requirements, see Table C.3-C.7. The Operations performance indicators are calculated as defined, and used for internal and external reporting. Operations performance should be reporting and followed by business areas, mills, and support functions on an online, monthly basis.

Table C.3: Summary of overall equipment efficiency (OEE)

Attribute	**Summary**
KPI	OEE
Definition	The Overall Equipment Efficiency[%] is a KPI used for board and paper machines at the case company. It is used for both external and internal reporting on Operations performance.
Calculation	OEE[%] = MaterialEfficiency[%] * TimeEfficiency[%] * SpeedEfficiency[%] * QualityEfficiency[%]
Input data	See definitions below.
Effect on other KPIs	TRI rate Net fixed costs NPS Net prime ton/day Variable production cost
Users	Operations developers Mill controllers Division controllers Machine operators Production management Division management (operations, strategy, and division lead)

Periodicity	Daily - for production Monthly - for controlling/finance Annually - for target follow-up and target planning

Table C.4: Summary of time efficiency.

Attribute	Summary
KPI	Time efficiency
Definition	Time efficiency is the fraction of operating time that is production time. Operating time is defined as all scheduled and unscheduled shutdowns and break times as well as the production time. Hence, production time is when the machine is "up and running".
Calculation	TimeEfficiency[%] = (Production time[h]/Operating time[h]) * 100%
Input data	Available time[h] Market curtailments[h] Scheduled major shutdowns[h] Exceptional and unforeseeable event[h] Strike[h] Unscheduled shutdown time only due to technical reasons[h] Unscheduled shutdown time due to non-technical reasons[h] Scheduled shutdown time[h] Break time[h]
Effect on other KPIs	OEE Net prime ton/day TRI rate Reduce net fixed costs

Users	Operations developers Mill controllers Division controllers Machine operators Production management Division management (operations, strategy, and division lead)
Periodicity	Daily - for production Monthly - for controlling/finance Annually - for target follow-up and target planning

Table C.5: Summary of material efficiency

Attribute	**Summary**
KPI	Material efficiency
Definition	Indicates the share of net production after all material losses of the process (length, trim, and reject losses)
Calculation	MaterialEfficiency[%] = 100% - LengthLosses[%] - TrimLosses[%] - RejectLosses[%]
Input data	LengthLosses[%] are losses of board length in any process stage of the board machines. Based on area or weight as % of gross reel production TrimLosses[%] are defined as the material loss in board width. Calculated as % of possible board width measured in area or weight. RejectLosses[%] are all corrections that are made to the 'after winder net' production due to projected production, warehouse or market returns as well as good production after salvage winder. Calculated based on area or weight as % of gross reel production.
Effect on other KPIs	OEE Net fixed costs

	Variable production costs NPS
Users	Operations developers Mill controllers Division controllers Machine operators Production management Division management (operations, strategy, and division lead)
Periodicity	Daily - for production Monthly - for controlling/finance Annually - for target follow-up and target planning

Table C.6: Summary of speed efficiency

Attribute	Summary
KPI	Speed efficiency
Definition	Speed efficiency is calculated as the ratio of average speed and maximum proven rate. Each product produced during the reporting time frame has to be considered separately and is weighted by the runtime.
Calculation	SpeedEfficiency[%] = Avg speed[m/min]/ maximum proven speed[m/min]
Input data	Speed of machine reels[m/min] Runtime[min]
Effect on other KPIs	OEE Net prime ton/day Net fixed costs
Users	Operations developers

	Mill controllers Machine operators Production management
Periodicity	Daily - for production Monthly - for controlling/finance Annually - for target follow-up and target planning

Table C.7: Summary of quality efficiency

Attribute	Summary
KPI	Quality efficiency
Definition	Quality efficiency is calculated as the percentage of total produced board that is classified as prime grade. Non-prime grade is board/paper that cannot be sold for their intended purpose that they were originally produced for or at the intended price.
Calculation	Quality efficiency[%] = Prime grade production[m2]/Total production[m2]
Input data	Share of prime grade production Total board production
Effect on other KPIs	OEE Net fixed costs Net prime ton/day
Users	Operations developers Mill controllers Machine operators Production management
Periodicity	Daily - for production Monthly - for controlling/finance

	Annually - for target follow-up and target planning

D

Appendix - Definitions, acronyms, and abbreviations

This appendix includes a list of all definitions, acronyms, and abbreviations that were derived in the first step of the DM-BI requirements elicitation method.

Data	Anything that can be processed into information
Information	Processed data that are understandable and can be acted upon
Trend analysis	Visualize historical data in a manner so that patterns can be identified to increase the understanding of operations performance
Operations performance	A measure of the organization's overall Operations performance in terms of speed, quality, financials and actuals measured against targets
Operations data	Data about the operational performance registered by the board machines and manually coded by operators
Heterogeneous data sources	The fact that data can originate from sources such as SQL databases on mill level, cloud databases, excel sheets from external or internal sources, OLAP cubes, and data warehouses from other departments and division etc.
Incident codes	Codes that are used to describe the cause of an incident/event in production
Root cause analysis	The ability of deriving causes for incidents/events that occur unexpectedly in production. The analysis allows prioritization of efforts to mitigate these incidents/events in the future

Dynamic reporting	Interactive reports where features can be used to filter information on different criteria such as periods, products, machines etc.
User friendliness	Intended users should find the interface intuitive and easy to use
Information transparency	The ability for information to travel through the organization without the need of person-to-person-communication
Report	A specified bundle of information that contains graphics to make it understandable and actionable in a specified use case
Tool support	Accessible help and information about a BI solution, either internally or externally (support center/community)
Access rights	Assigned authorization levels specifying the access to a report in a BI solution
Processing capacity	How much processing capacity e.g. servers (such as database servers) have. This restricts how much they can be utilized for reporting purposes
Ad hoc reporting	Reports that are built as a need emerges to satisfy that specific need
Uncoded data	Incidents/events in production that have not been assigned an incident code
Cloud service provider	Companies that offer BI software along with other cloud services either as IaaS, SaaS, or PaaS.
Data quality	That data is of value and correctly coded
Use case	The purpose of a report
Analysis paralysis	An abundance of data leads to overanalyzing without coming to a conclusion in a timely manner
Confidential information	Information that is not accessible outside of the organization
Target data	Data that represents goals set by the division

Definitions	Descriptions of KPIs; how they are measured, calculated and classified
Organization-wide	Throughout the division

E

Appendix - Requirements produced from the BIM

This appendix includes all requirements produced from the BIM and a higher resolution figure of the BIM model.

E.1 Requirements from the BIM

Table E.1: All requirements produced from the BIM.

Index	Requirement	Entity
B1	System should have access to net prime ton/day data	Goal
B2	System should be able to visualize trends of net prime ton/day development	Goal
B3	System should have access to target data for net prime ton/day	Goal
B4	System should have access to TRI ratio data	Goal
B5	System should be able to visualize trends of TRI ratio development	Goal
B6	System should have access to target data for TRI ratio	Goal
B7	System should have access to NPS data	Goal
B8	System should be able to visualize trends of NPS development	Goal
B9	System should have access to target data for NPS	Goal
B10	System should have access to time efficiency data	Goal
B11	System should be able to visualize trends of time efficiency development	Goal
B12	System should have access to target data for time efficiency	Goal
B13	System should have access to production time data	Goal

B14	System should be able to visualize trends of production time development	Goal
B15	System should have access to target data for production time	Goal
B16	System should have access to operating time data	Goal
B17	System should be able to visualize trends of operating time development	Goal
B18	System should have access to target data for operating time	Goal
B19	System should have access to speed efficiency data	Goal
B20	System should be able to visualize trends of speed efficiency development	Goal
B21	System should have access to target data for speed efficiency	Goal
B22	System should have access to avg. speed data	Goal
B23	System should be able to visualize trends of avg. speed development	Goal
B24	System should have access to target data for avg. speed	Goal
B25	System should have access to net fixed cost data	Goal
B26	System should be able to visualize trends of net fixed cost development	Goal
B27	System should have access to target data for net fixed cost	Goal
B28	System should have access to of claims data	Goal
B29	System should be able to visualize trends of of claims development	Goal
B30	System should have access to target data for of claims	Goal
B31	System should have access to material efficiency data	Goal
B32	System should be able to visualize trends of material efficiency development	Goal
B33	System should have access to target data for material efficiency	Goal
B34	System should have access to material waste in production data	Goal
B35	System should be able to visualize trends of material waste in production development	Goal
B36	System should have access to target data for material waste in production	Goal
B37	System should have access to OEE data	Goal

B38	System should be able to visualize trends of OEE development	Goal
B39	System should have access to target data for OEE	Goal
B40	System should have access to quality efficiency data	Goal
B41	System should be able to visualize trends of quality efficiency development	Goal
B42	System should have access to target data for quality efficiency	Goal
B43	System should have access to variable production cost data	Goal
B44	System should be able to visualize trends of variable production cost development	Goal
B45	System should have access to target data for variable production cost	Goal
B46	System should have access to MPR data	Domain assumption
B47	System should be able to visualize trends of MPR development	Domain assumption
B48	System should have access to target data for MPR	Domain assumption
B49	System should be able to break down OEE data into quality efficiency data, material efficiency data, speed efficiency data, and time efficiency data	Refinement
B50	System should be able to break down material efficiency data into of claims data and material waste in production data	Refinement
B51	System should be able to break down time efficiency data into production time data, and operating time data	Refinement
B52	System should be able to break down speed efficiency data into avg. speed data data, and MPR data	Refinement
B53	System should be able to access product assortment data	Situation
B54	System should be able to access demand data	Situation
B55	System should be able to access spot market price data	Situation

B56	System should be able to access plant investment data	Situation
B57	Changes in net prime ton/day shall impose a change in customer satisfaction by a magnitude of (++)	Influence
B58	Changes in of claims shall impose a change in customer satisfaction by a magnitude of (++)	Influence
B59	Changes in production time shall impose a change in safety by a magnitude of (+)	Influence
B60	Changes in production time shall impose a change in net prime ton/day by a magnitude of (++)	Influence
B61	Changes in avg. speed shall impose a change in net prime ton/day by a magnitude of (++)	Influence
B62	Changes in quality efficiency shall impose a change in net prime ton/day by a magnitude of (++)	Influence
B63	Changes in production time shall impose a change in net fixed cost by a magnitude of (++)	Influence
B64	Changes in avg. speed shall impose a change in net fixed cost by a magnitude of (-)	Influence
B65	Changes in of claims shall impose a change in net fixed cost by a magnitude of (+)	Influence
B66	Changes in quality efficiency shall impose a change in net fixed cost by a magnitude of (-)	Influence
B67	Changes in demand shall impose a change in operating time by a magnitude of (++)	Influence
B68	Changes in demand shall impose a change MPR by a magnitude of (+)	Influence
B69	Changes in spot market prices shall impose a change in variable production cost by a magnitude of (–)	Influence
B70	Changes in spot market prices shall impose a change in plant investments by a magnitude of (-)	Influence

E.2 The BIM model

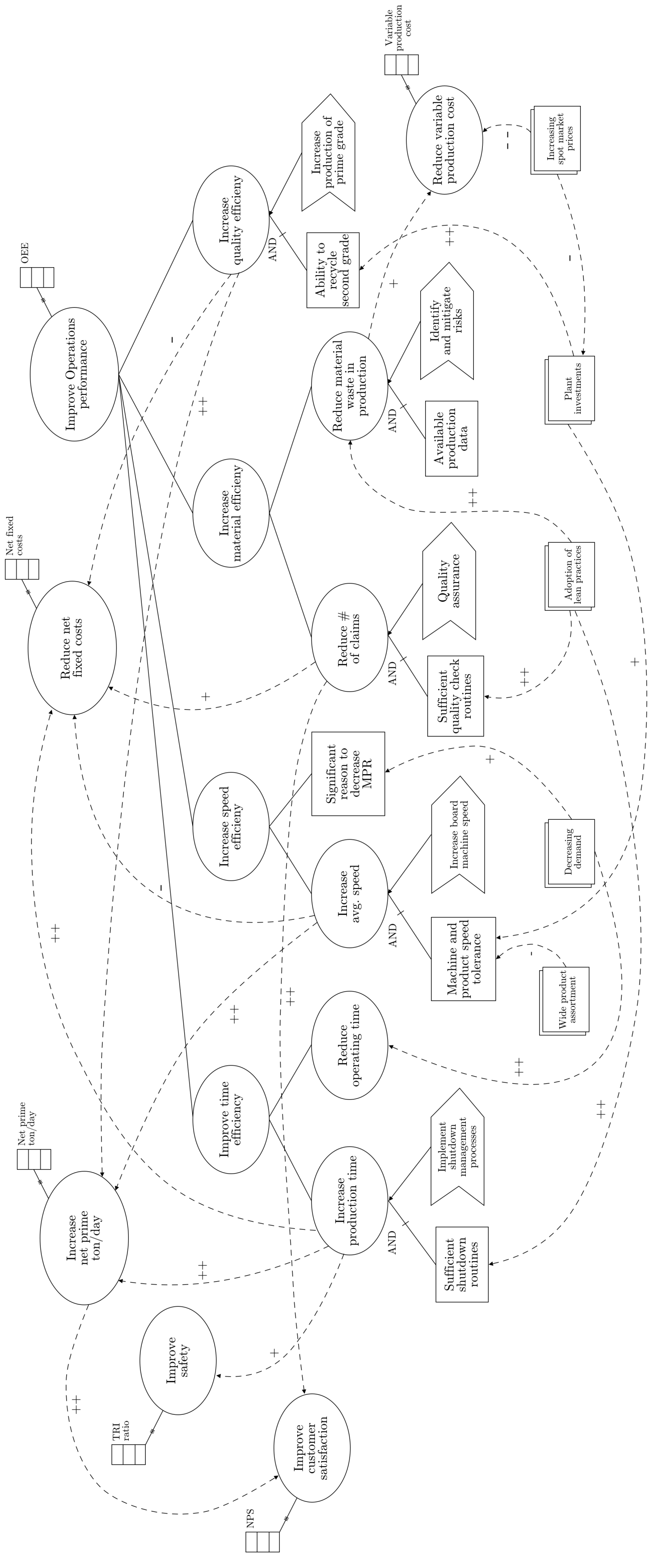

Figure E.1: Higher resolution figure of the BIM model.

F

Appendix - Requirements prioritization

This appendix includes a full list of graded requirements produced from the three methods as prioritized by the project steering group.

Table F.1: All requirements with their associated average grade from the grading process.

Index	Avg grade	Index	Avg grade	Index	Avg grade
RS12	5	RG1	4,5	RC3	3,5
B1	5	RG4	4,5	RG13	3,3
B4	5	RG6	4,5	RR11	3,3
B7	5	B3	4,5	RR12	3,3
B10	5	B6	4,5	RC9	3,3
B13	5	B9	4,5	RS11	3,3
B16	5	B12	4,5	RG7	3
B19	5	B15	4,5	RG9	3
B22	5	B18	4,5	RS3	3
B25	5	B21	4,5	RS9	3
B28	5	B24	4,5	RS13	3
B31	5	B27	4,5	B57	3
B34	5	B30	4,5	B58	3
B37	5	B33	4,5	B59	3
B40	5	B36	4,5	B60	3
B43	5	B39	4,5	B61	3
B46	5	B42	4,5	B62	3
R8	4,8	B45	4,5	B63	3
RG2	4,8	B48	4,5	B64	3
RG10	4,8	R3	4,3	B65	3
RS1	4,8	R4	4,3	B66	3
RS7	4,8	RG11	4,3	B67	3

B2	4,8	RC4	4,3	B68	3
B5	4,8	RS6	4,3	B69	3
B8	4,8	RS14	4,3	B70	3
B11	4,8	R9	4	RG14	2,8
B14	4,8	RG5	4	RR13	2,8
B17	4,8	RG8	4	RC7	2,8
B20	4,8	RR6	4	B53	2,8
B23	4,8	RR7	4	B54	2,8
B26	4,8	RC1	4	B55	2,8
B29	4,8	RC5	4	B56	2,8
B32	4,8	RC8	4	RR1	2,7
B35	4,8	RS4	4	RG12	2,5
B38	4,8	RS5	4	RG3	2,3
B41	4,8	RS10	4	RR4	2,3
B44	4,8	R1	3,8	RS8	2,3
B47	4,8	R2	3,8	RR8	2
B49	4,8	RR2	3,8	RR9	2
B50	4,8	RR5	3,8	RR10	2
B51	4,8	RR8	3,8	R7	1,8
B52	4,8	RC2	3,8	RR3	1,5
R5	4,5	RC10	3,8	RC6	1,5
R6	4,5	RS2	3,8		

G

Appendix - Requirements elicitation concepts

This appendix includes a list of requirements elicitation concepts that are suggested to be analyzed when producing requirements in the new method.

Results from reading reviews of tools and comparing them:

- Support functions
  - Peers (online)
  - Professional support
- Implementation process
  - Time
  - Hard/easy
  - Resources/Competences
- Extensiveness of use within organization
- Similarity to current software used by end users
- Capability to model business scenarios
- Graphical capabilities for visualization
- End user training availability
- Data source connectors
- End user's ability to create reports
- Plotting trends
- Making predictions
- Model business targets
- Cross-info, realtime data and data accessed on the internet
- Desktop and/or web
- Web and/or mobile
- Amount of data in organization
- Shareability
- Objectives for using a BI solution
- Cloud questions, hybrid/on-premise
- Overall cost and pricing
- Integration questions
- Completeness of product
- Customizability
- Permissions
- Update frequency (new versions of software)

- Addons availability
- Response rates from support
- Deployment time
- Usage rate in organization
- Tool speed
- Language support
- Administrative resources in organization

H

Appendix - Evaluation workshop

This appendix includes the feedback, from the evaluation workshop held with the steering group. Each question and its corresponding answers are presented in Table H.1. The number in the parentheses indicates how many that supported that specific answer.

Table H.1: A summary of the findings from the evaluation workshop.

Question	**Comments**
Can you understand the method?	The method can be understood. (8)
	It seemed like a reasonable process. (7)
	Most parts can be understood well but it feels like a large effort to select a BI solution. (3)
	The visuals aided the comprehension of the method. (4)
Can you understand the purpose of the method?	The purpose was to select a BI solution. (8)
	The purpose was to understand organization's needs of BI and the BI maturity. (1)
Would the organization be able to use this method?	It would be doable. (7)
	Would probably be hard to find someone internally to take on the full method. (5)
	Some terminology is difficult and might require definitions or that practitioners have knowledge before applying the method. (2)

	Theoretically yes, but in practice, it could be hard to allocate resources and it seems likely that there would be a need for external expertise to ensure the best possible selection. (2)
How long do you estimate that the suggested method will take to complete?	Difficult to estimate. At the case company, due to its size, it could probably take everything from 1-3 years. Depends on if it should be organization-wide or only for certain divisions/teams/functions. (1) Would depend on organization size. Probably 3-6 months for a smaller organization. (3) At least one year. (3) It is also important to consider the time required for implementation. Therefore, perhaps the BI solution selection should not take too long, e.g. not longer than 6 months. (1) It depends on how urgent it is. (3) Pre-study and feasibility study will probably be the most time-consuming, i.e. mapping users, use cases etc.(1)
Can the steering group asses the concepts from Appendix G? If not, who can?	From their own perspective yes. (5) Would need to have more perspective from more users, i.e. not only managers. (2) Some terminology is unknown to individual steering group members, but together they believed they could understand it. (3) Needs a cross-functional team since some concepts are more related to IT while others concern e.g. costs. (4)

	Unlikely that one person could assess this by themselves. (7)
For each phase, is it clear what is supposed to be input and output?	The input for the first two phases is not stated but it is intuitive to derive based on the expected output. (3) “Understanding of BI maturity” quite fuzzy. Unclear how this assessment is done and what it results in. (2) Figure was helpful in describing the flow of the method and how different parts connected to each other. (7) It was clear. (7) It was very clear for the three last phases. (8)
For each phase, is anything missing?	Validation of the stakeholder map to make sure that there are not too many or too few interests present in the project. (1) Indication of who could be a plausible stakeholder, i.e. what roles are relevant to include in a project such as this. (2) Would be good to understand how to scan the market in the market analysis, i.e. where to look. (1)
For each phase, is anything redundant?	Unclear what the objectives from the first phase are used for. (2) It seemed reasonable. (6)
Are there any phases that are missing or redundant?	Organizational feasibility is more of a managerial issue and will not affect what solution that can be used for BI. (1)

	Perhaps not all requirements elicitation concepts would be necessary to study in Appendix G since the selection mainly would be based on the feasibility study rather than the requirements. In the end, the revealed constraints from the feasibility study are probably more important for a company. (2) Even if it is not done in full and the decision is not optimal according to the method, the outcome would not be catastrophic since it is a support system that probably will satisfy the majority of the organization's needs regardless. (1) Hard to assess without applying it in full. But one could imagine that it would be very time-consuming to complete the entire method, and therefore perhaps not all phases are necessary in practice. (3) Nothing was missing, the method would help the organization to not only select a BI solution but also to understand where an organization stands in terms of BI. (3)
Would the outcome have been different if this method had been used?	The requirements would have been more specific to the actual BI solutions so that a more actionable comparison could have been made. Not definite that this would aid. (3) Probably yes. But it is obvious that the differences between the BI solutions are very small. It would probably therefore be better to produce more BI-solution specific requirements which this method suggests. (2) The outcome would probably have been the same but the process would have been much easier to understand and perhaps could have been done without external help. (3)