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Assessing quality of care by making use of Business Intelligence.

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In this master thesis we will focus on how business intelligence (BI) can support the assessment of quality of care in academic hospitals and on how the current BI environment maturity in which the BI solution is used can be assessed and improved to enlarge the contribution of the BI solution in the assessment of quality of care.

PREFACE

In this master thesis I research how BI can be used to assess quality of care, this research is mainly conducted at the academic hospital in Utrecht (UMCU). In this preface I would like to use the opportunity to thank my supervisors of the University of Utrecht and UMCU which supported me and assisted me during my research.

First, I would like to thank my 1st and 2nd supervisor dr. Ronald Batenburg and dr. Marco Spruit for their support, feedback and advice during the project.

Second, I would like to thank my external supervisor Dennis Mul, who offered me the opportunity to do my research at UMCU. He has been extremely helpful in finding the right people for my research, and providing access to the sources that I needed for my research. He also provided opportunities to ask questions.

Besides the supervisors I would like to thank all interviewees, even if they had very busy schedules, they took the time to answer my questions and to give feedback. These interviewees made it possible to do my research.

Finally I would like to thank my friends and family for supporting me during this research.

Fiona Gelink

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1. Research approach

1.1 Problem statement

While medical science and technology has advanced the last couple of years, are healthcare providers still not able to provide high quality of care on a constant base. This implies that increased know-how and increased resources cannot automatically be translated in the delivery of high quality of care. However this high quality of care is expected by the population and healthcare workers (WHO, 2006).

According to the Institute of Medicine (2011) are the underlying reasons for inadequate quality of care:

- The growing complexity of medical science and technology
- Increase chronic conditions
- A poorly organized delivery system and
- Constraints in exploiting the revolution in information technology.

Healthcare institutes today need to know more, manage more, watch more, do more and involves more people than there is ever been. The current methods of organizing and delivering care are unable to meet the expectations of patients because the medical science/knowledge and technology involved in healthcare have advanced more rapidly than the ability to deliver them safety, effectively and efficiently.
One of the consequences of the advanced medical science and technology is that people are living longer now. Innovations in medical science and technology have contributed in increasing the life expectancy. One consequence of the aging population is an increase in the incidence and prevalence of chronic conditions. Effective care of the chronically ill is a collaborative process involving patients, family of patients, and multiple providers. The collaboration adds another layer of complexity to the delivery of health care which influences the quality of care. Besides the growing complexity of medical science and technology, and the collaborative complexity there is a third underlying reason for inadequate quality of care. The prevailing model of healthcare delivery is complicated and exists out of compromising layers of processes and handoffs, that patients and families find confusing and clinician see as wasteful. Care delivery processes are often experienced as overly complex, contain steps and handoffs that slow down the care process and decrease the safety of the patient. Another underlying reason for inadequate quality of care is the constraints on exploiting the revolution in information technology. Information technology can contribute to an improved healthcare delivery system. However, there are many technical, organizational, behavioral and public policy challenges to greater use of information technology.

How a health institute organizes the delivery of care has become a very important issue. Orienting systems on how to deliver, evaluate and improve the quality of care are fundamental to meet the expectations of the population and the healthcare worker.

Health care quality problems can be classified into three categories (Korenstein et al., 2012):

- Underuse: is the failure to provide a health care service when it would have produced a favorable outcome for a patient.
- Overuse: occurs when a health care service is provided under circumstances in which its potential for harm exceeds the possible benefit.
- Misuse: occurs when an appropriate service has been selected but a preventable complication occurs and the patient does not receive the full potential benefit of the service.

Reducing overuse and misuse improves quality of care and reduces the costs at the same time. This can contribute in the mission of most health institutes to decrease the health expenditure. However, fixing underuse problems nearly always results in both increased costs and increases quality. Health care quality problems influence the delivery of quality of care (Chassin et al., 1998). Therefore, it causes variations in the delivery of care.
Most of these quality problems are not unpredictable, rare or inevitable concomitants of the delivery of health care. Rather they are frighteningly common, often predictable, and frequently preventable (Chassin, 1998).

The Dutch Healthcare scores above average compared to other wealthy countries in the quality of the care (van den Berg et al., 2014). There are however a lot of variation in the delivery of quality of care and there is insufficient transparency.

As response, a Quality institute has been established in 2013. This is a part of the Care Institute since 2014. The Quality institute promotes professions in healthcare to develop quality criteria. These criteria should ensure that:

- the quality of care goes up;
- And care is transparent.

The quality criteria are developed by care providers, insurers, patient organizations and the Health Care Inspectorate (IGZ). The quality criteria exist out of quality indicators, which can be used to measure the quality of care. Reliable, transparent and comparable information on health care can be compared by making use of theses quality indicators. IGZ supervises the quality of Public health. The Health Care Inspectorate (IGZ) uses quality indicators to determine which issues require extra attention in a hospital or require further research. IGZ carries out phased and thematic supervision. For the phased supervision are indicators used to identify risks at individual

organizations or institutions. For the thematic supervision is the entire sector or specific parts object of supervision.
The indicators make it also easier for Dutch insurers to buy care based on not only the price but also on quality, and for patients it becomes easier to choose the right care-provider based on the quality of care outcome (van den Berg et al., 2014).

By making use of the quality indicators, hospitals can monitor if the quality of care stays high. Most of the data that is necessary to measure these indicators are stored in de databases of the electronic patients records (EPRs) and other applications that support the care processes. All care processes that take place around the care of the patients are supported by information processes which are registered in the EPR's and other applications. The EPR and these other applications which support the information flow are called information systems. These information systems are the backbone of an organizations information flow and the main vehicle for consolidating business information (Spil et al., 2002). The information systems are used in hospitals as a tool to support daily work. A lot of information is hidden in these information systems. The information/data in the information systems are nowadays mainly used to support the delivery of good care, for the communication between healthcare workers, for clinical decision making and for the continuity of care (Zegers et al., 2011).
This means that very useful data about the quality of care is stored in the databases of the information systems. There is a growing need to use the data of about the care in a hospital for multiple different purposes, than just for the continuity of care. The data that is generated during the information processes could be used for assessing the quality of care. This data is however unclear, inaccessible and incomplete. Most doctors and hospitals collect and manage health information pretty much the same way Hippocrates did 2,400 years ago. Paper is replaced for computers, but almost everything else is the same. Quality of care can however not be assessed until this unclear, incomplete and inaccessible data is transferred into useful data. Therefore, it is necessary to research how this data that is stored in the databases of the information systems can be transferred into useful data. This way, the data becomes more valuable to the hospitals and can be used to assess the quality of care.
Dutch hospitals also need this useful data to assess the quality of care; this can be done by making use of the quality indicators. By measuring the quality indicators Dutch hospitals know where quality of care can be improved and are able to submit external accountability to the health insurers and society (van den Berg et al., 2014). Spil (2002) argues that Business Intelligence solution can be used to gain a deeper understanding of the quality of care. A Business Intelligence solution enables interactive access to organized data. Therefore, it would be interesting to research how a Business Intelligence solution can contribute in the assessment of quality of care.

1.2 Research objectives

A BI solution can be used in a BI environment to access useful data. The BI solution is a tool that can be used to access data and the BI environment is the context in which the BI solution is used by the hospitals. In this master thesis we will focus on how a BI solution can be used to assess the quality of care in academic hospitals, and on how the current BI environment maturity can be assessed, to improve the use of a BI solution in the assessment of quality of care.

The first objective is to understand how a BI solution can be used in assessing the quality of care in academic hospitals. I would like to research the gap between what is necessary to assess the quality of care, and how a BI solution can be used fill in these needs.
The second objective is to develop a maturity model by which the maturity of a BI environment in academic hospitals can be measured. Better usage of a BI solution can contribute in the assessment of quality of care. The usage of a BI solution depends on the BI environment in which the BI solution is implemented. The maturity model should address the context (technology, usage, adoption and alignment) in which the BI solution is used, and the BI solution itself. The model should help the hospitals in measuring the current maturity of their BI environment, and provide guidelines to evolve to a higher maturity level.

1.3 Research questions

The main research question and the sub- research question are formulated to accomplish the objectives of this research. These sub- questions need to be answered to provide an answer to the main research question.

1.3.1 Main Research question

The main research question for this research is:

> "To what extent can a BI solution in Dutch hospitals be configured to situationally assess and incrementally improve the quality of care?"

1.3.2 Sub research questions

The following sub-research questions are formulated, which I would like to answer by doing this research.

What is quality of care?
This research question addresses the definition of 'quality of care' and describes the dimensions of quality of care. It is necessary to understand what quality of care is, in order to understand what is needed to assess the quality of care.

Why asses quality of care?
This research question addresses the motivation to assess quality of care. It is important to understand why the quality of care needs to be assessed. There are multiple reasons nowadays to assess the quality of care.

How to assess quality of care?
This research question addresses the assessment of quality of care. It is important to know which methods are available to assess the quality of care in academic hospitals.

What is a Business Intelligence solution?
This research question addresses the definition of Business Intelligence solution, and describes the three major components of a BI Solution. It is important to understand what a BI solution is, so, there can be determined which needs can be filled in by a BI solution, to assess the quality of care.

How can a Business Intelligence solution be used to assess quality of care?
This research question addresses how the quality of care can be assessed by developing a method. The method should provide a way to assess the quality of care by making use of a BI solution.

How can the maturity of a BI environment be assessed and improved?
The usage of a BI solution depends on the maturity of the BI environment, in which the BI solution is used. This research question addresses the maturity of a BI environment and provides a way to evolve to a higher maturity level. It introduces a BI Environment Maturity Model, which can be used to assess and improve the maturity of a BI environment in an academic hospital. Better usage of a BI solution can contribute in the assessment of quality of care.

1.4 Scientific relevance

Scientific research should serve the public and the research community, the scientific contribution is a method which uses a BI solution to assess the quality of care. The method can contribute in the improvement of the overall quality of care. Assessing the quality of care by making use of a BI solution enables care managers and health workers to deliver the right care at the right time, in the right way to the right person by making use of best information (Turban et al., 2011).
The second contribution exists of a maturity model, which can be used by academic hospitals to access the maturity of their BI environment and to

evolve to a higher level of maturity. A higher level of maturity can contribute in the assessment of quality of care. Causes of defect and variability in quality of care can be identified by assessing the quality of care.

1.5 Business relevance

Assessing quality of care by making use of a BI solution
Looking at the business relevance it is very useful for an academic hospital to determine how a Business Intelligence solution can be used to assess the quality of care. As said before assessing the quality of care can contribute in the improvement of quality of care. The method can be used by multiple hospitals, and help them in improving the quality of care.

Assessing the maturity of the current BI environment
The business relevance lies also within assessing and evolving to a higher BI environment maturity. The goal of evolving to a higher maturity is to improve the BI environment in which the BI solution supports the assessment of quality of care. Improving the BI environment can contribute in a better assessment of quality of care. If the data in the BI solution is used by the right people in the right way, up-to-date, and are in alignment with the quality goals of the academic hospital, it will return more relevant and accurate information about the current status of quality of care. By using this accurate information the hospitals knows which care practices need extra attention and improvement.

This thesis will give academic hospitals a method on how to assess quality of care and a model on how to measure the current maturity of the BI environment and recommendations on how to evolve to a higher business intelligence environment maturity level.

1.6 Research method

This section describes the research methods that have been used to answer my main research question. First is described how I approached my research with the corresponding steps that need to be performed, at the end is described which research methods are used to design the method and model.

First I am going to do a literature research on the subjects '*Quality of care*', '*Assessing the quality of care*' and on a '*Business Intelligence solution*'. Based on the results I am going to research what the needs are to assess quality of care and research which needs can be filled in by making use of a BI solution. If the needs can be filled in by making use of a BI solution, I am going to develop a method that uses a BI solution to assess the quality of care. To research if the method is applicable in an academic hospital I will conduct a case study. After the case study I will describe my results and conclusions.
If a BI solution can be used to assess the quality of care I am going to research which elements influence the use of a BI solution in a BI environment. The information that I retrieved from the literature review about the Business Intelligence environment is used to determine the maturity levels of the elements. These elements determine the maturity of a BI environment. With the all information I am going to develop a model with which the maturity of a BI environment in an academic hospital can be measured. To research if the model is complete, consistent and correct, first, an expert interview is done. The results of the expert interviews are going to be included in the maturity model. Another case study is conducted to research if the reviewed maturity model is also applicable in an academic hospital. If the results of the case study propose changes to the maturity model, than these changes are applied, if possible. After that the conclusions and future research for this thesis will be described.

The next research model demonstrates the steps that need to be performed to answer the main research question. Research model by Verschuren & Doorewaard (2000).

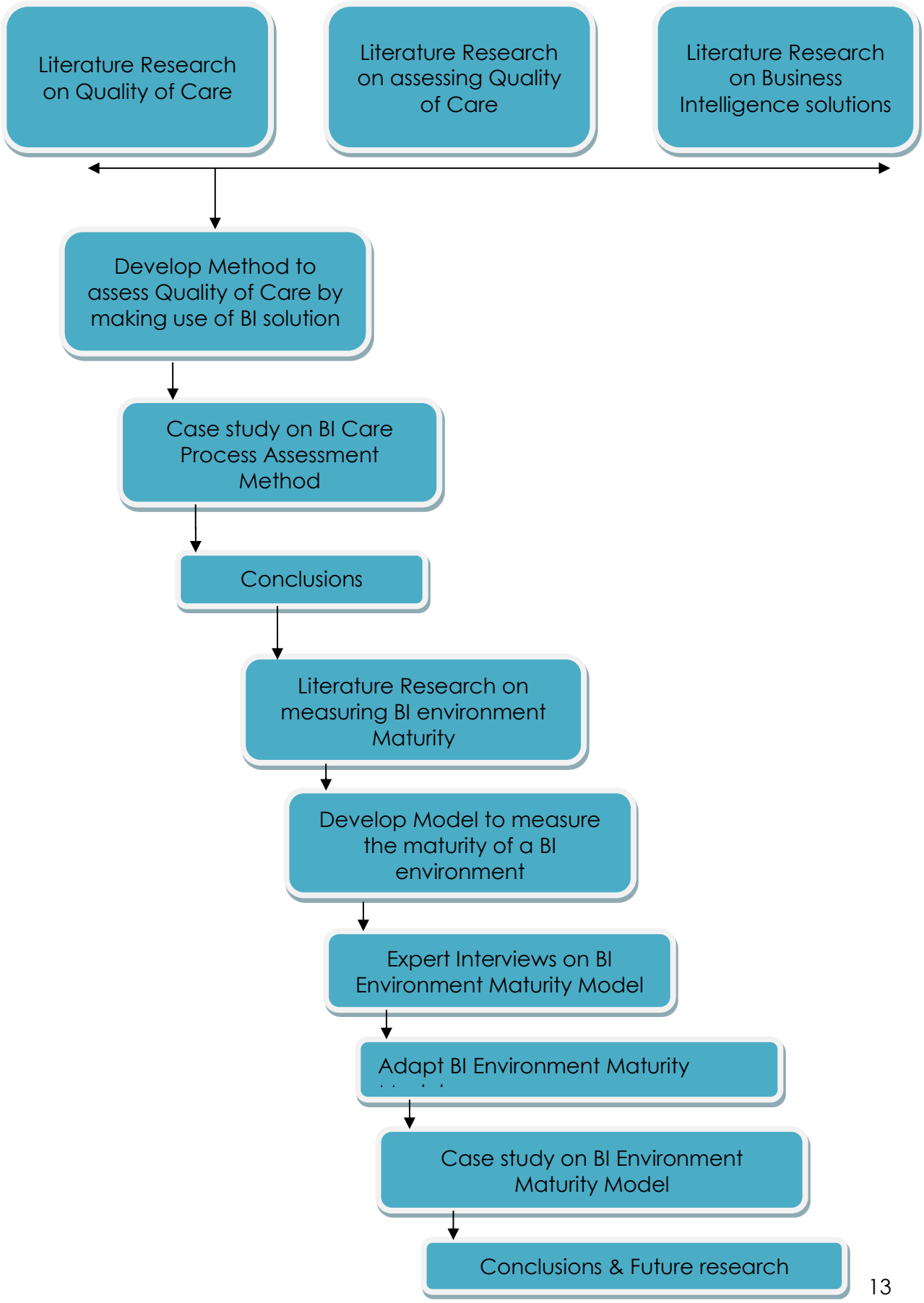


Figure 1: Research model

1.6.1 Exploratory research

Exploratory research is mainly conducted for a problem that has not been clearly defined. It often occurs before there is enough knowledge to make conceptual distinctions or posit an explanatory relationship. Exploratory research often relies on secondary research such as reviewing available literature, data or qualitative approaches such as formal interviews, focus groups, projective methods, case studies or pilot studies.

For this research is an exploratory research approach conducted to generate a new method on how to assess the quality of care by making use of a Business Intelligence solution, and to generate a new maturity model to measure the maturity of a BI environment. The exploratory research exists out of multiple literature research.

Deliverables

The results of the literature research on the subject *quality of care*, *assessing the quality of care* and *business Intelligence* are used to develop a method that shows how a BI solution can support the assessment of quality of care. This method is called the BI Care Process Assessment Method (BICPAM).

The results of the previous literature research and the results of the literature research on the subject *measuring the maturity of a BI environment* is used to develop a model that can be used to measure the maturity of a BI environment and to evolve to a higher maturity level, this maturity model is called the BI Environment Maturity Model (BIEMM).

1.6.2 Qualitative research approach

A qualitative research called a 'case study' is used to evaluate the Business Intelligence Environment Maturity Model and to evaluate the BI Care Process Assessment Method; according to Yin (2014) case studies can be used to test a theory. The theory is for the first case study a method and for the second case study a model. The theory can be validated by the case study or can be found inadequate and may need to be refined, based on the results of the case study.

The evaluate BICPAM; a single case study is conducted. The method is going to be implemented in a Dutch academic hospital to find out if the method is applicable for the assessment of quality of care.
To evaluate BIEMM also a single case study is conducted. However, the model is first going to be evaluated by multiple BI expert interviews. For the first evaluation are the BI experts interviewed face-to-face. For the second evaluation is BIEMM implemented in an academic hospital.

The strength of the case studies is its ability to discover a wide variety of social, cultural, and political factors potentially related to the phenomenon of

interest. Analysis tends to be qualitative in nature, but heavily contextualized and nuanced. However, interpretation of findings may depend on the observational and integrative ability of the researcher, lack of control may make it difficult to establish causality, and findings from a single case site may not be readily generalized to other case sites (Bhattacherjee, 2012).

1.6.1 Single Case study to evaluate BI Care Process Assessment Method (BICPAM)

To evaluate the method a single case study is conducted on the quality of care in an academic hospital. For the assessment of quality of care in the academic hospital is researched if the method is applicable or if the method should be adapted.

1.6.2 Expert interviews to evaluate the BI environment Maturity Model (BIEMM)

To evaluate the BIEMM, semi structured interviews is conducted to research if the maturity model is complete, correct and consistent according to BI experts. A semi-structured interview is a qualitative method of inquiry that combines a pre-determined set of open questions with the opportunity for the interviewer to explore particular themes or responses further. Semi-structured interviews are used to understand how interventions work and how they could be improved. It also allows respondents to discuss and raise issues that you may not have considered. The interviews are conducted face-to-face, and the interviewer asks questions directly to the respondent and records their responses. The questions are open and the respondents are able to provide an answer in their own words. The questions are designed so that respondents are able to read, understand, and respond to them in a meaningful way.

1.6.3 Single-Case study to evaluate the BIEMM

Another way to evaluate the BIEMM assessment instrument is to actually measure the BI environment of an academic hospital by making use of the BIEMM assessment instrument. The maturity model provides advice on how to evolve to a higher maturity level. The academic hospital can use the maturity model to evolve to a higher maturity if the assessment instrument of the maturity model is applicable in an academic hospital. The BIEMM assessment instrument is a questionnaire in which questions can be answered in an ordinal format. In an ordinal response, the respondents have more than two ordered options as response possibilities. After assessing the environment of a Dutch academic hospital an advice is given on which focus areas need improvement. Besides the advice that is given to the academic hospital, the case study will determine if the assessment instrument of the maturity model was applicable in an academic hospital.

2. Literature research on the Quality of Care and Business Intelligence solutions

This chapter describes the literature research on quality of care, and the Business intelligence solutions. First the literature research approach is described, than the results are described, and at last are the conclusions described. In the next chapter are the results of the literature review used for developing a method that can be used to access the quality of care.

2.1 Literature research

The research method starts with a literature research about the subjects' quality of care, assessing quality of care, and Business Intelligence solution.

Research Method

The purpose of a literature research is three-fold: (1) to survey the current state of knowledge in the area of inquiry, (2) to identify key authors, articles, theories, and findings in that area, and (3) to identify gaps in knowledge in that research area (Bhattacherjee, 2012).
The review provides some intuitions or potential answers to the sub-research questions and help identify theories that have previously been used to address similar questions.

Data was gathered through Google Scholar, which was chosen for its high accessibility. By using a data source that can be accessed by the general public the reproducibility of this review will be higher and easier compared to when a data source would be used that can only be accessed by a limited amount of users (e.g. an online university library). Furthermore, Google Scholar is a general provider of literature and contains, apart from its own results, also the results of other databases. This reduces the chance of a bias towards a specific domain or viewpoint within science.

By describing the process of research I try to make this research as transparent as possible and allow an easy reproducibility. The following keywords were used in the search of literature: "Quality of care", "Improve quality of care", "Measure Quality of Care", "Assess quality of care", "Monitor quality of Care", "Assessing quality of care", "Business Intelligence", "Data warehousing", "Data warehouse", "Business Intelligence solution".

Inclusion and Exclusion Criteria

The results from Google Scholar were excluded based on the following parameters:

- Articles must contain scientific literature or white papers.
- A keyword or combination of keywords must be present in the title or abstract of the article;

Study selection and Data collection process
Some articles were excluded due to access restrictions. I choose to exclude articles that required a payment because such articles are not accessible by everybody and would thus lower the reproducibility of this study. The remaining articles were evaluated by reading their title and abstracts and further exclusion was based on the following criteria:

- Articles must be written in English or Dutch;

The full texts of the remaining articles were read and further exclusion was based on the content. Some contents of the articles were either too broad or too specific (e.g. a specific country) and therefore not useful for this systematic literature research. We admit that the decisions made based on content are personal interpretations and therefore not objective.

The results of the systematic literature research on the key words '*quality of care'* and '*Improve quality of care'* are used to answer the following sub-research questions:

What is quality of care?
Why assess quality of care?

The results of the systematic literature research on the subject '*assessing quality of care*', '*Improve quality of care', 'Measure Quality of Care', 'Monitor quality of care' and 'Assess quality of care'* are used to answer the following sub- research questions:

How to assess quality of care?

The results of the systematic literature research on the subject '*Business Intelligence*', '*Data warehousing*', '*Data warehouse*', and '*Business Intelligence solution'* are used to answer the following sub- research questions:

What is a Business Intelligence solution?

2.2 What is quality of care?

The Institute of medicine has defined quality of care in 1990 as "the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge (Chassin et al., 1998).

The term health services refer to all the services that are provided by health workers and affect the health of the patient. The services are aimed at preventing diseases and illnesses. However, the services are also aimed at promoting health and well-being.
The term health outcomes refer to the desired health outcomes of patients. Current professional knowledge emphasizes that health workers must keep abreast of the knowledge base in their professions. They also need to use this knowledge in an appropriate way.

In 2005 the Agency for Healthcare Research and Quality came with another definition for quality of healthcare: "Doing the right thing, at the right time, in the right way, to achieve the best possible result". *Doing the right thing* refers to getting the health care services that the patient needs, *at the right time* refers to getting the health care service when the patient needs it, and *in the right way* refers to using the appropriate test or procedure.
Providing quality of care also means avoiding overuse and underuse and eliminating misuse (AHRQ, 2005).

The Dutch government also uses this definition as a starting point to access quality of care (van den Berg et al., 2014).

A high quality of care means providing patients with appropriate services in a technically competent manner, with good communication, shared decisions making, and cultural sensitivity.

According to the World Health Organization (WHO) (2006) there are six focus areas in quality of care, these focus areas require that healthcare should be:

- Safe: avoiding injuries to patients from the care that is intended to help them.
- Effective: providing services based on scientific knowledge to all who could benefit and refraining from providing services to those not likely to benefit (avoiding underuse and overuse).
- Patient-centered: providing care that is respectful of and responsive to individual patient preferences, needs, and values and ensuring that patient values guide all clinical decisions.
- Timely: reducing waits and sometimes harmful delays for both those who receive and those who give care.
- Efficient: avoiding waste, in particular waste of equipment, supplies, ideas, and energy.

- Equitable: providing care that does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socio-economic status.

Also the Dutch Health Care Performance Report 2014 (van den Berg et al., 2014) describes three dimensions for the quality of care which are care effectiveness, safety of care and responsiveness. Responsiveness refers to patient-centered care. This report also mentions that transparency is necessary for these three dimensions. Transparency can be used to secure and promote quality of care.

2.3 Why asses quality of care in hospitals?

There are multiple arguments for promoting a focus on quality of care. Research has shown that even if the healthcare environment is well developed and resourced, there is clear evidence that quality remains a serious concern. The outcomes of quality of care for example were expected but not predictably achieved and there are still wide variations in the standards of healthcare delivery within and between hospitals. By assessing the quality of care, it is possible to create standards with which all hospitals can work (WHO, 2006).

Assessing the quality of care can also be useful for optimizing the use of resources and expanding the population coverage of the healthcare environment. That is why hospitals are moving away from assessing only the costs and activities, they moved on to assessing quality of care. The focus is on efficient use of resources and on the effectiveness of healthcare. However, the process of quality improvement and scaling needs to be based on local strategies for quality of care so that the best possible results are achieved from new investments (WHO, 2006).

Assessing the quality of care can also be useful to compare the quality of care between health care providers, without comparison it is often unclear whether the results of quality measurements are good or bad and whether quality improvements at a care provider is necessary (van den Berg et al., 2014).

There is also an increased interest in assessing the quality of care because the demand of health care is still growing, the health expenditure is still rising, the resources are constrained and there is evidence that there is a variation in clinical practice. The hospitals learned that practice patterns and the quality of medical care vary much more than many people had realized, the ability to assess the quality of care has advanced considerably, and clinicians are increasingly interested in having objective information about their practices (WHO, 2006).

By assessing the quality of care, hospitals can offer transparency to themselves, patients, and the government to secure and promote quality of care, transparency is characterized by making information about the quality of care available and comparable. (van den Berg et al., 2014).

Another reason/goal for assessing effective health care for patients and health workers is to maximize health benefit according to the need.

2.4 How to assess quality of care?

Accessing Quality of care

The Donabedian Framework is the most widely used framework for assessing the quality of healthcare. According to this framework, inferences about the quality of healthcare can be evaluated based on structure, process and outcomes.

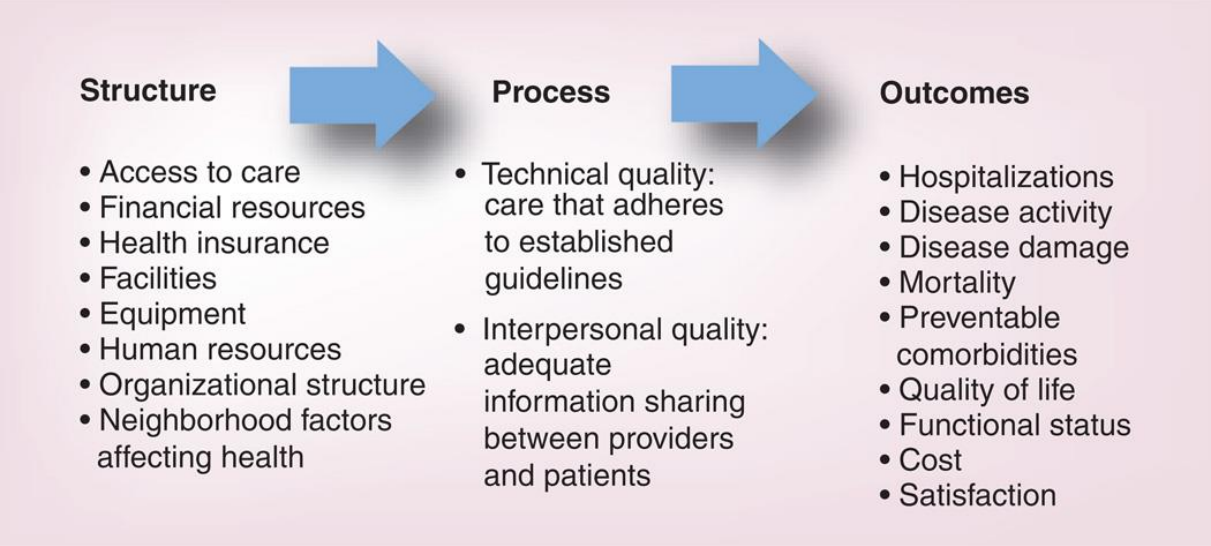


Figure 2: Donabedian Framework

Structure

Structure refers to the organizational factors that define the health system and under which care is provided (Campbell et al., 2000). This includes the attributes of material resources (such as facilities, equipment, and money), human resources (such as the number and qualifications of personnel), and organizational structure (such as medical staff organizations, methods of peer review, and method reimbursement) (Donabedian, 1988).

Structural features of health care provide the opportunity for individuals to receive care but do not guarantee it. Structural features within a hospital can have a direct impact on processes and outcomes. For example if necessary equipment or skills are not available to provide the best care possible, or when a patient cannot access care because a hospital is fully booked (Campbell et al., 2000).

Process

The process category describes the actions performed in giving and receiving healthcare (Donabedian, 1988). Processes of care refer to the interactions between users and to the health care structure. The mainly two processes that occur in care are technical interventions and inter-personal interactions. Technical processes relate to whether medical interventions are appropriate and are delivered in a timely and skillful manner (Cooperberg et al., 2009). Most technical processes are described in a protocol. Technical process assessments underlie the development of reportable quality indicators.

Interpersonal care describes the interaction between health care professionals and between the hospitals and health care users; this includes the social and psychological interaction. Interpersonal processes are those which relate to aspects of the health worker-patients interaction such a communication skills. Both technical and interpersonal care processes involve the definition and communication of problems or needs, diagnoses, their management and co-ordination by the patient and professional concerned (Campbell et al., 2000).
The best measures are those for which there is research evidence that better processes lead to better outcomes (Institute of Medicine, 2001).

Outcome
The outcome category describes the effects of care on the health status of patients and populations (Donabedian, 1988). Outcome measures represent the health care delivery endpoint of greatest interest to both health workers and patients, but are the most complex to access and interpret. Outcomes comprise both beneficial and adverse impacts of healthcare on survival, complications, functional status, and both general and disease specific health related quality of life (Cooperberg et al., 2009).
Structure and processes can influence the outcome directly or indirectly. The effectiveness of structure and processes can be defined in terms of their capacity to result in two principal domains of outcome: health status and user evaluation. Health status refers to the health related quality of life while user evaluation refers too satisfaction and enablement (Campbell et al., 2000).
The best outcome measures are those which are tied to process of care, in other words, those over which the healthcare system has influence (Institute of Medicine, 2001). Most people believe that most differences in outcomes among patients receiving the same treatment are the result of factors not under the control of health care providers, such as differences in patients' characteristics (Brook et al., 1996).

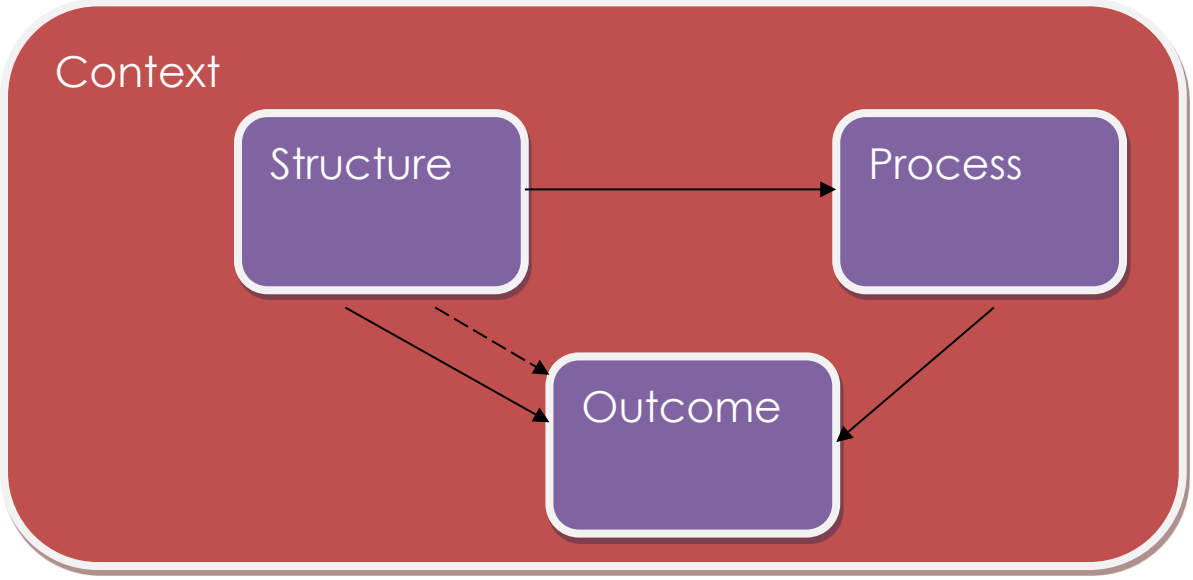


Figure 3: Donabedian Framework dependencies

All three focus areas can provide valuable information for measuring quality of care, but most of the quality of care literature focuses on measuring processes of care. Process data are usually more sensitive measures of quality than outcome data, because poor outcome does not occur every time there is an error in the provision in care (Brook et al., 1996). Two measurement approaches dominate the literature (Institute of Medicine, 2001):

- assessing appropriateness of care processes
- adherence to professional standards**:**
    - screenings and interventions
    - the process of care is adequate
    - best practices and protocols (scientific evidence)

Assessing appropriateness of care:

An intervention or service is considered appropriate if, for individuals with particular clinical and personal characteristics, its expected health benefits exceed its expected health risks by a wide enough margin to make the intervention or service worth doing. A subset of appropriate care is necessary for crucial care. Care is considered necessary if there is a reasonable chance of nontrivial benefit to the patient and if it might be considered ethically unacceptable not to provide this care (Institute of Medicine, 2001).

Adherence to professional standards:

Process quality can also be assessed by determining whether care meets or adheres to professional standards. This can be done by creating a list of quality indicators that describe a process of care that should occur for a particular type of patient or clinical circumstance and by evaluating whether patients' care is consistent with the indicators. Quality indicators are based on standards of care, which are either found in the research literature and in statements of professional medical organizations or determined by an expert panel. Current performances in care processes can be compared against a physician's and plan's own prior performance, against the performance of other physicians and plans, or with reference to a benchmark that establishes a goal. Indicators can cover a specific condition, or they can cover general aspects of care regardless of the condition (Institute of Medicine, 2001).

2.4.1 Quality criteria for care processes in hospitals

As mentioned before in the Netherlands promotes the Quality institute professions in healthcare to develop quality criteria. The quality criteria are developed by care providers, insurers, patient organizations and the Health Care Inspectorate (IGZ). The quality criteria exist out of quality indicators, which can be used inter alia to measure the quality of care processes. IGZ supervises the quality of Public health. Besides IGZ there are more than hundred other quality systems and platforms in the Netherlands that define and describe quality for hospitals. The five most used quality systems and platforms in the Netherlands are: IGZ, NIAZ, HKZ, JCI, and VMS. Some quality systems have a quality label. A label or certificate recognizes a hospital for the quality of the delivered care. A hospital can distinguish themselves from other hospitals with a certificate.

NIAZ

The Dutch Institute for Accreditation in Healthcare (NIAZ) contributes to improvement and ensuring of the quality of health care in the Netherlands and Flanders (Belgium) by making use of the International Accreditation Program NIAZ Qmentum. The NIAZ accreditation indicates that the corresponding hospital provides care in a secure way, and provides ongoing commitment to improve the quality of care and operates according to current insights (Nictiz, 2014).

HKZ

HKZ stands for Harmonization of Quality in Healthcare. The HKZ certificate indicates that a hospital meets the predetermined quality standards of the delivered care. If an hospital obtains the certificate, the hospital is recognized as well organized, client-centered, constantly working on optimizing the care supply, present reliable results, and meets the requirements set by the sector itself, funders, clients and the government. HKZ is based on ISO 9001. The ISO 9001 is a standard that sets requirements for the quality management system of an organization (Nictiz, 2014).

JCI

The Joint Commission International (JCI) certifies hospitals that score high on quality of care and patient safety. The JCI accreditation is awarded to more than 50 countries, including the Netherlands. The JCI was founded in 1994 to improve global quality, safety and efficiency in health care and is recognized by the World Health Organization (WHO)(Nictiz, 2014).

VMS

VMS stands for safety management system. VMSzorg.nl is a platform on which knowledge and information around the safety management systems and an additional ten themes about the quality of care is made accessible to hospitals. Hospitals must achieve the stated goals of ten themes to get a NIAZ or HKZ certificate. In consultation with the Health Care Inspectorate (IGZ) is a limited set of safety indicators formulated. The IGZ uses these indicators in

monitoring the extent to which hospitals work on the themes. In addition, the Inspectorate uses the spearheads of the program as a framework for inspection visits.

2.4.2 How can quality of care processes be assessed?

In 2006 the World Health Organization (WHO) introduced three processes that facilitate a comprehensive approach to assess and improve care processes (WHO, 2006):

Analysis (understand the problem):
- Stakeholder involvement
- Situational analysis
- Confirmation of health goals

Strategy (plan):
- Determine quality goals
- Choosing interventions to improve quality of care processes

Implementation (take action):
- Implementing the improved process
- Monitoring the improved progress

The main implication of this approach is that strategies for quality improvement are not fixed. Responding to results will always require that adaptations be made to some elements of the strategy and to the approach for implementation.

To evaluate and improve the performances of care processes, it is necessary to research a method that makes it possible to assess the performances of the care processes and supports all three processes that are recommended by the WHO above.
Nowadays, there are multiple philosophies and methods in healthcare that can be used to assess the performances of care processes. The methods that are used the most for quality improvements in healthcare are described in the next table (Table 1) with their criteria and activities.

Model	Description
TQM (Reid, 2008)	Total Quality Management exist out of the following criteria: - Customer focus: Goal is to identify and meet customer needs. - Continuous improvement: A philosophy of never-ending improvement. - Employee empowerment: Employees are expected to seek out, identify, and correct quality problems. - Use of quality tools: Ongoing employee training in the use of quality tools. - Product design: Products need to be designed to meet customer expectations. - Process management: Quality should be built into the process; sources of quality problems should be identified and corrected. - Managing supplier quality: Quality concepts must extend to a company's suppliers.
PDCA (Sokovic et al., 2010)	PDCA stands for the following activities: - Plan: determine objectives and plan activities - Do: execute the planned activities - Check: check how well the objectives are realized - Act: Analysis of deviations and adjusting the process
Six Sigma (Sokovic et al., 2010)	Six Sigma contains the following activities: - Determine: define the business goals and the measurable elements of the business goals. - Measure: gather data about the business goals and determine the start point or baseline of the process by measuring the performance of the process. - Analyze: gather extra information about the process to define the root cause. - Improve: select a solution and implement the solution. - Control: monitor the performances of the processes

Table 1: Quality assessment models

Wasmann and Spruit (2012) introduce a process improvement method that based on the PDCA-model. This method is however not used improve care processes but to improve performances within social network sites. According to Schroeder et. al. (2008) is the Six Sigma method consistent with the steps of the PDCA-model and places more emphasis on integrating specific tools and techniques into each step of the method. Six Sigma also involves different employees and roles at different steps in the method.
The activities of Six Sigma are in thesis used to develop a new method. One of the reasons why Six Sigma is chosen as input for the method, with which the quality of care processes is going to be assessed, is that it is the only model that uses the business goals to determine the quality indicators which are

used to measure the performances of the baseline. The Six Sigma framework also contains all four activities of the PDCA and the three processes that are mentioned by the WHO above. 'Analysis' is captured by the Define, measure and Analyze- process, 'Strategy' is partially captured by Define, Measure and Improve-process, and 'Implementation' is partially captured by the Improve and Control-process. According to Lucas (2002), do all quality improvements occur on a project-by-project basis and in no other way, which is an essential element in the foundation of Six Sigma. Also Six Sigma is perceived to be a business system that improves the bottom line and only brings in technical details as needed. Chassin (2013) mentioned also that Six Sigma is one of the techniques that have been proven to be far more effective in tackling clinical quality problems than the tools and methods that came out of the industry in the 1980s were, such as TQM. TQM is perceived to be a technical quality system owned by technical specialists rather than all employees. TQM does not provide steps on how to improve quality; it mentions the criteria that should be managed for quality improvement.
Moreover, Six Sigma drives out fear by making health workers agents of change rather than resister to change (Lucas, 2002). This is also important in health care because it is likely that health workers are more willing to change if they can manage the changes themselves than if they have to follow orders from a care manager because they are professionals.

Six Sigma principles can be applied into hospitals to minimize the variation in care processes (Sehwall et al., 2003). Six Sigma identifies and aligns improvement possibilities by making use of the quality goals and strategic objectives and by looking at the care processes in the hospital. Quality of care processes can be examined by Six Sigma so that the health workers are able to improve the performance of care processes and meet the expectations of care. The main benefits of Six Sigma are better operational efficiency, cost effectiveness and higher process quality (Sehwall et al., 2003). For which the latter is an aimed benefit in improving the performances in quality of care processes.

The Six Sigma framework can be used to assess the performances of care processes. Six Sigma is a management philosophy developed by Motorola that emphasizes setting extremely high objectives, collecting data, and analyzing results to a fine degree as a way to reduce defects in products and services (Klefsjö et al., 2001). The Greek letter sigma is sometimes used to denote variation from a standard. The philosophy behind Six Sigma is that if you measure how many defects are in a process, you can figure out how to systematically eliminate them and get as close to perfection as possible. In order for a company to achieve Six Sigma, it cannot produce more than 3.4 defects per million opportunities, where an opportunity is defined as a chance for nonconformance.

> *"Six Sigma is an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method (DMAIC), and performance metrics) with the aim of achieving strategic objective* (Schroeder et al., 2008)"

The Six Sigma framework exists out of the following 5 activities (Sehwall et al., 2003):

- Define
- Measure
- Analyze
- Improve
- Control.

For each activity is described how an academic hospital should perform them to assess the quality of the care processes.

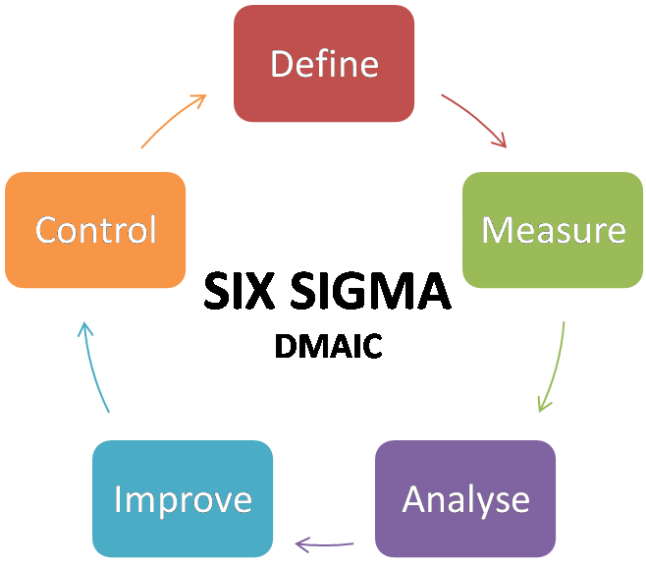


Figure 4: Six Sigma activities

Define:
First, the quality goals, which require improvement in the performances of care processes need to be defined. The quality goals should be derived from the mission and the vision that is chosen by the hospital management. Critical success factors should be derived from the quality goals. The critical success factors define the prerequisites to reach the quality goals. The strategy should state how the quality goals can be reached.
The quality goals and the strategy that are chosen should lead to the protocols and the objectives. The protocols describe business rules about the care processes. The business rules describe how care processes should be executed to keep the performances of the care processes high, the objectives can be measured by making use of Key Performance Indicators. Key performance indicators are also called quality indicators. The business rules can be enforced by the information system that is used in the hospital.

Measure:
The next step is to make the performances of care processes measurable. The quality of care processes can be measured by making use of information about the care processes. This information can be found in the data that is often stored in the databases of an information system, which are used to support the care processes. The databases of information systems contain all the information of the information processes that support the care processes. However, this data is often unstructured data and stored in multiple databases that cannot communicate. Facts and data need to be used, to measure the care processes. The performances of the care processes can be measured by making use of Key Performance Indicators (KPIs). It is important to establish valid and reliable metrics to measure the progress towards the objectives defined at the previous steps.

Analyze:
Analyze the care processes to identify ways to eliminate the gap between the current performance and the desired objectives/goals. The analysis should reveal the underlying causes of the gap. The situation can be analyzed by using facts and data to determine the root cause(s) of the problem that is inhibiting the performance. First, the current baseline of quality of care needs to be analyzed by making use of exploratory and descriptive data analysis to help understand the data. The context in which the care processes take place should be analyzed to understand the cause. Statistical tools can be used to guide the analysis.

Improve:
When the hospital identifies the root cause it can move on to the Improve phase and identify, select, and implement the most appropriate solution. Improvement of care processes can be improved by changing the way that care is delivered. The quality of care processes can be improved by implementing new interventions. Using project management and other planning and management tools to implement the new approach.

Control
The hospital should monitor the performances of the care processes to see if the care processes are improving or to maintain the quality of the care processes. The performances provide a way to determine how hospitals are actually performing, and to compare that information with the original objectives in order to identify opportunities for improvement (Shaw, 2003). Hospital needs to use data to help it hold his gains. Progress reports can help the hospital in monitoring the quality of care processes (Pyzdek et al., 2003). Monitoring can be done at different levels, for example, top-management can be interested in the overall performance of a division, while a care-manager of a department can be interested in monitoring the performance of his department.

2.5 What is a Business Intelligence solution?

As mentioned before Information technology can contribute to an improved healthcare delivery system. To improve the quality of care processes it is necessary to evaluate the performances of the care processes. This can be done by using the data that is derived from the information processes that supports the care processes. This data is often stored in the databases of the information systems. A business intelligence solution makes it possible to combine the data from different databases and to reuse this data for other purposes than the support of care processes. Combining the data of different information systems solves the information gaps in and between information systems. A BI solution makes it also possible to organize the data and to use the data for performance measurements.

A good Business Intelligence solution delivers the right information at the right time, in the right format to the right person. BI is all about providing people with the information they need to do their job more effectively. A Business Intelligence solution supports reporting, analyzing and modeling of a business, aligned with its goals and objectives. Making use of a Business Intelligence solution can have a direct positive impact on the business performance of an enterprise; it can also dramatically improve the ability to accomplish a mission by making smarter decisions at every level of the business from corporate strategy to operational processes.
By making use of reporting capabilities, a hospital can monitor its performances. The analyzing capabilities enable the hospital to identify opportunities and determine the reason for bad or good performances. The modeling capabilities enable the hospital to predict performances by simulating business rules (Roekel et al., 2009).

A BI solution contains three components (Turban et al., 2011):

- A data warehouse or data mart, which contains the source data
- A collection of tools for manipulating, mining and analyzing the data in the data warehouse
- User interface, which visualizes the progress of the performances of quality of care processes (BI products).

BI solution

A BI solution is a database used for reporting and data analysis. Data warehousing is the integration of data from one or more disparate sources to create a central repository of data. The data stored in a BI solution is uploaded from various operational systems (information systems) and are cleansed and organized in a manner consistent with the organization's needs. The BI solution and its variants are the cornerstone of any medium-to-large BI environment. Originally, the BI solution included only historical data that were organized and summarized, so end users could easily view or manipulate data and information. Today, some BI solutions include current data as well, so they can provide real time decision support.

The major steps of the data warehousing process (Turban et al., 2011):

- Data sources: data are sourced from multiple operational systems and possibly from external data providers.
- Data extraction and transformation: data are extracted and properly transformed using custom –written or commercial software called ETL. An ETL tool is responsible for data transfer, from operational or transaction systems to data warehouses.
- Data loading: data are loaded by the ETL-tool into a staging area (this is a copy of the original data), where they are transformed and cleansed. The data are then ready to load into the BI solution, which in the picture below is a data warehouse.
- Comprehensive database: essentially, this is the BI solution, which supports all decision analysis by providing relevant summarized and detailed information originating from many different sources. The BI solution provides some room for thematic storing of aggregated and analyzed data.

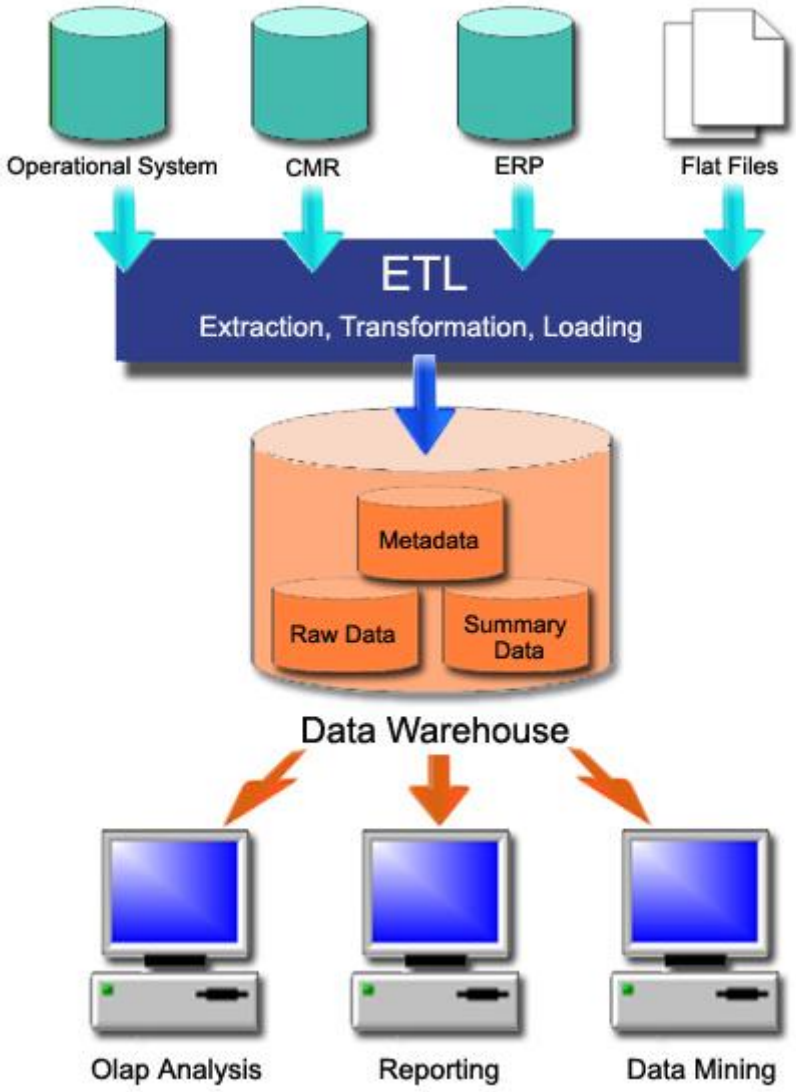


Figure 5: Data warehousing

Business Intelligence solutions are designed to accept data from any source, and to transform the data into actionable information. It requires a conscious approach, a blending of enterprise resources to deliver a complete, consistent, and reliable source of information to fulfill the promise of BI.

BI products

Dashboard and reports provide a comprehensive visual view of corporate performance measures, trends and exceptions. Corporate performance measures are also known as key performance indicators (KPIs). The dashboard integrates information from multiple business areas. Dashboards and reports present graphs that show actual performance compared to desired metrics. In other words, dashboards and reports present an at-glance view of the performances of quality of care of a hospital. Many visualization tools, ranging from multidimensional cube presentation to virtual reality, are

integral parts of BI solution. The visualization tools provide users with information in a comfortable and accessible form (Turban et al., 2011).

The reports that show the information that are provided by visualization tools will be called BI products. The BI solution refers in this thesis to the data warehouse or data mart. More information about the data warehouses and data mart can be found in the next chapter.

Analyze tools
End users can analyze the data and information in a BI solution by using a variety of tools and techniques. These tools and techniques fit into three major categories (Turban et al., 2011):

- Reports and queries: this includes static and dynamic reporting, all types of queries, discovery of information, multidimensional view, drill down to detail, and so on.
- Advanced analytics: Advance analytics includes statistical, financial, and sophisticated mathematical models used in analyzing data and information.
- Data mining: Data mining is a process of searching for unknown relationships or information in large databases or data warehouses, using intelligent tools such as neural computing, predictive analytics techniques, or advanced statistical methods.

2.5.1 BI solution architectures

There are three main BI solution architectures (Turban et al., 2011):

- The enterprise data warehouse architecture
- The data mart architecture
- The enterprise data warehouse data mart architecture

The enterprise data warehouse architecture:
The attention is focused on building a scalable and maintainable infrastructure, which includes a centralized data warehouse. This centralized data warehouse serves access to all data in the data warehouse. It reduces the amount of data the technical team has to transfer or change, therefore simplifying data management and administration. If it is designed and implemented properly, this architecture provides a timely and holistic view of the entire enterprise to whomever, whenever, and wherever they may be within the organization.

The data mart architecture:
Whereas data warehouses combines databases across an entire enterprise, a data mart is usually a small warehouse designed for a strategic business unit or department. A data mart typically contains data from a single subject area. Individual data marts are linked to each other via some kind of middle ware, because the data is linked among the individual marts, there is a better chance of maintaining data consistency across the enterprise. The data marts are not completely independent because they are linked.

The enterprise data warehouse data mart architecture:
This is perhaps the most famous data warehousing architecture today. Here the attention is focused on building a scalable and maintainable infrastructure that includes a centralized data warehouse and several dependent data marts. Dependent data mart is a subset that is created directly from the enterprise data warehouse. This architecture allows for easy and customization of user interfaces and reports

Most of these architectures work also with operational data stores (ODS), which provides a recent form of information from the databases of the information system. This type of database is often used a staging area for a data warehouse or data mart. A stating area contains a direct copy of the database of an information system. The contents of the operational data stores are updated throughout the course of business operations. ODSs store only very recent information (Turban et al., 2011).

2.6 Conclusion

The objective of this chapter was to understand how a BI solution can be used in assessing the quality of care in academic hospitals. To understand how a BI solution can be used to assess the quality of care I researched how quality of care is defined and how quality of care can be assessed.
According to the Donabedian Framework, inferences about the quality of healthcare can be evaluated based on structure, process and outcomes. Brook (1996) mentioned that all three focus areas can provide valuable information for measuring quality of care. However, process data are usually more sensitive measures of quality than outcome data, because poor outcome does not occur every time there is an error in the provision in care. And structural features of health care can provide the opportunity for patients to receive high quality of care but do not guarantee it. Therefore it is interesting to assess the quality of care processes. Quality of care process can be assessed by two kinds of measurements:

- assessing appropriateness of care processes
- adherence to professional standards

Assessing the appropriateness of care processes is however difficult to measure since almost every patient can need a different care process for a similar condition as another patient. Process quality can also be assessed by determining whether care meets or adheres to professional standards. Adherence to professional standards is however much easier. This can be done by creating a list of quality indicators that describe a process of care that should occur for a particular type of patient or clinical circumstance and by evaluating whether patients' care is consistent with the indicators.
An assessment tool is needed to assess the quality of care processes by making use of the quality indicators. There are multiple quality systems and platforms that define quality of care processes. To improve the quality of these care processes it is necessary to use an assessment tool in which the quality indicators can be used to improve the quality of care processes. As mentioned before there are multiple quality assessment tools, however Six Sigma is one of the best assessment tools in which quality indicators are used to improve the quality of processes. According to Chassin (2013) is Six Sigma one of the techniques that have been proven to be far more effective in tackling clinical quality problems than other tools and methods.
Data is necessary to measure the quality indicators. This data is often stored in the databases of the information systems that support the care processes. The data can be provided by a Business Intelligence solution. A Business Intelligence solution makes it possible to combine the data from different databases and to reuse this data to analyze the quality of care processes. In the next chapter the benefits of using a BI solution in healthcare are described and an assessment method is created that uses Six Sigma and a Business Intelligence solution to assess the quality of care processes. Useful information should arise by assessing the quality of care, which can be used to improve the quality of care processes.

3. Using BI to access quality of care processes

3.1Benefits of using Business Intelligence in care processes?

Multiple benefits can be derived from making use of a BI solution in health care (Olszak et al., 2012):

Consolidation and protection data:
The possibility, of a single point access to data, that is stored in multiple systems. This enables health institutes to provide 'one version of the truth' which is one of the fundamental objectives of BI. The patient data can also be better protected by providing access only to those with appropriate access levels.

Efficiency improvement:
Users can access any type of information with a fast and consistent response time, independent of the data volumes analyzed or questions asked. Due to this fact the process of decisions making in areas like patient treatment is shorter and information-based.

Improved patient treatment and care:
A BI solution can be used in improving patient outcomes using point-of-care information. Through the use of BI, healthcare professional have easy access to patient's data and they can create a variety of /classifications reports based on demographic data, sex, age, etc. Thanks to the evidence based medicine and capture of medical history of the patient, doctors can accurate diagnosis and apply efficient treatment with reduction of risks during treatment. Timely and effective clinical decisions are better facilitated by increasing the potential of BI.

Reduction of medical errors and improved patient safety:
It could be reached by supporting medical research and data treatment and through efficient diagnostics and the identification and enforcement of best practice protocols (Muraina et al., 2011). BI solutions can support a larger healthcare system, by the exchange of medical information on a patient.

Improved decision making:
Improved decision making can be accomplished in the area of comprehensive health care policies, by the authorities of the organizations in the health sector. It can be reached with monitoring the performance of doctors, departments and medical material requirements. Multiple individuals can be put together by emphasizing the accurate data, which brings them closer to the point of service in order to enhance decisions-making and make data actionable (Olszak et al., 2012).

3.1.1 Business Intelligence layers

According to Wasmann & Spruit (2012), there needs to be taken several layers into account when implementing a Business Intelligence solution to manage performances. These layers are introduced by Roekel et. Al (2009) and are also described in the previous chapter for each Six Sigma activity. The Six Sigma activities take all layers into account to improve a process. The layers are represented in Figure 6 and are described below.

Figure 6: Business Intelligence Layers

Vision: A vision gives a visionary and ambitious idea of what an organization wants to be. In the definition of the vision, one looks at the world of today and the future opportunities and describes the desired dream situation. The vision statements lead to business goals and a strategy. The vision is described in the define activity in the Six Sigma model.

Strategy: The strategy described the approach to achieve the vision. A strategy is the way in which resources are deployed to achieve goals. The goals are determined by looking outward and forward. The strategy is also described in the define activity in the Six Sigma model.

Critical Success Factors: A critical success factors describe the essential areas of activity that must be performed well to achieve the vision, objectives or goals for a business or project. Critical Success Factors (CSFs) define the prerequisites to reach the goals. The CSIs also described in the define activity in the Six Sigma model.

Key Performance Indicators: Key Performance Indicators (KPIs) define how the objectives will be measured. KPIs help an organization define and measure progress toward organizational goals. They are also quantifiable measurements that reflect the critical success factors of an organization. Key Performance Indicators are determined in the measure activity in the Six Sigma model.

Reporting & Dashboards: Within the BI environment the KPIs will be presented in reports and dashboards. Reports and Dashboards are used in the analyze and control activity of the Six Sigma model.

3.1.2 Challenges

The challenges of using a BI solution to assess the quality of care processes are:

- Define critical success factors and key performance indicators to measure quality goals.
- Provide access to the data about the KPIs and provide it only to those who should have access and deny access to those who should not have access.
- Provide access to useful and accurate data/ information about the current quality of care processes.
- Measure the quality indicators (KPIs) of the care processes.
- Provide information to improve the quality of care processes.
- Improve quality of care processes.
- Provide access to useful and accurate data/ information about the quality of the care processes after improvement.
- Make it possible to monitor improvements in the performances of quality of care.
- Provide a comprehensive visual view of the performance, trends and exceptions of quality of care.
- Provide users with action-oriented information and analysis capabilities in a collaborative environment.

These challenges are based on the five Six Sigma steps that need to be executed to assess quality of care processes. These challenges are a must for decisions making, strategy planning and for survival.

3.2 How can a BI solution be used to assess the quality of care processes in hospitals?

In this chapter are the BI solution and Six Sigma used to create an assessment method. Situational method engineering is utilized to design the method that can be used to assess the quality of care processes in academic hospitals. Situational method engineering provides the ability to integrate the BI solution and the Six Sigma method into one situational method that is applicable to care processes in academic hospitals. A situational method is a method that is tuned to the situation of the project at hand. A situational method engineering approach exists out of four steps (van de Weerd., 2009):

- Analyze project situation and identify needs.
- Select candidate methods that meet one or more aspects of the identified needs.
- Analyze candidate methods and store relevant method fragments in a method base.
- Select useful method fragments and assemble them in a situational method by using route map configuration to obtain situational methods.

The last two steps are supported by a meta modeling technique that is developed especially for method engineering processes. The meta modeling technique produces a process delivery diagram (PDD). This technique can be used to analyze, store, select and assemble method fragments from other existing methods. The purpose of the technique is to reveal the relations between activities (the process of the method) and concepts (the deliverables) which is expressed in a PDD. A PDD consist out of two integrated diagrams. The process view on the left side of the diagram is based on a UML activity diagram and the deliverable view on the right side of the diagram is based on a concept diagram. An activity diagram shows the flow from activity to activity, it consist out of activities and transactions. The activities can be decomposed into sub-activities. For each activity can be stated by which individuals or organizational role the activity needs to be carried out. The role should be indicated in the activity. The concept diagram is an adjusted UML class diagram. A concept diagram is a set of objects that share the same attributes, operations, relations and semantics.

The situational method will be called the Business Intelligence Care Process Assessment Method (BICPAM).

3.2.1 Identify needs

As mentioned before hospitals moved away from assessing costs and activity, and are moving to assessing quality of care. The focus is on efficient use of resources and on the effectiveness of healthcare.

The need is to develop a method that can be used to assess quality of care processes. The assessment method should provide activities that need to be taken for assessing the performance of the care processes in hospitals. The results of the activities should contain valuable information that shows the current performances of the care processes according to the norm.

3.2.2 Select method that meet the needs

The methods that can be used to assess the performances of quality of care processes are the Six Sigma method which addresses the performances of processes and the BI solution which addresses methods/components to collect information/data about the care processes. Both methods are applicable in healthcare.

3.2.3 Store relevant method fragments in a method base

The method base is stored with the process data diagrams of the Six Sigma method and with the information retrieving and collecting methods of the BI solution.

3.2.4 Select method fragments and assemble them in a situational method

Based on the implementation situations needs useful method fragments were chosen to compose the new method. The method is depicted in a PDD (Figure 7), the activities are described in an activity table (Table 2) and the

concepts are described in a concept table (Table 3). The PDD as mentioned before consist of a process side and a deliverable side. The process side depicts the five main activities which are further specified to a more concrete level with the use of sub activities. The deliverable side depicts the various deliverables that are produced by the activities on the process side. The activity table describes each activity and its sub activities whereas the concept table provides definitions of the concepts used in the PDD. For the activities and the concepts are abbreviations used, CSF stand for Critical Success Factors, KPI stands for Key Performance Indicators and QoC stands for Quality of Care.

Activity	Sub Activity	Description
Define	Determine business goals	Top-management determines the objectives about the QoC processes which results in multiple BUSINESS GOALs.
	Determine CSFs	Top Management determines the prerequisites to reach the BUSINESS GOALs. The prerequisites are described in CSFs.
	Determine KPIs to measure performance	Top management determines how performances of the care processes can be measured by producing KPIs.
Measure	Determine nominator and denominator for each KPI	Business Analyst determines the NOMINATOR AND DENOMINATOR that should be measured to determine the PERFORMANCE RESULT.
	Use BI solution to access, collect and store data about KPI in dataset	Business Analysts determine source and research if data is available. Business analysts access and collect the data about the KPI by making use of the BI solution. The BI solution can help out in organizing, accessing, collecting and storing the data. The data is stored in a dataset called 'DATASET KPI'.

	Measure the performance of the care processes with data about the KPIs	Business Analyst measures the performances of the care process by making use of the DATASET KPI.
Analyze	Use BI solution to access, collect and store additional data about KPI in dataset.	Business Analysts research if additional data is available. Business Analyst can access the data about the context of the KPI by making use of the BI solution. The BI solution can help out in accessing, collecting, analyzing and storing the data about the context of the KPI. This data is stored in a dataset called 'DATASET CONTEXT KPI'.
	Use BI analyze tool to analyze the KPIs and the additional data about the KPI	Business analyst analyses the DATASET CONTECT KPI, which results in an ANALYSIS RESULTs. By making use of exploratory and descriptive data analysis, unknown relationships and new trends in care processes can be discovered. There can also be analyzed which factors are responsible for low quality of care, and which factors are responsible for a high quality of care, and which factors can improve the quality of care to get to the desired goal.
Improve	Choose interventions to improve the care processes	Care manager chooses one or more INTERVENTIONs based on the PERFORMANCE RESULTs and the ANALYSIS RESULTs to improve the quality of care processes.
	Implement interventions	Care manager implements the INTERVENTIONs.
Control	Use BI reporting tool to visualize the performances	Top management and care manager use the BI

	of the care processes	reporting tool to visualize the PERFORMANCE RESULTs in BI REPORTs.
	Monitor care processes to keep quality high	Top management and care manager monitor the quality of the care processes to keep the quality of the care processes high. If the quality of the care processes is low they should be analyzed again. If the quality of the processes stays high, management should keep on monitoring the PERFORMANCE RESULTs.

Table 2: Actvity Table

Concepts	Description
BUSINESS GOAL	The BUSINESS GOALs describe the objectives of the company. Most BUSINESS GOALs are describe in a business plan.
CSF	CSFs define the prerequisites to reach the BUSINESS GOALs. Most of the CSFs are the described in protocols and business rules. The CSFs are based on one or more BUSINESS GOALs. In a protocol is described how care processes should be provided and executed. Most of the protocols are derived from research, best practices and from practical experiences. Business rules describe how care processes should be executed to keep the quality of the care processes high.
KPI	KPIs define how the objectives will be measured. KPIs are based on one or more CSFs. KPIs are called quality indicators when it comes down to assessing quality of care. The quality indicators contribute in improving the quality of care.
NOMINATOR AND DENOMINATOR	The NOMINATOR AND DENOMINTOR of a KPI describe the elements of a KPI that can be measured. Each KPI has one NOMINATOR AND DENOMINATOR.

DATASET KPI	The DATASET KPI contains all the data that is necessary to measure a specific KPI. DATASET KPI contains information about the NOMINATOR AND DENOMINATOR for each KPI. The data of the DATASET KPI is stored in a BI solution. By organizing the data in a data warehouse (or data mart), data is assessable, data is collectable, and easy to understand.
PERFORMANCE RESULT	The PERFORMANCE RESULTs are the results of the data from the DATASET KPI that is measured for each KPI. The PERFORMANCE RESULT contains only the results based on one DATASET KPI.
DATASET CONTEXT KPI	The DATASET CONTEXT KPI consists out of all the data from the DATASET KPI and data about the context of the KPI to analyze the KPI. This data needs to be accessible and easy to analyze to understand the context in which the care processes take place. The data of the DATASET CONTEXT KPI is stored in a BI solution. By organizing the data in a data warehouse (or data mart), data is assessable, easy to understand, and to analyze. In order to support analysis, the BI solution must have highly quality data and make that data accessible through intuitive interface technologies.
ANALYSIS RESULT	Are the results from analyzing the DATASET CONEXT KPI. The analyze results show the health workers how well they were operating, how they are operating right new.
INTERVENTION	INTERVENTION is an attempt to improve the care processes. One or multiple INTERVENTIONs can be taken based on the PERFORMANCE RESULT and the ANALYSIS RESULTs. To improve the care process, the process needs to change or done more efficient by making use of other equipment or better information. To implement the INTERVENTION, project management and other planning and management tools are needed.
BI REPORT	BI REPORT depicts the PERFORMANCE

	RESULTs in a diagram. To improve the quality of care processes, care managers need BI REPORTs that provides the ability to monitor the performances of care processes and the interventions. This is necessary so they can see where they are and what the intended goal is. By making use of trend reports, management can monitor/evaluate the performances of the care processes in hospitals and maintain the performances of care processes. By making progress reports there can be seen if the hospital improves (Pyzdek et al., 2003). The reporting data can also be used as input to models to analyze trends and to anticipate the impact of possible alternative decisions or developments (Spil et al., 2002). Health workers need to understand the protocols to provide the highest quality of care processes but the health workers also need to understand the relation between the protocols and the derived KPIs. So, they see the necessity to monitor and evaluate the performances of the care processes.

Table 3: Concept Table

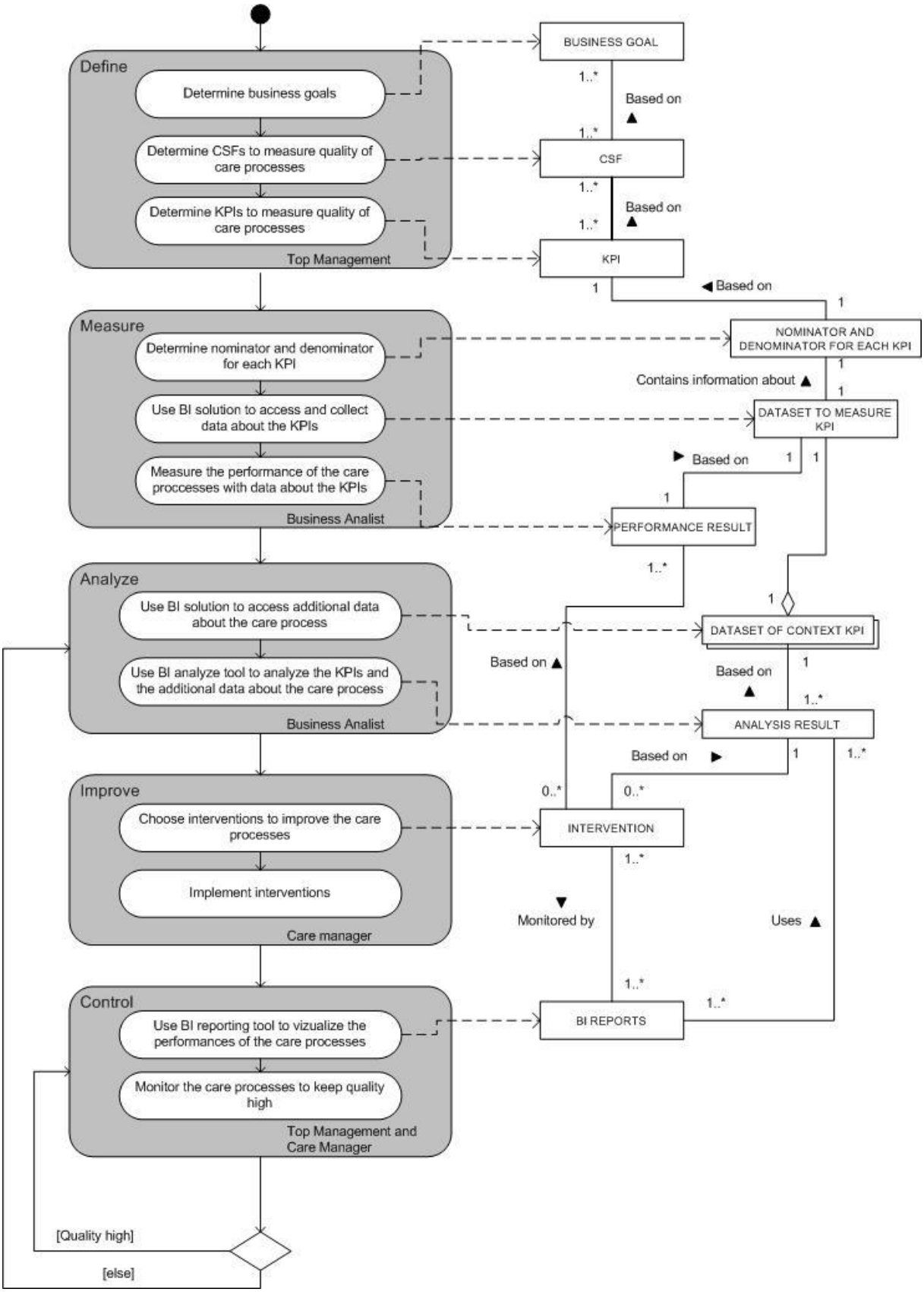


Figure 7: BI Care Process Assessment Method (BICPAM)

3.3 Case study

This chapter describes the case study performed within UMC Utrecht, using the BI Care Process Assessment Method as described in the previous chapter. First is the quality of care in the Dutch setting is described. Second, the organization's structure and the set-up of this case-study is described, and at the end is described how the method contributes in the improvement of care processes.

3.3.1 Dutch government and promoting quality of care

In 2007 the Netherlands started a program called "Zichtbare Zorg"; within this program multiple indicator sets were developed that provide information to care users, care providers, insurances companies and the government. The program provided information about the quality of care in hospitals for care users and care providers.

In 2013 the activities of the program were partly continued in the Quality Institute. The focus of the Quality institute is on improving the performances of quality of healthcare in the Netherlands. The Quality Institute makes sure that everyone has access to comprehensive and reliable information about the quality of care that was delivered. Furthermore, the Quality Institute helps healthcare parties to be able to improve. The Quality institute is a part of the Care institute. Much of the work of the Care Institute covers the basic care insurance as laid down in the Dutch healthcare laws.

The quality of care is made transparent by making use of the quality indicators. As told before these are measurable aspects of care based on the standards of care. The indicators give an indication about how good the performances of quality of care are. In the Netherlands these indicators are provided by the 'Inspectie voor de Gezondheidszorg' (IGZ), which promotes public health through effective enforcement of quality of care. The indicators based on patient safety are provided by the 'Veiligheidsmanagementsysteem' (VMS). They support the Dutch hospitals by offering knowledge about unintended avoidable damage and provide a cooperation structure to prevent or reduce the damage. This allows Dutch hospitals to contribute to a fifty percent reduction of unintended avoidable damage.

The Quality institute retrieves the data about the quality of care processes from the quality measurements which are executed at the academic hospitals. The data in the hospitals are often gathered by hand, or by searching through the EPD. The data is also often retrieved from unstructured and unorganized data stores, this is the reason why most measurements are often time consuming. The results of the data measurements are anonymized and made public. This way, anyone can use it for research or for publication on a website. The Quality Institute publishes the data on a website so that patients can see for each condition or need of care what good care is and

where that quality of care is delivered. The goal is that the patients or clients are able to make a better choice in choosing care and healthcare providers know which care processes need improvement.

3.3.2 UMC Utrecht

The University Medical Center Utrecht is one of the largest public health institutions in the Netherlands and consists of:

- AZU (adult hospital)
- WKZ (Children)
- Faculty of Medicine of the University of Utrecht

With more than 11,000 employees, the hospital is working on delivering the best care, by making use knowledge and people. According to the hospital, healthcare will not improve without new knowledge about diseases and health, and patients will not receive the best care without people who can generate, apply and transfer this knowledge.

The Mission of UMC Utrecht is:

"UMC Utrecht is an internationally leading academic medical center where knowledge about health, illness and care for the patient and society is created, tested, shared and applied."

3.3.3 Quality of care in UMC Utrecht

At the moment a lot of data in the UMC Utrecht is gathered in a BI solution The BI solution can be used to assess the quality of care processes as explained in the method that is described in the previous chapter. To evaluate the method a case study is conducted at the UMC Utrecht to see if the method is applicable in an academic hospital.

The UMC Utrecht is trying to make quality and safety measurable and verifiable in 2015. The UMC Utrecht wants to positively distinguish in the field of quality and safety in healthcare, education and research. A hospital-wide accreditation by JCI is an important tool in realizing this ambition. The Joint Commission International (JCI) is an international non-profit institution which supports and encourages healthcare organizations to continuously optimize the quality and safety of care. JCI is recognized by the World Health Organization (WHO) as an accrediting agency. JCI appoints several (ongoing) quality initiatives.

UMC Utrecht obtained the international seal of JCI in 2014; it is the first hospital in the Netherlands that obtained the international seal with the new accreditation standards. The hospital is tested on academic standards, which implies that JCI looked at more than 1,400 aspects of quality of care, research

and education. Worldwide only 5% off all hospitals are able to achieve an international seal at once.

This Case study is conducted to evaluate the BI Care Process Assessment Method. In this case study is looked into three care process that needed improvement according to the JCI- project. All three care processes take place in UMC Utrecht. For each care process is researched if the method could be used to assess the quality of the care processes.

The three care processes of which the performances need to improve are:
- Main responsible practitioner
- Pain measurements
- Informed consent

It is important to improve the performances of these three care processes because they are hospitals-wide care processes. Almost every patient comes in contact with these care processes. It is important that a qualified individual is identified as responsible during all the phases of inpatient care, because it will improve the continuity, coordination, satisfaction of the patient, the quality and it may also improve the results. It is also important to screen for pain. Pain is a common aspect of the experience of the patient in a hospital, and when pain is not relieved, it can have unwanted physical and psychological effects. It is also important to obtain an Informed consent before surgery, because, it is one of the main methods in which patients can be involved in decisions about the provided care to them.

3.3.4 Application of the BI Care Process Assessment Method

3.3.4.1 Define

To improve the quality of care processes it is important to understand why they need to improve and what the intended goal is. The care processes that need improvement in the UMC Utrecht are derived from the JCI project. UMC Utrecht uses protocols in which is described how the care processes should be executed to keep the quality of the care processes high. For all three care processes there is a protocol. To improve these processes is it important to derive the key performance indicators (KPIs) from the protocols. The KPIs can be measured to see how the hospital currently is performing. For each care process is described what the intended goal is, the reason of the intended health goal and the key performance indicators that are the derived from the protocol and goal.

Main responsible practitioner

Goal:
"***During all phases of inpatient care, there is a qualified individual identified as responsible for the patient's care***".

To maintain continuity of care throughout the patient's stay in the hospital, the individual with overall responsibility for coordination and continuity of the patient's care or particular phase of the patient's care is clearly identified. This individual may be a physician or other qualified individual. The responsible individual is identified in the patient's record. A single individual providing the oversight of care during the entire hospital stay will improve continuity, coordination, patient satisfaction, quality, and potentially the outcomes and thus is desirable for certain complex patients and others the hospital may identify. This individual would need to collaborate and to communicate with the other health care practitioners. When a patient moves from one phase of care to another (for example, from surgical to rehabilitation), the individual responsible for the patient's care may change, or the same individual may continue overseeing the entire patient's care (JCI).

KPI: The individual(s) responsible for the coordination of the patient's care is identified in the patient's record and available through all phases of inpatient care.

Pain measurements

Goal:
"All inpatients and outpatients are screened for pain and assessed when pain is present"

During the initial assessment and during any reassessments, a screening procedure is used to identify patients with pain. Examples of questions that may be used in a screening exam include the following:

- Are you having pain right now?
- Does pain keep you from sleeping at night?
- Does pain keep you from participating in activities?
- Do you experience pain every day?

Positive answers to questions such as these indicate the need for a more in-depth assessment of the patient's pain. When pain is identified in the outpatient setting, the patient may be more thoroughly assessed and treated in the hospital or provided with a referral for further assessment and treatment.

KPI: Patients are screened for pain.

Informed Consent

Goal:
"Informed consent is always obtained before surgery."

One of the main ways that patients are involved in their care decisions is by granting informed consent. To consent, a patient must be informed of those factors related to the planned care required for an informed decision. Informed consent may be obtained at several points in the care process. For example, informed consent can be obtained when the patient is admitted for inpatient care in the hospital and before certain procedures or treatments for which the risk is high. When the planned care includes surgical or invasive procedures, a separate consent is obtained.

KPI: Consent is obtained before surgical or invasive procedures.

3.3.4.2 Measure

To measure the key performance indicators (quality indicators) it is useful to determine the nominator and the denominator for each care process.

Main responsible practitioner

KPI: The individual(s) responsible for the coordination of the patient's care is identified in the patient's record and available through all phases of inpatient care.

Nominator: Number of clinical admissions in each department for which the individual responsible for the coordination of the patients care is registered.
Denominator: Number of clinical admissions in each department.

Pain measurements

KPI: Patients are screened for pain.

Nominator: Number of services per admission in which a patient has been screened for pain.
Denominator: Number of services per admission (For each service a pain measurement must have occurred).

Informed Consent

KPI: Patients give informed consent consistent with the process.

Nominator: Number of operations for each specialism for which consent is registered.
Denominator: Number of operations for each specialism.

After the nominator and the denominators are determined there must be researched if this data is available. To find out where useful data is stored it

was important to understand the care processes and the information process that supported the care processes. Two of the information processes were registered in an electronic patient record and one was registered in two different information systems. The data of both information systems were available in the BI solution. For all three care processes was electronic data available to measure the quality indicators. This data was used to measure the performances of the care processes.

3.3.4.3 Analyze

To find out why some departments or specializations are performing worse, the data about the operations, services and admissions should be analyzed. To understand the causes of the low performance of care processes it was necessary to analyze the context of the care processes.

To understand for which admission there hasn't been assigned an individual(s) that is responsible for the coordination of the patient's care. It was useful to know which division or department was responsible for assigning that individual during the care process, and when the care process took place.

To understand why there were not enough pain measurements in each of the admissions. It was useful to know which division or department was responsible for measuring the pain in each service and when the care process took place.

To understand why there was not always an Informed consent obtained before surgery. It was useful to know which specialism was responsible for obtaining the informed consent and when the care process took place.

All information/data was accessible in the BI solution (data warehouse) and could be analyzed with an analyze tool.

To analyze the performances of the care processes, care managers were given access to the data of the KPIs and the data about the context of the KPIs via BI products. In which the care managers became agents of the quality of care processes and use self-management to improve. For each KPI was data been visualized in a BI product, in which the users could adapt the parameters. By choosing the desired parameters, the division, department or specialism could see for themselves how they were performing. By giving access to the reports they knew where extra attention was needed to improve the overall performances of the quality of care process.

Main responsible practitioner

The parameters for the report about Main responsible practitioner are:

- Year: Here can be chosen in which year the clinical admission took place.
- Week: Here can be chosen in which week the clinical admission took place.
- Division: Here can be chosen in which division the clinical admission took place.
- Department: here can be chosen in which department the clinical admission took place.

Jaar Ontslag week	Ontslag Week	Divisie	Ontslag Afdeling	Aantal Opnames	Aantal Ingevulde Vragenlijsten	KPI perc. (%)
2013	22	DH&L	C.C.U. Cardiologie	14	5	35
2013	23	DH&L	C.C.U. Cardiologie	15	9	60
2013	24	DH&L	C.C.U. Cardiologie	11	9	81
2013	25	DH&L	C.C.U. Cardiologie	14	12	85
Totaal				**54**	**35**	**64.81**

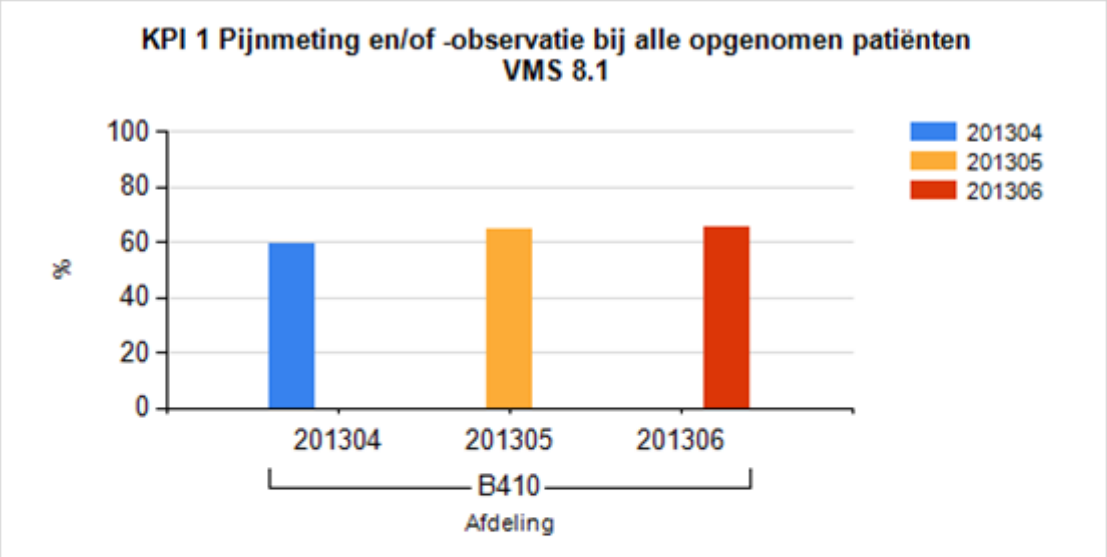
Figure 8: BI product main responsible practitioner

Pain measurements

The parameters for the report about Pain measurements are:

- Year: Here can be chosen in which year the services took place.
- Days: Here can be chosen in which days the services took place.
- Division: Here can be chosen in which division the services took place.
- Department: here can be chosen in which department the services took place.

Pijnscores en -observaties- (deel)opnameperiode / afdeling



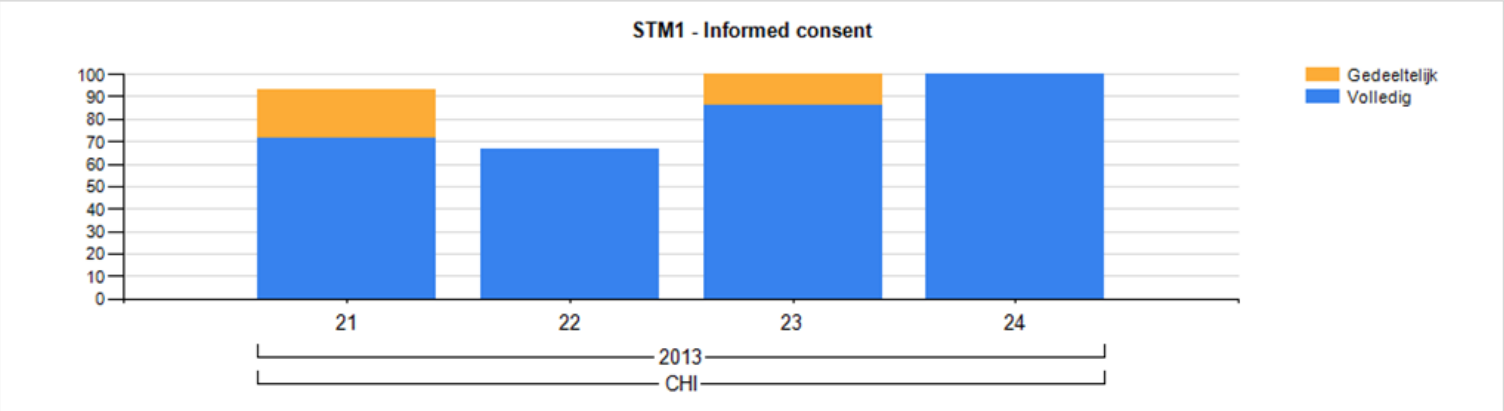
Periode dienst	Afdeling	# (Deel)diensten	# (Deel)diensten met meting/observatie	%
201304	B410-C.C.U. Cardiologie	616	365	59.25
201305	B410-C.C.U. Cardiologie	616	397	64.45
201306	B410-C.C.U. Cardiologie	614	404	65.80
Totaal		**1846**	**1166**	**63.16**

Figure 9: BI product pain measurements

Informed Consent

The parameters for the report about Informed Consent are:

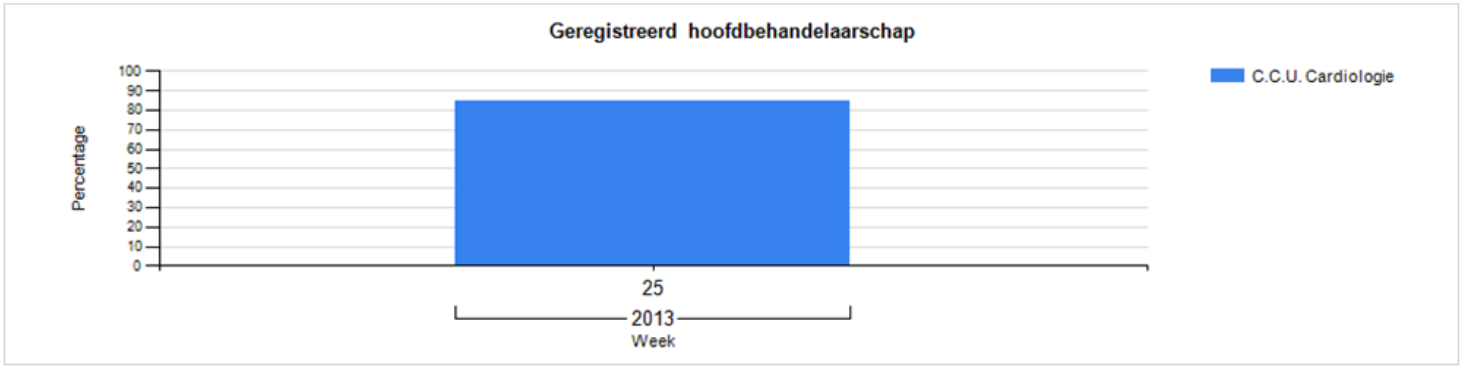
- Year: Here can be chosen in which year the operations took place.
- Week: Here can be chosen in which weeks the operations took place
- Location: Here can be chosen in which hospital the operation took place.
- Specialism: Here can be chosen under which specialism the operation took place.
- Urgent: Here can be chosen if only urgent operation are shown or all operation.



Jaar Operatie Week	Week nr	Specialisme omschrijving	# Operaties	STM1 - # volledig	STM1 - # gedeeltelijk	STM1 - % volledig	STM1 - % gedeeltelijk
2013	21	Chirurgie [CHI]	14	10	3	71.43	21.43
	22	Chirurgie [CHI]	6	4	0	66.67	0.00
	23	Chirurgie [CHI]	22	19	3	86.36	13.64
	24	Chirurgie [CHI]	16	16	0	100.00	0.00
Totaal			**58**	**49**	**6**	**84.48**	**10.34**

Figure 10: BI product informed consent

Analyzing of data in a report (self-management)
In each report, the users can drill down into the information to see/analyze the context in which the admission for example took place and for which admission there has not been assigned an individual(s) that is responsible for the coordination of the patient's care. This way the care managers can analyze the context of care processes themselves.



Jaar Ontslag week	Ontslag Week	Divisie	Ontslag Afdeling	Aantal Opnames	Aantal Ingevulde Vragenlijsten	KPI perc. (%)
2013	25	DH&L	C.C.U. Cardiologie	14	12	85
Totaal				**14**	**12**	**85.71**

Jaar Ontslag week	Ontslag Week	Divisie tekst	Ontslag Afdeling Code	Ontslag Afdeling	Patient Nummer	Opnamenummer	Ontslag Datum	Status	Opname Categorie	Ontslag Specialisme	Ingevulde Vragenlijst
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	18-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	21-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	19-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	18-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	19-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	20-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	19-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	20-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	21-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	23-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	21-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	23-6-2013	Ontslagen	Klinische behandeling	CAR	ja
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	22-6-2013	Ontslagen	Klinische behandeling	CAR	nee
2013	25	DH&L	B410	C.C.U. Cardiologie	[redacted]	[redacted]	22-6-2013	Ontslagen	Klinische behandeling	CAR	nee

Figure 11: Self-management BI product

3.3.4.4 Improve

The improvement of the quality of the care processes were done by choosing several interventions. For each, care process was determined which intervention was needed to improve the quality.

For the first care process 'Main responsible practitioner', several departments had not identified a qualified individual for the patient's care during all phases of inpatient care. This was needed according to the guidelines of the corresponding protocol. The departments were found by making use of the parameter 'Department'. Some departments were performing less than others. Because it was not clear why these departments were performing this way, the care managers did different interventions. One of the interventions focused on the importance of the protocols in which the care processes were described. The health workers could follow a workshop on how to find a protocol and on how to perform the care process that was described. There was also explained how the health workers could register the information process properly that supported the care processes. This information process is important because useful information about the care process can be derived to measure the performances. The performance results show that the interventions helped in improving the quality of the care process 'Main responsible practitioner'.

For the second care process 'Pain measurement', several departments had not screened all inpatient and outpatient for pain and assessed if pain is present. This was also one of the quality business rules that were described in the corresponding protocol about that care process. The departments were analyzed by making use of the 'Department' parameter. In this case were also some departments performing less than others. It was also unclear why these departments were performing this way; the care managers did the same interventions as mentioned for the care process 'Main responsible practitioner'. The intervention contributed in the improvement of the performances of care process 'Pain measurements' that can be seen in the performances results.

For the third care process 'Informed Consent', several specializations had not obtained an informed consent before each surgery. This was also one of the quality business rules that were described in the corresponding protocol about that care process. The specializations were analyzed by making use of the 'Specialism' parameter. Also here, were some specializations performing less than other specializations. Why these specializations were performing less than other specializations were also in this case unclear. Therefore the same interventions were done as those that were done for the care process 'Main responsible practitioner'. These interventions were executed in those departments in which the specialism was operating. The intervention also contributed in improvement of the performances of the care process 'Informed Consent' that can be seen in the performances results.

The academic hospital was able to improve the quality of the care processes by doing different interventions based on the information that was gotten from the BI solution in which the data about the care processes is stored.

3.3.4.5 Control

The same data that is used to analyze the care processes could be used to monitor the quality of the care processes. However, the data needs to be visualized in a different way, so that, the performances of the multiple care processes can be monitored for multiple divisions or multiple specializations (hospital-wide) at the same time and not for each department/specialism. Monitoring the quality of care is done by top-management. To understand which and how data need to be visualized, I interviewed three managers simultaneously (which represented Top-management) that were interested in information about the quality of the care processes. The interview was performed with open questions. Each manager had to answer two questions:

- Which data would you like to see?
- How do you want it to be visualized?

Top-management mentioned that they did not need to know the details about the care processes such as 'Main responsible practitioner'. For example they did need to know for each admission, for which there wasn't assigned an individual(s) that is responsible for the coordination of the patient's care, also they did not needed to see the performance results of every week. The top-management liked to see aggregate information of each month, about how well the divisions/specializations were performing on the three care processes. Top-management also wanted to monitor if the divisions/specializations were improving the quality of the three care processes (if improvement was possible), or if the quality of the care processes was decreasing. If the quality was improving, top-management also wanted to see if the performances of the care processes were reaching the designated norm.

For visualizing this information, a dashboard was made by making use of a BI reporting-tool. A dashboard shows a graphical presentation of the current status (snapshot) and historical trends of an organization's key performance indicators to enable instantaneous and informed decisions to be made at a glance. There was made one dashboard in which it was possible to select one of the three care process. The care processes 'Main responsible practitioner', 'Pain Measurement', and 'Informed Consent' could be selected. For first two care process it was able to see how well the divisions were performing together the past few months and the norm (goal) that needed to be reached. It was also possible to see how well the divisions were operating separately the past few months and what the average score was of the last month. At last, they could see for each division the amounts for the numerator and denominator, for the chosen care process. For the third care process the same information was visualized, however, not for each division but for each specialism.

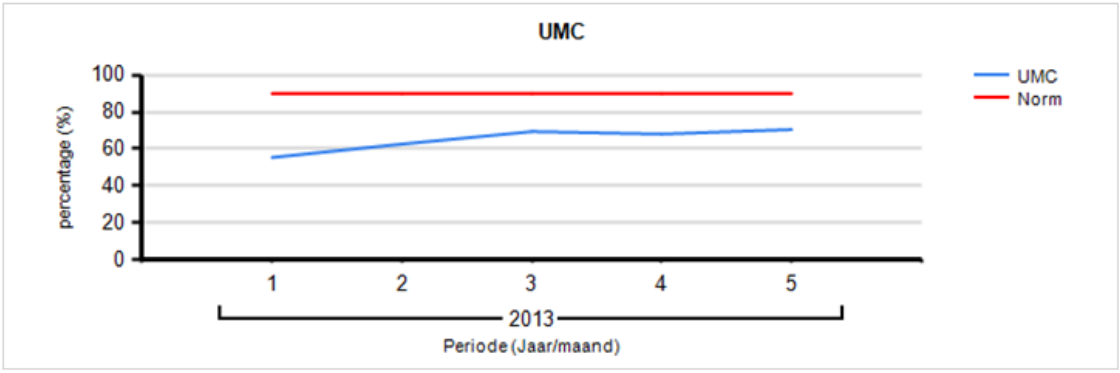
If the performances of the divisions or specializations were decreasing they analyzed the care process again, if the quality of the care processes were still high, top-management kept on monitoring. An example of a dashboard for the care process 'Main responsible practitioner' for top-management can be found in Figure 12.

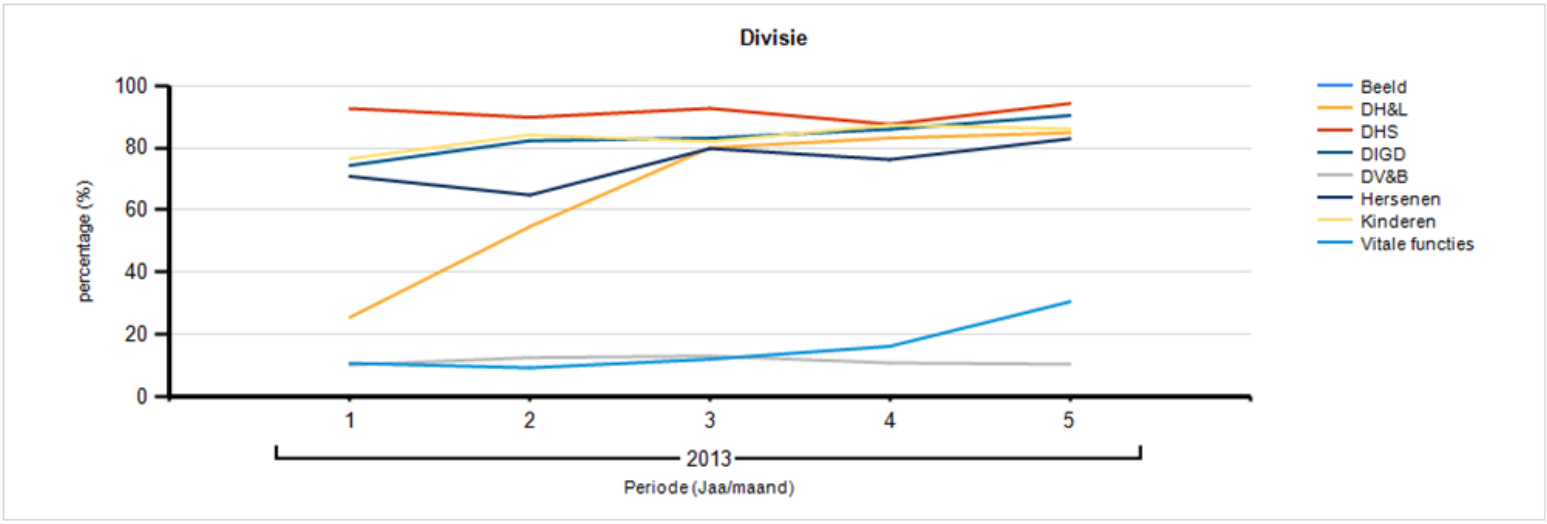
Hoofdbehandelaar

<< Back Dashboard **Trendoverzicht UMC - alle divisie**

UMC Utrecht

Gemiddelde score over Mei 2013





UMC	Divisie:	Teller:	Noemer:	Percentage:	Norm:		
	Beeld	0	23	0 %	90 %	✗	Details
	DH&L	315	371	85 %	90 %	✗	Details
	DHS	467	495	94 %	90 %	✓	Details
	DIGD	304	336	90 %	90 %	✓	Details
	DV&B	53	509	10 %	90 %	✗	Details
	Hersenen	278	335	83 %	90 %	✗	Details
	Kinderen	362	420	86 %	90 %	✗	Details
	Vitale functies	18	59	31 %	90 %	✗	Details

Figure 12: Dashboard Top-management

3.4 Conclusion

The objective of this chapter was to research how a BI solution can be used in assessing the quality of care in academic hospitals. In the previous chapter I researched which steps are needed to assess the quality of a care processes. The method Six Sigma could be used to assess the quality of a care processes. Six Sigma introduces five steps that need to be taken to assess the quality of care process:

- Define
- Measure
- Analyze
- Improve
- Control

For each step I determined if it could be supported by a BI solution.

Define:
There is no business intelligence needed to define the quality improvement goals in a healthcare institute. As mentioned before business rules describe how care processes should be executed to keep the quality of the care processes high. Most of the business rules are described in protocols, saved as a text document and printed to use in practice. In a business intelligence environment, frontline employees have to understand the protocols to provide the highest quality of care and to understand which KPIs are necessary to monitor.

Measure:
Key performance indicators are called quality indictors when it comes down to monitoring and measuring quality of care. To measure the quality indicators data is needed. These data needs to be accessible and easy to analyze to understand how the care processes work and perform. Most of the data that is stored in de databases of the operational information systems in the hospitals are unstructured. This way data is hard to analyze and measure. A BI solution can help out in organizing, accessing, analyzing and measuring the data. By organizing the data in a data warehouse or data mart, data is assessable, easy to understand, to analyze and to measure.

Analyze:
To analyze the current quality of care or the quality of care that has been given, one can use a BI solution and analyzing tools. As said before a BI solution is a database used for reporting and data analysis. The BI solution enables ad-hoc analyses of critical health care issues. By making use of exploratory and descriptive data analysis, unknown relationships can be discovered. There can be researched which factors are responsible for low quality of care, which factors are responsible for a high quality of care, and which factors can improve the quality of care to get to the desired goal. In order to support analysis and reporting tasks, the BI solution must have highly

quality data and make that data accessible through intuitive interface technologies

Improve:
To improve a care process, the process needs to change or done more efficient by making use of other equipment or better information. The improvement of a care processes is not supported by a BI solution. An intervention is often used to improve the care process. Interventions need project management and other planning and management tools.

Control
To improve quality of care health workers need reports that provide the ability to monitor the quality of care processes. This is necessary so top-management can see how well health-workers were operating, how they are operating right new, and they monitor improvements in the quality of care processes and what the intended goal is.
The data that was used for analyzing the care process can also be used to control and maintain the improved processes. By making use of trend reports and dashboards, top-management can monitor the quality of care processes in hospitals and maintain the quality of care processes. The reporting data can also be used as input to analyze trends and to anticipate the impact of possible alternative decisions or developments (Spil, 2002).

The second objective of this chapter is to develop a method that uses elements of a BI solution to assess the quality of care processes, and evaluate the method by doing a case study.
The aim of the case study was to research if the method was applicable in an academic hospital to assess the quality of care processes. All activities of the Six Sigma framework an all components of the BI solution were implemented in a new method called 'Business Intelligence Care Processes Assessment Method'. The method was used to assess the quality of care processes in an academic hospital. All activities of the method were applicable in the assessment of three care processes. So, the Business Intelligence Care Processes Assessment method was applicable in the academic hospital. Since there is only done one case study the results can't be generalized to all academic hospitals, but there is light evidence that the method can be used to access quality of care processes.

In the next chapter is researched which aspects influences the use of a BI solution in a BI environment. Better usage of a BI solution can contribute in the assessment of quality of care processes. The usage of a BI solution depends on the BI environment in which the BI solution is implemented.

4. Assessing the maturity of a BI environment

In the previous chapter is researched if a BI solution can be used to assess quality of care processes. In this chapter is researched which elements in a BI environment influences the use of a BI solution. As mentioned before, better usage of a BI solution can contribute in the assessment of quality of care processes. The usage of a BI solution depends on the BI environment in which the BI solution is implemented. To measure if the BI solution is used appropriately and used for the right goals, a BI maturity model is developed.

Problem definition

A BI maturity model is a model that indicates the level at which the BI solution development and usage of an organization is. The reason to evolve to a higher maturity level is that technologies which are on a higher level of BI maturity bring higher value to an organization because they address larger issues that business faces. Also, the higher an organization is on a BI maturity scale the higher the effectiveness and efficiency in decision making. Effectiveness and efficiency in decision making corresponds to the seamless translation of a vision into an actual product or service (Cates, 2005). The service in this case would be delivering high quality of care processes.

Therefore, if the technology of the BI solution is mature enough, it should ensure high IT performances and high quality of data. If the BI solution is also adopted, used and aligned with the care processes in a mature way, and can be used to assess the quality of care, it can improve the effectiveness and efficiency of decision making which may contribute in the improvement of quality of care. A BI environment can however be complex and challenging. This is why it is important to assess and gain some insight into the focus areas that determine the maturity of a BI environment in which the BI solution is used.

At the moment there are multiple maturity models with which the maturity of a BI solution or the use of it can be determined, these maturity models have all different and corresponding measurable elements. All these business intelligence maturity models also focus on different aspects to determine the maturity of these different aspects. I am going to integrate these BI solution and Data maturity models. By integrating these maturity models I am going to create an overview on the measurable elements that needs to be taken into account to measure the maturity of a BI environment. The maturity of the BI environment refers not only to the maturity of the BI solution but also to how well and often the BI solution is used and in which context it is used.

Purpose of the BI environment maturity model is to determine the current BI environment maturity-level in hospitals and to provide a way to evolve to a higher maturity level to enlarge its contribution in the assessment of quality of care processes. The maturity model should provide focus areas for hospitals to

be aware of their current situation and to know the steps they have to take to get to a higher level of maturity.

To see if the BI environment in academic hospitals is mature enough it is important to understand which BI elements in a BI environment can be measured. In a maturity model is the maturity of the elements represented in multiple maturity levels. Maturity levels have a number of sequentially ordered levels, in which the lowest stage stands for an initial level, which can be described as an organization that has little capabilities in the BI domain. The highest level represents a conception of total maturity. Each level of maturity is an intelligence level that enables better, deeper, and quicker understanding of the business environment. For each level are the maturity levels described for multiple focus areas.

The maturity model can be used as an assessment of the position on the evolution path, and for each level a certain set of criteria and characteristics needs to be fulfilled. By using maturity modeling we will gain some insight into the different BI environment maturity levels and the corresponding maturity levels within each focus area.

The maturity model is designed by making use of the generic method that is designed by Steenbergen et al. (2010). This generic method is designed for developing focus area maturity models. Focus area maturity models are based on the concept of a number of focus areas that have to be developed to achieve maturity in a functional domain. The generic model that is designed by Steenbergen et. al. (2010) exists out of 9 activities:

4.1 Identify and scope the functional domain.
4.2 Determine focus areas
4.3 Determine capabilities
4.4 Determine dependencies
4.5 Position capabilities in matrix
4.6 Develop assessment instrument
4.7 Define improvement actions
4.8 Implement maturity model
4.9 Improve matrix iteratively &
4.10 Communicate results

For each activity is the chapter mentioned in which the activity is described.

4.1 Identify and scope the functional domain:

A BI Environment Maturity Model is a model that indicates the level at which the BI environment of an organization operates.

The focus in this thesis is not on the maturity of the BI project, but on the maturity of the BI alignment, People, BI solution/BI products (Technology) and the Processes.

- BI alignment: describes the alignment of the BI strategy with the business strategy.
- Process: describes how well the business and BI processes are managed, standardized and documented.
- Technology: Technology describes the focus areas that measure the maturity of the BI solution and its BI products.
- People: Here is the maturity described of the users characteristics and involvement in the development of the BI product, the more mature the more specialized.

4.2 Determine the focus areas

4.2.1 Literature research

A literature has been conducted to find out which focus areas should be in the BI maturity model. Data was gathered through Google and Google Scholar, which was chosen for its high accessibility. Google was also used because not all maturity models were available through Google scholar.

The following keywords were used in the search of literature: "BI maturity model", "Data warehouse maturity model" and "Business Intelligence Maturity Model".

This literature review uses the same inclusion and exclusion criteria that were mentioned in the literature review described in chapter 2.1.

The results of the literature research on the subject *measuring the maturity of a BI environment* are used to answer the following sub- research questions:

How can the maturity of a BI environment be assessed and improved in order to enlarge its contribution in the assessment of quality of care processes?

The focus areas are the areas that need to be measured to determine at which level a BI environment of a company operates. There are multiple models about the maturity of BI and the use of it, with each different focus areas. These different maturity models are going to be used to compose the BI Environment Maturity Model. First, the different maturity models that are used to determine the focus areas of the BI environment will be shortly described. After that, a table is shown in which the different maturity models and there corresponding focus areas are depicted.

From all these (sub-) focus areas are the final main focus areas and the sub-focus areas determined for the BI environment maturity model, the final sub-focus areas that are derived from the maturity models will be classified under the main focus areas. The similar sub-focus areas that are mentioned in multiple maturity models but are named differently are integrated into one sub-focus area. For each sub-focus area will be depicted if one or multiple maturity models mention or describe that sub-focus area. At last, an overview of the main focus areas and their sub-focus areas are shown that determine the maturity of a BI environment.

4.2.2 Description of the maturity models:

Peter stock (2013)

Peter Stock describes a BI maturity model in which the evolution of companies' BI capabilities is described. The capabilities are divided into three main capabilities: business enablement, information management and strategy & program management. The model outlines a path forward and should help companies work towards closer alignment between business and IT.

SAS (2007)

SAS describes five steps to evolve into an intelligent, high-performance enterprise. For each step are four focusing areas described that help the company in managing its information assets. The four focus areas are: infrastructure, knowledge processes, human capital and culture. A company's maturity along theses focus areas are represented in a five-level evolutionary path.

Chuah and Wong (2013)

Chuah and Wong propose an Enterprise Business Intelligence Maturity Model (EBI2M) and evaluate it in one of the financials companies in Malaysia. The maturity model describes five maturity levels. For each maturity level are thirteen focusing areas described for which de BI capabilities are determined. The EBI2M is used to provide symmetric guidelines for companies to improve the BI implementation in the future.
The thirteen focus areas are: Data warehouse perspective, data management, Meta data management, knowledge management, infrastructure, analytics, performance, balanced scorecard, information quality, people, organizations culture, strategic management and change management

Hagerty (2006)

Hagerty introduces a Business Intelligence/Performance Management Maturity Model, which is a framework for business and IT leaders to asses group and firm-wide actions while charting a course for eventual broader deployment of business intelligence and performance management. The

maturity model describes four maturity levels, for each maturity level are the attributes and characteristics determined.

Watson et al. (2001)

Watson et al. describes a study that identified three data warehousing stages of growth. For each stage are the variable described that define each stage. The data warehousing stages of growth model can be used in understanding and predicting how the data warehouse of the organization change. The paper also provides recommendation for managing the progression through the stages. The variables that are described are: data, architecture, stability of the production environment, warehouse staff, users, impact on user's skills and jobs, applications, cost and benefits, and organizational impacts.

Hawkin et al. (2010)

Hawkin et al. describes a research that provides a snapshot of the BI practices of Australian companies and a potential roadmap for future BI opportunities. He introduces a BI Maturity Model which is developed by the American SAP User Group (ASUG) as part of their BI benchmarking service. The model describes four maturity stages which are determined by four categories. The four categories are: information and analytics, governance, standards and processes, and application architecture.

Miller et al. (2009)

Miller et al. describes a data warehouse maturity assessment service that is provided by Teradata Corporation. The assessment can be used to define and measure the characteristics of the overall maturity of a data warehousing environment. The white-paper introduces a Data Warehouse Maturity Scorecard that exists out of 6 maturity levels. For each level are ten focus areas mentioned that need to be measured to determine the maturity level. The focus areas are: business alignment, architecture practices, performance management, BI/decisions support, business analytics, data management, data integration, business continuity, communications and training and program/project management. However these focus areas are not fully described.

Cates et al. (2005)

Cates et al. describes The Ladder of Business Intelligence (LOBI) which is a methodology that facilitates the creation of an information technology (IT) plan and design of IT architecture for a business. The LOBI methodology derives the plan and the architecture on the basis of the business objectives by analyzing the people, process and technology. The paper introduces a LOBI maturity model in which the IT technology is mapped into six distinct levels of intelligence. The methodology looks at how to provide meaningful, useful and accessible data to core entities in an organization.

Fisher (2005)
Fisher describes the Enterprise Data Management Maturity Model, which helps companies identify and quantify their respective levels of data maturity. By assessing the maturity of the data management, the company can understand the risks that are associated with bad data management practices. The model can also be used to understand the benefits and the costs of moving to the next stage. By understanding the maturity model, the organization can control its data management environment. The focus areas for each level are: people, process, technology, and risk and reward.

Sacu & Spruit (2010)
Sacu & Spruit present the Data Warehouse Capability Maturity Model which exist out of 5 maturity levels and encompasses both technical and organizational aspects involved in the development of a data warehouse environment. The maturity model can be used to help organizations asses their current data warehouse solution and provide the companies with improvements for the future. To assess the data warehouse solution the model introduces a maturity matrix and a maturity assessment instrument. The maturity levels measure the following focus areas: architecture, data modeling, ETL, BI applications, development process and services processes.

Eckerson (2009)
Eckerson introduces a six stage BI maturity model that shows the trajectory that most organizations follow when they evolve their BI infrastructure from the lowest maturity level to the highest. The model provides a view of where a BI program is, where it needs to go and how to get there. For each level are the following focus areas determined: architecture, scope, type of system, analytics, user, BI focus and executive perception about the role of BI.

4.2.3 Maturity models and the mentioned (sub-) focus areas

The next four diagrams show the eleven maturity models that are described in the previous chapter (4.2.2). For each maturity model is indicated which sub-focus area are mentioned in that model and which sub-focus areas are not mentioned. If a sub-focus area is mentioned in model it means that the model uses that sub-focus area to determine the maturity. The sub-focus areas are clustered into four main focus areas: Business Alignment, People, Processes and Technology.

Business Alignment

1	BI strategy	BI Governance	BI Requirement	Business rules	Business benefits of Business Intelligence	Business intelligence used in Care processes
Peter Stock (2013)		✓			✓	
SAS (2007)				✓	✓	✓
Chuah & Wong (2013)		✓			✓	
Hagerty (2006)						
Watson et al. (2001)		✓			✓	
Hawking et al. (2010)		✓				✓
Miller et al. (2009)						✓
Cates et al. (2005)						
Fischer (2005)		✓			✓	✓
Sacu et al. (2010)			✓	✓		
Eckerson (2009)					✓	

People

2	Manual vs. Auto-matic activities	BI users	BI Developers Characteristics	BI Developers	C-level involve-ment	BI developer expertise	Infor-mation culture	C-level under-standing data-integrity	Training
Peter Stock (2013)	✓	✓			✓	✓	✓		
SAS (2007)	✓		✓			✓	✓		
Chuah & Wong (2013)	✓			✓			✓		✓
Hagerty (2006)					✓		✓		
Watson et al. (2001)		✓	✓	✓		✓			
Hawking et al. (2010)									
Miller et al. (2009)					✓				✓
Cates et al. (2005)									
Fischer (2005)	✓				✓	✓	✓	✓	
Sacu et al. (2010)					✓				
Eckerson (2009)	✓	✓	✓				✓		

Processes

3.	SLA MT	Change MT	Incident MT	Release MT	Resource MT	Availability MT	Knowledge MT	Data MT	Evaluation
Peter Stock (2013)	✓	✓						✓	
SAS (2007)							✓	✓	
Chuah & Wong (2013)		✓					✓	✓	
Hagerty (2006)								✓	
Watson et al. (2001)									
Hawking et al. (2010)									
Miller et al. (2009)	✓							✓	
Cates et al. (2005)									
Fischer (2005)							✓	✓	
Sacu et al. (2010)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Eckerson (2009)									

4.1	ETL	BI solution architecture	Data model levels	Integration of data	Data Availa-bility	Data granularity	Environ-ments	Meta data
Peter Stock (2013)		✓		✓	✓			
SAS (2007)		✓		✓	✓			
Chuah & Wong (2013)	✓	✓		✓				✓
Hagerty (2006)				✓	✓			
Watson et al. (2001)		✓		✓				
Hawking et al. (2010)		✓						
Miller et al. (2009)				✓	✓			
Cates et al. (2005)		✓		✓	✓			
Fischer (2005)		✓		✓				
Sacu et al. (2010)	✓	✓	✓	✓	✓	✓	✓	✓
Eckerson (2009)		✓			✓			

4.2	Data quality	Data access security	BI analyze tool	BI products
Peter Stock (2013)	✓		✓	✓
SAS (2010)	✓	✓	✓	✓
Chuah & Wong (2013)	✓		✓	✓
Hagerty (2006)	✓		✓	✓
Watson et al. (2006)	✓		✓	
Hawking et al. (2010)				
Miller et al. (2009)	✓	✓		
Cates et Al. (2005)	✓		✓	✓
Fischer (2007)	✓			
Sacu et al. (2010)		✓	✓	✓
TDWI			✓	✓

4.2.4 Main focus areas with the derived sub-focus areas

The next figure shows an overview of the four main focus areas that determine the maturity of the BI environment, with their sub-focus areas:

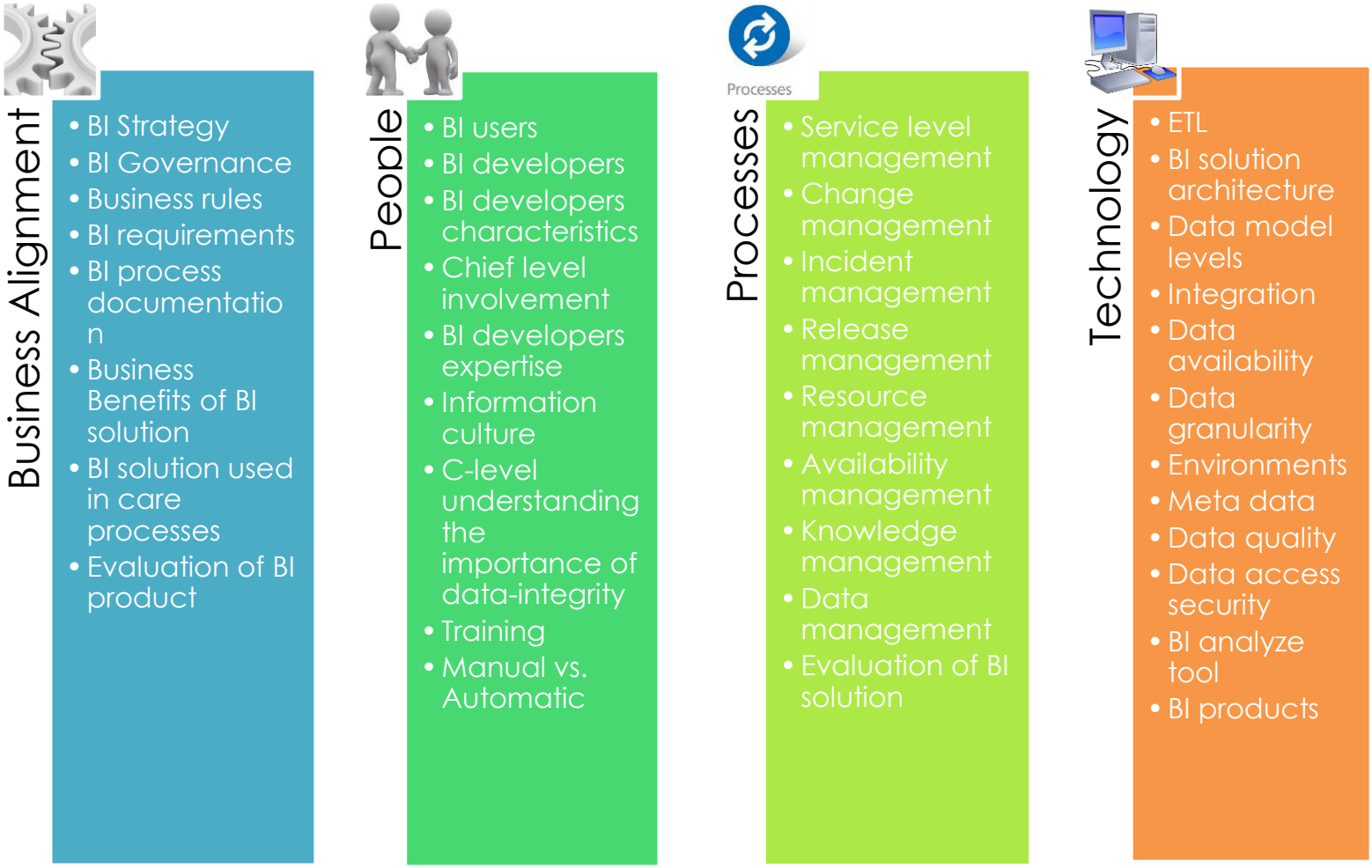


Figure 13: Main focus areas

4.3 Determine capabilities of the BI Environment Maturity model

The next chapters describe the sub-focus areas and their capabilities for each main focus area. The sub-focus areas that are described below are adjusted focus areas. The adjustments were introduced after the capabilities were reviewed by multiple experts, which are described in chapter 4.6. The original focus areas can be found in Appendix A.

4.3.2 Business Alignment

4.3.2.1 BI strategy

A BI strategy is driven by business objectives, such as the improvement of the performances of quality of care processes. The BI strategy enables top-management with better decision making capabilities and helps enterprises in achieving the desired goals. Effective BI strategy should ensure that enterprise objectives, business strategy, investments and BI solution are aligned. Enterprise that are able to connect BI strategy to overall enterprise objectives become intelligent enterprises. BI strategy should include a broad set of processes, technologies and stakeholders for collecting, integrating, accessing and analyzing information for the purpose of helping enterprise make better business decisions. BI strategy should also have a comprehensive approach in describing the current and future behavior of the business alignments, processes, technology, people and other components to ensure that they are aligned with the goals and strategic direction of the enterprise (Deloitte, 2009).
It is also vital to establish a BI vision to ensure that implementation of specific components fits in the overall BI strategy. BI strategy should state and document the needs as identified by top-management, highlighting how BI fits in the broader enterprise vision. BI vision should for example help to drive better performances of quality of care processes, by empowering all care managers to be able to play their roles effectively because of the BI adaption (Deloitte, 2009).

BI strategy	BI strategy present, No alignment with Business strategy.	BI strategy present, aligned with some parts of business strategy.	BI strategy present, aligned with current business strategy and enterprise objectives.	BI strategy present, aligned with overall business strategy. BI strategy describes current BI processes and goals.
BI strategy documentation	Some documentation in Business strategy.	Report with the vision and goals of the BI strategy.		

4.3.2.2 BI governance

The most mature hospitals have moved towards developing a business intelligence competency center (BICC). A BICC enables hospitals to adopt an enterprise wide approach, standardize and co-ordinate their BI efforts. This enables hospitals to leverage their experiences and best practices while at the same time limiting reoccurrence of mistakes. The organization and operation of a BI solution is important for the outcome of a BI initiative. Establishing a BI competency center will help in integrating BI best practices with the on-going BI work and the BI environment of the hospital. According to Deloitte (2009) the setup of a BICC could be the factor that improves the use of BI from a nice to have report system to a solution that provides top-management/ management with the accurate and timely information to improve the performances of quality of care processes. The BI people, BI processes and BI solution need to be aligned with the strategic objectives to maximize investment and deliver measurable business value such as the imrpovement of quality of care processes.

BI governance	Best practices are not documented but are standardized.	IT best practices are documented and standardized, to develop and maintain the BI solution.	IT and analytical best practices are documented and standardized, to design the BI solution based on the information needs.	The best practices of IT, analytical and business processes are documented and standardized in a Business Intelligence Competence Center for some part of the organization, to manage and align the Business Intelligence strategy with the Business strategy.	Enterprise wide BI governance with business leadership.

4.3.2.3 Business rules

Business rule documentation

Determines if the business rules are described and documented. Business rules describe the operations, definitions and constraints that apply to a hospital. Business rules can apply to people, processes, corporate behavior and computing systems in a hospital, and are put in place to help the hospital achieve its goals. Business rules about the quality of care processes are described in protocols. The business rules describe how care processes should be executed to keep the quality of the care processes high, the objectives of the business rules can be measured by making use of key performance indicators (SAS, 2007).

Business rule documentation	Some business rules are defined and documented.	Most business rules are defined and documented.	All business rules are documented.

Business rule availability

Determines if the business rules are available digitally, for example via a webpage or shared documents.

Business rule availability	Some business rules are available digitally.	Most business rules are available digitally.	All business rules are available digitally.

Business rule usage

Determines if the business rules are known by the health workers. As mentioned before, the business rules are described in the protocols of hospitals and should be followed to keep the quality of care processes high. Business rule usage determines also if the health workers know how to execute the business rules in the care processes. It has no use to measure the performance of quality of the care processes if health workers don't understand the contribution of the business rules in keeping the quality of care processes high or don't know how to perform those (SAS, 2007).

Business rule usage	Some health workers know that the business rules exist, but do not execute them.	Health workers know they exist but do not understand how to use them or how they contribute in the improvement of quality of care.	Health workers know they exist and why to use them, most of the health workers use the rules.	All health workers that needed to know the business rules know them and try to improve the quality of care.

4.3.2.4 BI requirements

BI solution requirement documentation

Determines how well the requirements for the BI solution are described, documented and available (Sacu et al., 2010). The documents are often written by BI developers and define the BI solution they are making, or the document defines the requirements for one or more new features for an existing BI solution. The requirements document of a solution exists out of functional requirements, technical requirements and sometimes service level agreements (SLAs). It is important to define, classify and document the functional requirement, technical requirements and SLAs of the BI solution. Each requirement needs to be categorized as essential, important or desired. Examples of a requirement of a BI solution are the inclusion and exclusion criteria of data for a report. Requirements for the BI solutions can be described for three levels of management: Strategically management, Tactical management and Operational management and IT. While most organization starts with the requirements for operational management, some start with strategic management. So, it is not clear which level comes first. Therefore, the maturity levels start with the requirement documentation for none levels until the highest maturity level in which requirements are documented for all levels.

BI solution requirement documentation	Documentation for one of the levels.	Documentation for two levels.	Documentation for all levels.			
BI solution requirement availability	Some requirements are available for one level.	Some requirements are available for two levels.	Some requirements are available for all levels.	All requirements are available for one level	All requirements are available for two levels	All requirements are available for all levels

BI Requirements method

Encompasses which methodology is used for eliciting, analyzing and recording the requirements for the BI solution. In a BI environment, user requirements represent the most powerful driving force as they affect virtually every aspect of BI environment.

BI solution requirements method	Ad-hoc requirements definition, no methodology.	Methodologies differ from project to project; interviews with care managers to collect the requirements.	Standard methodology for all the projects; interviews and group sessions with both care managers and IT management for collecting the requirements.	Qualitative assessment and measurement of the methodology, the BI requirements are documented and also published.	Causal analysis meeting to identify common bottlenecks causes and subsequent elimination of these causes.

4.3.2.5 Business intelligence solution used in Care processes

Refers to how well the BI solution is used to support the assessment of quality of the care processes. The highest level that can be reached is where a BI solution is used as a strategic and competitive asset and provides useful information to improve the quality of care processes and decision making (Stock, 2013).

BI solution used in business processes	Limited use, BI has to evolve. Local use. Users build awareness and understanding of quality of care processes. (Historical data).	BI solution is used to follow trends in care processes, to save time and increase useful information. Users build awareness and understanding of quality of care processes (historical data).	Care processes improve through analysis by making use of BI solution. More useful information. BI solution is used as a strategic and competitive asset BI users understand how BI solution can be used to assess the quality of care processes.	BI solution is fully embedded in all levels of the hospital to promote and enable strategic agility, and to support decision making.	BI solution is used to predict outcomes. BI solution is used to support corporate strategy. BI is used to redesign care processes. Users exploit right-time information to work proactively to solve problems and optimize performance.

4.3.2.6 Business benefits of BI solution

Refers to the benefits that arise when a hospital uses a business intelligence solution. The highest level that can be reached is when the focus of a hospital is only on improving the performances of quality of care processes and not on improving the BI solution/data quality. The Business value of a BI environment is being realized when metrics are defined and when the BI processes are in place and are coming together into a set of assets and capabilities that directly target quality of care improvements through broad-based us of BI (Stock, 2013).

Business benefits of BI investment	Vague, mostly costs. BI is a cost center. Time is spent on data quality.	Some benefits are identified, New and better information. BI informs care managers better. Time is spent on data quality.	Quality of care processes increases by making use of complex analytics. Make better decisions BI empowers the care managers and care processes can be monitored. Time is spent on data quality and on improving quality of care processes.	Business benefits are improved through operational, tactical and strategically BI. BI helps the hospital drive the business. Time is spent on improving quality of care processes. Users have access to insights that help them work more effectively and optimize care outcomes.	Realization of the full business value of BI. Business benefits improve through predictive analytics. BI helps the hospital to drive the market. Time is spent on improving quality of care processes.

4.3.3 People

4.3.3.1 Manual versus Automatic BI processes

Determines if most of the BI processes are done by hand (ad-hoc) or if the BI processes are done automatically. At the beginning most activities will be done manually (ad-hoc) (SAS, 2007). Automating processes improves the BI processes and the availability of data. It makes it also able for BI developers/suppliers to focus on new products that can contribute in the improvement of the performances of quality of care processes.

Manually vs. Automated	Some BI processes are done manually (analyzing, ETL, integrating, cleansing of data and reporting).	Most BI processes are automated (ETL, quality checks and reporting).	All most all BI processes are automated except for specific requests.

4.3.3.2 BI users

Refers to the kind of management that uses the Business Intelligence solution. There are three levels of management: strategically, tactical and operational management (Roekel et al., 2009). Care managers are a part of operational management. The BI products can support the care managers. The care managers can improve the care processes by making use of the information that is provided via a BI product/solution. Care managers can also track trends in the care processes. They can analyze how long a certain trend occurs and what causes it. If it is, an unfavorable trend there can be found a way to prevent it next time, if it was a favorable trend there can be analyzed what caused it and how to continue this trend (Watson et al., 2001). The maturity levels determine in how many management levels the BI solution/products are used.

BI users	One level.	Two levels.	All levels.

4.3.3.3 BI developers

BI developers are the providers of the BI solution. BI developers understand the BI processes and the information processes that support the care process, which are needed to produce information products. BI solution developers refer to the size of the group and the extensiveness of the BI roles of the BI developers. The BI developers can have different roles in the beginning because they have to do different tasks. The BI developers are focusing in the beginning more on the BI processes while later on they are focusing on the information processes (Watson et al., 2006). How more mature the BI solution becomes the more specific the tasks become, and the more specialized the assigned role is.

BI developers	1-3 BI developers, all developers know something about all BI processes and data products.	3-5 BI developers, certain roles are assigned however BI solution developers are not specialized in their roles.	5 or more BI developers, each BI developer has been assigned to a specific task and is specialized in their task.

4.3.3.4 BI developers characteristics

BI developers refer to the characteristics of the BI developers that provide the BI solutions. It refers to the information skills of BI developers within a hospital and the quantifiable aspects of their capabilities, recruitment, training, assessment and alignment toward the enterprise goal (SAS, 2007).

BI developers characteristics	People, who prize autonomy, work well in unstructured environments and are fairly outgoing and risk tolerant.	People who support departmental rather than individuals or enterprise agendas. Charismatic leaders, but are more likely to select and align themselves with team players rather than individuals.	People who collaborate well within their peer group, but they also think outside their functional unit about the greater good of the enterprise.	People are driven, diverse and adaptable, and they drive one challenge. They prefer creative challenges to predictable tasks and are not afraid to take risks. They bring diverse intellectual skills to the table and use historical and predictive analysis to increase the effectiveness of their organization.	People are proactive creative thinkers with a venture-capitalist mentality. They hold various roles within the organization. They focus on moving the business forward while always considering new ways their expertise might create value.

4.3.3.5 Chief level involvement

The improvement of quality of care processes is putting pressure on Chief level (C-level) executives to make better-informed decisions, and on the CIO to provide accurate, consistent and timely information from a dynamic organization. Chief level involvement refers to the extent of top-management support and sponsorship for the BI environment. Strong support and sponsorship from top-management is critical for a successful BI initiative (Roekel et al., 2009). The visibility that management support brings will open the door for investments in both manpower and capital (Stock, 2013). Management support can be provided through centralized management and decentralized management (locally) The sponsoring via centralized management is provided via IT management which is top-down and the sponsoring via decentralized management is provided via management of different departments/wards that uses the BI solution.

C-level involvement	Sponsoring by IT-director via central management.	Limited sponsoring by C-level involvement via central management.	Decentralized sponsoring by management of multiple departments/ wards, central sponsoring by C-level management which is engaged in BI.	Decentralized sponsoring by management of multiple departments/ wards, central sponsoring by C-level management which sponsors the BI portfolio.	Top level management sponsorship, C-level management embraces BI as a strategic lever for the business and all C-level management of each department sponsors BI because they want to make use of BI information products.

4.3.3.6 BI developers expertise

Determines how much the BI product developers know about the information processes that support the care processes. It is important to understand the information processes. The BI reports can display the performances of the care processes if analysts known how the information is registered and how it is stored. The data from these information processes can be used to measure the performance of quality of the care processes, which can be displayed in a BI report.

BI developers expertise	1-3 talented individuals, focus is on IT skills to develop the BI solution.	3-5 individuals who have substantive BI knowledge or BI consulting partner.	In-house resources and 5 or more individuals who have knowledge about BI processes.

4.3.3.7 Information Culture

Shows how information is used and how it is improved and shared. The information that is provided via a BI product can be used for individual objectives and for enterprise objectives. At the highest level most is used for enterprise wide objectives (SAS, 2007).

Information culture	Individual objectives, 'everyone for himself' Measure what is happening.	Department objectives, 'us versus them' How to monitor the business.	Enterprise objectives, Information-quality improvement. To make better and new information products on a project base.	Information is used for enterprise objectives, to improve information quality constantly and to improve collaboration and interdependency between departments on a project base.	Information is used for enterprise objectives, to improve collaboration and interdependency between departments constantly.	Information is used for enterprise objectives, to come up with new ideas to improve strategy constantly.

4.3.3.8 Chief-level understanding the importance of data-integrity

Determines if C-level management understands the importance of a high level of data–integrity. It is important that chiefs understand why a high level of integrity is important. If they understand what the consequences are if the integrity is low, than they are more willing to provide more personnel and resources to reach a high level of data-integrity (Fischer, 2005).

Chief-level understanding the importance of data-integrity	Limited corporate management buy-in to the data integrity.	Receive executive and management approval to improve the data. The data improvement initiatives receive personnel and resources to create high-quality data.	Procedures help the enterprise to achieve the highest levels of data integrity. Department-head is responsible for information-quality.

4.3.3.9 Training

Education and communication regarding BI initiatives is necessary to help the care managers derive value from the BI environment. As the data/report is introduced in the BI environment, trainings sessions, data forums, and metadata needs to be made available to the BI community (Deloitte, 2009).

Training	Company develops skills with extern-training programs.	Employees gain information skills through formal intern training.	Intern information skill training programs are available through email and portal.	Comprehensive training plan program is scheduled and organized. All levels of employee have access to the training.

4.3.4 Processes

4.3.4.1 Service level management

Describes the service level agreements between BI developers and BI users, about the BI solution/products. Service level agreements are made during the completion of the BI solution/products requirements. The service level agreements need to be documented and formalized. BI application management services are based on clear service level agreements, and by making use of blended delivery models. By ensuring the service level agreements, BI developers can use the BI solution to produce BI products. The BI solution is used by the BI users (care-managers). By monitoring the agreements, care managers can focus on their job to monitor and improve the care processes if possible. When information is delivered via a service oriented framework, BI solutions and BI developers have to ensure that agreements are met by continual monitoring and reviewing. When service levels are discussed, set and measured consumers and users will know what to expect (Sacu et al., 2010). As a result, they will develop confidence in the BI solution/BI product and the BI providers (Miller et al., 2009).

Service level management for BI solution	Customer needs are documented ad-hoc.	Some of the customer's needs are documented and formalized. SLA's.	All the customer's needs are documented and formalized SLA's.	SLA reviewed with the customer on periodic and event-driven base.	Actual service delivery is continuously monitored and evaluated for continuously improvement.

4.3.4.2 Change management

Aims to ensure that standard methods and procedures are used to handle changes as soon as possible and in an efficient way. It is important to use a standard procedure and a change management system to store, approve, verify, prioritize and schedule changes. This way there is a good overview of what has changed and what still needs to be changed (Sacu et al., 2010). Also the quality of BI solution will go up because errors are documented or solved. A standard procedure enables a quick change when necessary. A quick change is necessary when a BI product is used for improving the quality of care but shows the wrong data, or when the way of registering data in the application has changed. It is also important to track changes in BI solution a product requirements, by tracking them you can see the progress of the BI solution that supports the improvement of quality of care processes.

Change management for BI solution	Change request are made and solved in an ad-hoc manner. No alignment between information system and BI solution.	A change-management system is used for storing the request for change. No alignment between information system and BI solution.	A standard procedure is used for approving, verifying, prioritizing and scheduling changes. Changes in the information system are aligned with changes in the BI solution.	Standard reports concerning the change status are regularly produced for all the involved teams. Changes in the information system are aligned with changes in the BI solution.	Trend analysis and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them. Changes in the information system are aligned with changes in the BI solution.

4.3.4.3 Incident management

An incident is an event which does not belongs to the standard operation of a service and which causes or may cause interruption or reduction in the quality of that service. Incident management refers to the activities of an organization that identify analyze and correct hazards to prevent future re-occurrence (Sacu et al., 2010). It is important to report incidents into a ticket handling system and to assess and classify the incidents by following a standard procedure. By following a standard procedure the most necessary incident are treated first. By classifying the incidents one can measure how much the BI product contributes in the improvement of the quality of care. For example an incident may cause that a health worker can't access multiple reports which he/she needs to provide a high quality of care, but an incident can also cause that a health worker can't download a report but can see the results she needs. The former incident is more crucial than the last incident, because the health worker can't provide the best care possible. Solving incidents improves the productivity of the consumers/ users, improves process monitoring, higher customer/user satisfaction.

Incident management for BI solution	Ad-hoc, No specialized ticket handling system or service desk.	A ticket handling system.	A service desk, Incidents assessments and classification is done following a standard procedure.	Standard reports are regularly produced, An incident management database is established.	Trend analysis in incident occurrence, in customer satisfaction, and value perception of the service provided to them.

4.3.4.4 Release management

A release is a composition of one or more changes. A release exists out of different categories:

- Major Release (major roll-out new hardware / software, significant new functionality, often takes several Known Errors way, including Quick Fixes and workarounds)
- Minor release / hardware upgrade (minor improvements in Fixes Known Errors, last good basic configuration is updated)

Release management refers to the process of managing releases from development stage to the actual release. Release management ensures the use of high quality software and hardware, and less implementation. Releases take place in BI solutions and BI products. Release management should be documented and be done by following a standard procedure (Sacu et al., 2010). By documenting the releases, users of the reports can see what has changed and what the new possibilities are. Therefore the users can fully exploit the BI product.

Release management for BI solution	Ad-hoc releases, No release naming and numbering conventions.	Release naming and numbering conventions.	Release management is documented and done following a standard procedure.	Standard reports concerning release management.	Release management trend analysis.

4.3.4.5 Resource management

The purpose of resource management is to maintain control of the necessary hardware and software resources needed to deliver the agreed DWH service level agreements. Before commitments are made to BI developers, resources are checked. If not enough resources are available, either the commitments are adapted or extra resources are installed. It also involves monitoring the ETL and the BI solution in order to see if the current resources are enough for the desired BI solution performance (Sacu et al., 2010).

Resource management	Ad-hoc resource management activities.	Resource management following some procedures.	Resource management following documented standardized procedures.	Resource management following documented standardized procedures and standard reports concerning performance.	Resource management following documented standardized procedures and standard reports concerning performance and trend analyzing.

4.3.4.6 Availability management

The goal is to address the issue of a cost effective and established level of availability of the BI solution/products. Availability management is responsible for ensuring application systems to be up- to -date and available for use according to the conditions of the service level agreements (Sacu et al., 2010). Availability should be managed for the BI solution and the BI product. Availability management ensures that new product and services meet the agreed availability requirements and standards with the customers.

Availability management BI solution	Ad-hoc availability management.	Availability management for a specific group of people.	Availability management for the whole organization.	Risk assessment to determine the critical elements and possible problems	Availability management, trend analysis and planning to ensure that all elements are available for the agreed service level targets.

4.3.4.7 Knowledge management

The primary role of knowledge management is to improve the quality of decision making by ensuring that accurate, reliable and trustworthy information is available throughout the service lifecycle. It is about the process which is responsible for gathering, analyzing, storing and sharing knowledge and information within a hospital. The primary purpose of knowledge management is to improve efficiency by reducing the need to rediscover knowledge (SAS, 2007).

Knowledge management encompasses all the knowledge activities and the way they are implemented. To exploit the use of a BI environment fully, knowledge need to be shared and documented. It is important to share the BI knowledge, for example when care management/ top-management in a hospital don't know what the possibilities are with BI or they don't know how to use it, useful and available information will not be used and the performance of quality of care processes will not improve. BI providers on the other hand need to share knowledge about the information processes and care processes, so it is not reinvented.

Knowledge management	Ad-hoc knowledge gathering and sharing.	Organized knowledge sharing through written documentation and technology and also through training and mentoring programs.	Knowledge management is important to top level management, knowledge creation and sharing through brainstorming, training and mentoring programs.	Central business unit knowledge management; quantitative knowledge management control and periodic knowledge gap analysis.	Continuously improving inter-organizational knowledge sharing.

4.3.4.8 Data management

Key in achieving accountable, consistent and traceable information in a business intelligence solution is the presence of data management processes. To achieve high quality data it is important to governance the quality of the data and to have preventive measures. If data is not managed well, increasing amounts of time may be spent on corrective activity (Fisher, 2005). Assigning explicit responsibility for looking after data, documenting and applying procedures for data handling. Ensuring data is classified, stored safely and properly backed up will reduce the amount of time spent dealing with data-related problems. Data management provides a hospital-wide body, a policy, a set of processes, standards, controls, and an execution plan for managing the data. It promotes data quality, data integrity, data consistency and thus increases the information usability and reliability. Data management should include identification of data stakeholders, such as data owners, data stewards and their roles in handling enterprise data. The data management programs encourages the understanding and management of the data from both business and technical perspectives, plus it promotes the importance of the data as a valuable resource, allowing the hospital to use the data confidently to satisfy business needs. Data management improves information quality, confidence in decision making, lowers the cost of managing the data, designates accountability for data quality, and makes the best use of the data to achieve the overall hospital objectives. The realization that the data is a valuable and manageable hospital asset is one of the main business benefits of a data management initiative (Deloitte, 2009).

Data management	Efforts are ad-hoc and manual. Mainly ETL-based cleansing. Problem correction Enterprise realizes data management is valuable Enterprise is not willing to provide time and money.	Data quality and governance are becoming more important. Ownership of data, data stewards are identified, Preventive measures are in place to ensure high-quality data. Documentation about data management policies.	Robust data quality system is in place. Standards & policies are enforced, data quality problems are fixed at the source (no) cleansing , Preventive measures are in place to ensure high-quality data.	Data management groups operate across the hospital, data quality audits and data metrics to give insight into improvement.

4.3.4.9 Evaluation of the BI solution

An investigation conducted to provide stakeholders with information about the quality of the product or service. Testing can be stated as the process of validating and verifying that a product meets the requirements that guided its design and development, that the product works as described in the requirements and that the product satisfies the needs of stakeholders. Testing the BI solution reduces risk of failure and ensures that the users are able to operate productively (Sacu et al., 2010). Testing is important because it verifies that a report shows the information that it's actually should show. The tests should be documented and executed by following standard procedures. Requirements and the reports are mostly tested by key-users in the healthcare, or by verifying with old existing reports. It is increasingly common to see that controlled test sets and formal test projects are used. The functionality, features and the fit of the BI solution/products should be evaluated.

Testing BI solution	Only unit testing.	Unit tests, Integration tests and system tests take place.	Unit tests, integration tests, system and acceptance tests take place.	Unit tests, integration tests, system tests, acceptance testing and regression testing take place.
Documentation of BI solution test methods.	No documentation, but some of the tests are standardized.	Some tests are standardized and documented.	All tests are standardized and documented.	
Evaluation of BI requirements	The technical requirements of the BI product are tested by the BI developers.	The technical and functional requirements of the BI product are tested by the BI developers.	The technical requirements are tested by the BI product developers and the functional requirements of the BI product are tested by BI developers and the key-users.	The technical requirements are tested by the BI product developers and functional requirements of the BI product are tested by BI developers, key-users and/or subject expert.
Documentation of BI requirements evaluation method	No documentation, but some of the tests are standardized	Some tests are standardized and documented.	All tests are standardized and documented.	

4.3.5 Technology

4.3.5.1 ETL

An ETL tool is responsible for data transfer, from operational or transaction systems to data warehouses. Usually ETL processes are not very complex when a company uses ETL's that are written by hand. This shows a low level of maturity regarding ETL capabilities. It is very useful when a hospital uses standardized ETL-tools and ETL –scripts this will provide better performances. The more standardized an ETL is the less manual work needs to be done and the more predictable the outcome of the ETL run. To run an ETL it is important that the data is digitally available and stored in for example a CSV-file. An ETL can be monitored in a simple or advanced way (Sacu et al., 2010):

- Simple monitoring: statistics regarding ETL execution such as pending, running, completed and suspended jobs; MBs processed per second; summaries of errors
- Advanced monitoring: statistics on infrastructure performance like CPU usage, memory allocation, database performance, server utilization during ETL; job scheduler; time or event based ETL execution, events notification, data lineage and analyzer systems.

Data source support	Operational databases.	CSV file.	Unstructured data.	
Kind of ETL	Hand coded ETL.	Hand coded ETL and some standard scripts.	Standardized ETL-tool and some ETL Scripts for better performance.	Optimized ETL tool, with real-time capabilities.
Monitoring of ETL	Simple monitoring.	Manual restart and recovery system, simple monitoring, and a start in advanced monitoring.	Manual and Automatic restart and recovery system, simple monitoring, and advanced monitoring.	Automatic restart and recovery system advanced monitoring, and real-time monitoring.

4.3.5.2 BI Solution Architecture

Shows how the data is stored that is used to analyze care processes. It is very useful to have at least a centralized data warehouse this way a single version of the truth and facts can be provided (Turban et al., 2011). Explanation on the BI solution architectures can be found in chapter 2.5.1.

BI Solution Architecture	Desktop data marts (EXCEL).	Multiple independent data marts.	Multiple independent data warehouses.	Centralized data warehouse which contains data from different applications.	Centralized data warehouse with multiple dependent data marts which contains structured data.	A centralized data warehouse with multiple data marts which contains structured and unstructured data.

4.3.5.3 Data model levels

Data models for the subject areas of the core functions of the hospital should be defined. Conceptual, logical and physical data models should be drawn to provide the foundation for overall data architecture goals. Conceptual data models lays out business entities and their relationships. Logical data model defines detailed attributes of business entities. Physical data model provides for the actual implementation of the logical model. Data architecture acts as a key artifact to help in developing and implementing processes to support a data management strategy leading to effective BI governance (Deloitte, 2009).

Data models levels	Logical levels designed BI solution.	Logical and physical levels designed for all of the data models. Solution-dependent standards are defined.	Logical, physical and conceptual levels designed for BI solution. Enterprise wide standards.

4.3.5.4 Integration

Integration of data involves combining data residing in different sources and providing users with a unified view of these data. Data integration is required to process data into information. Enriching and aggregating data to support the different control levels within an organization should not lead to a lack of traceability of information. It is important to have the data stored in an integrated IT system, so there is a single version of the truth across the organization addressing multiple subject areas.

Within one source system data will not be stored redundantly in most cases. However, multiple source systems often do store the same data redundantly. In those cases the leading source system for that specific data element must be determined. A rule of thumb is to choose the source system that is first to store the data element in question, and in doing so limiting the chain of data transfers and possible loss of quality.

The data integration process can be optimized by documenting it, making it repeatable, easy to define and easy to use.

Integration	Integration within the same subject area. No integration between different subject areas. Single data view on a single subject.	Integration across subject areas and business unit solutions. Single view on one or two data subjects. Provides historical detail.	Data is stored in an integrated IT system. Semi-automated integration system. Single consistent version of the truth across the organization addressing multiple subjects. Provides historical detail. Automatic synchronization on all of the data models.	Integrated information is available seamlessly without regard to data source or integration technology used.
Synchronization	Manual synchronization.	Manual and Automatic synchronization depending on the data models.	Automatic synchronization on all of the data models.	

4.3.5.5 Data availability

Determines if data is available when needed and if there are no constraints. It is important to have the data in the data warehouse and the reports up-to-date. This way trends can be followed and decisions in the care process can be made near real-time. In the ideal situation the information is available when needed where it's needed, this way the best possible decision can be made. A BI solution should be available 24 hours a day to access and reporting applications. The loading of the DWH should therefore not interfere with the ability to report and analyze the available information in the DWH (Logica, 2009).
In some cases the required data is not available in any source system. In these cases research is performed to establish whether this data can be derived from available data based on transformation rules. In some cases missing pieces of data are available externally and can be purchased.

Data availability	System constraints.	Data is available in reports.	Data is available when it is needed (online) behind a desktop.	Data is available to the right person ate the right time in the right place (tablet).	
Data updates	Quarterly.	Monthly.	Weekly.	Daily.	Real-time.

4.3.5.6 Data granularity

Refers to the size in which data fields are subdivided (Sacu., et al). It is useful to have the granularity level as low as possible to really understand what the data means and to discover causal relationships. In general, source systems contain data with a lower level of detail than needed for the BI solution. Aggregation to the desired level in the BI solution is not a problem in those cases. It is even advised to store the lowest level of detail also in the data warehouse to assure that any time integration with other data sources is possible.

Data granularity	Summarized data. Few fact tables have their granularity at the lowest level possible.	Aggregated. Most fact tables have their granularity at the lowest level possible.	Lowest level. All fact tables have their granularity at the lowest level possible.

4.3.5.7 Environments

Refers to the environments that are available to set up a report. Development, testing, acceptance and production environments are used for different purposes to support the development phases (Sacu et al., 2010). For the development of a BI product (report) it is useful to have at least two different environments so the production environment doesn't get disturbed.

Environments	Two separate environments. Manual transfer.	Three or more environments. Some separation. Manual transfer.	Three or more environments. Some separation. Automatic transfer.	All environments are separated. Automatic transfer.	
IT infrastructure	No specialization, desktop platform.	Shared OLTP and data warehouse server.	Separated OLTP servers and BI solution server, manual transfer.	Separated OLTP servers and BI solution server, automated transfer.	Separated servers for OLTP, BI solution and ETL processes. Automated transfer.

4.3.5.8 Meta data

Meta data is an essential part of the BI strategy as metadata explains how, why, and where he data can be found, retrieved, stored and used in an information management system. Technical metadata is used for data lineage and impact analysis. Technical Meta data should include source system information, entity and attribute definitions. Operational Meta data provides information regarding change and update activity, archiving, back-up and system usage information. Business metadata provides context to the data and thus it makes the meaning of the data explicit and provides definitions of data elements in business terms from the business point of view.

The Meta data repository contains all the metadata information about source, target, transformations, mappings, workflows, sessions and business terms. Architecture of a Meta data repository should be centralized, distributed or hybrid. In a centralized architecture, Meta data from all data sources is stored in a central repository and all users can access it (Deloitte, 2014).

Meta data	Non-integrated metadata.	Multiple central metadata repositories separated by tools, the metadata is not up-to-date.	Central up-to-date metadata repository.	Web-accessed central metadata repository with integrated, standardized, up-to-date metadata.

4.3.5.9 Data quality

The state of completeness, validity, consistency, timeliness and accuracy that makes data appropriate for a specific use (Roekel et al., 2009).

Data completeness:
The extent to which data is not missing and is sufficient breadth and depth for the task at hand.

Data completeness	Some of the data is complete.	All data is complete.

Data validity:
Is the process of ensuring that a program operates on clean, correct and useful data. It uses routines, often called "validation rules" "validation constraints" or "check routines", that check for correctness, reasonableness, and security of data that are input to the system. Reasonableness of data means that numeric data are all digits; dates have valid month, day and year and; and the spelling of names is proper.

Data validity	Some of the data is validated, correct and reasonable.	All data is correct and reasonable.

Data consistency:
Means that data across the enterprise should be in synchronized with each other.

Data consistency	Some of the data is consistent.	All data is consistent.

Data traceability:
Results from analysis and reporting applications are often used for strategic decision making and must often comply with regulatory demands. Traceability and an audit trail of the data from a report back to the source

become very important in those cases. The BI architecture must be well equipped to support these capabilities.
An enterprise should be able to trace the data as it flows from data entry systems, transactional systems, data staging environments, data warehouses and data marts to the means of information delivery used for business analysis. Meta data enables the tracking and monitoring of the data through the entire data flow.

Data traceability	Some of the data is traceable.	All data is traceable.

Data accuracy:
The degree to which data correctly reflects the real world object or an event being described.

Data Accuracy	Some of the data is accurate.	All data is accurate.

4.3.5.10 Data access security

Information from different sources is integrated in a BI solution, creating a valuable and highly confidential integrated data collection. This often encompasses strategic information that should not reach unauthorized people, not within and definitely not outside the organization (Roekel et al., 2009). For a high security level a company uses an integrated companywide authorization security. Tools and methods also offer remedies to mask production data in an efficient way so that confidentiality is guaranteed and an effective test set is created. By masking the production data an unauthorized person cannot trace information back to the patients.

Data access security for BI solution	Authentication security (one password for multiple people to one report).	Independent authorization for each tool.	Role level security at database level.	Integrated companywide authorization security.

4.3.5.11 BI analyze tool

Determines how advanced the BI tool is that is used to analyze data. For analyzing historical data a basic analyze tool complies however for predictive analytics there must be used an advanced analytics technology.

BI analyze tool	Spreadsheets. Tools are client based. Analyzing history. Ad-hoc queries.	Basic analyze tool of ERP-vendor . For departmental needs. Ad-hoc queries. Trend analyzing.	Strategic BI partner Basic analyze tool of ERP-vendor For organization needs OLAP, predefined queries. Supports historical comparison. Trend analyzing.	Advanced analytic technologies, Predictive analytics (data and text mining).	Advanced analytic technologies, Ad-hoc complex calculations at report level/ cube level.

4.3.5.12 BI products

Determines how advanced the BI tool is that is used to visualize performance. For following trend a basic report is enough however for frontline decision making is an event centric decision support system necessary.

BI products	Spreadsheets. Static and parameter driven reports.	Web based interactive reports with adjustable parameters.	Basic dashboards and scorecards. Ad-hoc reporting.	Integrated reporting and balanced score cards and KPI's. Reports are made for frontline employees to enable frontline-decision making.	Reports for frontline decisions making (real-time), Operational BI/ event centric decision support system.

The dependencies between the sub-focus areas, the matrix, and the questionnaire that is used as instrument to determine the maturity of each focus area. The questionnaire is reviewed by 7 BI experts. After the questionnaire was reviewed by the experts, the focus areas with their capabilities were adjusted. The focus areas that are described below are the adjusted focus areas with their adjusted capabilities and dependencies, after interviewing the BI experts.

4.4 Determine dependencies

In this chapter the dependencies between capabilities are defined, this regards to the dependencies that may exist between capabilities of different focus areas. The dependencies of the capabilities were identified by stating the prerequisites other than the characteristics and prerequisites of the previous capabilities in the same sub-focus area. Behind each dependency is the focus area(s) described that contains the prerequisites.

Dependencies:
BI strategy: no capabilities of other sub-focus areas need to be implemented first.
BI strategy documentation: A BI strategy can only be documented if there is a BI strategy (BI strategy).
BI governance: the capability to have a BI solution in which data is gathered is necessary to measure the BI governance. This capability is described in the sub-focus area 'BI solution architecture'. BI governance also depends on knowledge documentation. (Knowledge management)
Business rule documentation: no capabilities of other sub-focus areas need to be implemented first.
Business rule availability: business rules can only be available if they are documented (Business rule documentation).
Business rule usage: business rules can only be used if they are documented and available (Business rule documentation and Business rule availability)
BI solution requirement documentation: BI solution requirements can only be described if the business rules are documented in a policy. (Business rule documentation)
BI solution requirement documentation availability: The requirements can only be available if they are documented (BI solution requirements documentation).
BI solution requirement method: no capabilities of other sub-focus areas need to be implemented first.
Business intelligence used in care processes: The use of BI in care processes depends on the availability of the data, information culture, the BI analyze tool, and the BI reporting tool. (Data availability, Information culture, BI analyze tool, and BI products)
Business benefits of Business Intelligence: To provide better information, integrated data is available. The business value increases through analyze tools. Monitoring can only be done if reports are available. Predictive analytics can only be done if such a tool is available. (Integration, BI solution architecture, BI products and BI analyze tool)
Manual vs. automatic activities: no capabilities of other sub-focus areas need to be implemented first.
BI users: no capabilities of other sub-focus areas need to be implemented first.
BI developers: no capabilities of other sub-focus areas need to be implemented first.

BI developers characteristics: the characteristics can only be measured it there are BI developers (BI developers).
Chief level involvement: no capabilities of other sub-focus areas need to be implemented first.
BI developers expertise: no capabilities of other sub-focus areas need to be implemented first.
Information Culture: no capabilities of other sub-focus areas need to be implemented first.
C-level understanding the importance of data-integrity: no capabilities of other sub-focus areas need to be implemented first.
Training: no capabilities of other sub-focus areas need to be implemented first.
Service level management for BI solution: SLA can only be provided for a BI solution if they are documented in a BI requirement (BI solution requirements documentation).
Change management for BI solution: changes can only be made for a BI solution if there is a BI solution and report. (BI solution architecture & BI reporting).
Incident management for BI solution: incidents can only be managed for a BI solution if there is a BI solution and a BI product (BI solution architecture and BI products).
Release management for BI solution: releases are only possible if BI solutions and BI products are present (BI solution architecture and BI products).
Resource management: no capabilities of other sub-focus areas need to be implemented first.
Availability management for BI solution: availability can only be managed if data is stored in a BI solution and is available via a BI product (BI solution architecture and Data availability).
Knowledge management: knowledge can only be managed if knowledge is available (BI developers expertise and Training).
Data management: Data can only be managed if data is stored appropriate in a BI solution (BI solution architecture) and if resources are available to manage the data (C-level involvement) and if C-level management understands the importance of data integrity. (C-level understands importance of data integrity)
Testing of BI solution: testing a BI solution is only possible if there is a data warehouse (BI solution architecture). A technical test can only be done when the technical requirements are available. (BI solution requirement documentation)
Documentation of testing BI solution: the tests can only be documented if the BI solution is tested (testing of BI solution).
Evaluation BI requirements: evaluating BI requirements can only be done if there is a BI product. The documentation about the BI solution requirements is also needed. (BI products & BI product requirements documentation).
Documentation of BI requirements evaluation method: the evaluation can only be documented of the BI product is evaluated (Evaluation BI requirements).

Data source support: no capabilities of other sub-focus areas need to be implemented first.
ETL: no capabilities of other sub-focus areas need to be implemented first.
BI solution architecture: The BI solution architecture can only exist if the data is extracted, loaded and transformed into a BI solution (ETL).
Data model levels: Data can only be modeled if it is stored in at least a data mart (BI solution architecture)
Integration: Integrating data is only possible data is available in a BI solution (BI solution architecture).
Synchronization: synchronization can take place if data is stored in at least a data mart.
Data availability: data availability can only be measured if data is stored in a BI solution (BI solution architecture).
Updates: data can be updated if it is available in a BI solution. (BI solution architecture)
Data granularity: data granularity can only be measured if data is stored in a BI solution (BI solution architecture).
Environments: Environments can only exist if data is stored in at least a data mart (BI solution architecture).
IT infrastructure: there can only be an IT infrastructure that contains a BI solution if a data is stored in an at least a data mart.
Meta data: meta data is only stored if data is extracted from an operational database and is stored in at least a data mart (BI solution architecture).
Data completeness: Data should be available in a BI solution (BI solution architecture).
Data validity: Data should be available in a BI solution (BI solution architecture).
Data traceability Data should be available in a BI solution (BI solution architecture).
Data accuracy: Data should be available in a BI solution (BI solution architecture).
Data access security for BI solution: Data access security can only be provided if access requirements are documented. (BI solution requirement documentation)
BI analyze tool: analyzing can only be done by using data that is stored in a BI solution (BI solution architecture).
BI products: reports can only be available if data that is stored in a BI solution (BI solution architecture).

4.5 Position capabilities in matrix

In this chapter are the capabilities positioned in a matrix. Capabilities that are dependent on other capabilities are always positioned in a higher maturity scale further to the right. Capabilities that are not dependent on each other are put in the same maturity scale. If many capabilities are contained in the same maturity scale they are assigned to a higher or lower maturity scale to get a more balanced matrix.

Maturity scale Sub-Focus areas	0	1	2	3	4	5	6	7	8	9
BI strategy		A		B		C		D		
BI strategy documentation			A			B				
BI governance				A	B		C		D	E
Business rule documentation		A			B			C		
Business rule availability			A			B			C	
Business rule usage				A		B		C		D
BI solution requirement documentation				A		B		C		D
BI solution requirement availability					A	B	C	D	E	F
BI solution requirement method		A		B		C		D		E
BI solution used in care processes					A	B	C	D	E	
Business benefits of BI solution		A			B	C		D		E
Manual vs. automatic activities		A		B		C		D		
BI users		A			B			C		
BI developers		A			B			C		
BI developers characteristics			A		B		C		D	E
Chief level involvement		A		B		C		D		E
BI developers expertise		A			B			C		
Information		A		B		C		D	E	F

culture										
Chief level understand importance of data-integrity		A			B			C		
Training		A		B		C		D		
Service level management for BI solution					A	B	C	D	E	
Change management for BI solution					A	B	C	D	E	
Incident management for BI solution					A	B	C	D	E	
Release management for BI solution					A	B	C	D	E	
Resource management		A		B		C		D		E
Availability management BI solution					A	B	C	D	E	
Availability management BI product						A	B	C	D	E
Knowledge management			A		B		C		D	E
Data management				A		B		C		D
Testing BI solution				A		B		C		D
Documentation of testing BI solution					A		B		C	
Evaluation of the BI requirements					A		B		C	D
Documentation of BI requirements evaluation method						A	B	C		
Data source support			A			B		C		
ETL		A		B		C		D		
Monitoring of ETL			A		B		C		D	
BI solution			A	B	C	D	E	F		

architecture										
Data model levels					A		B		C	
Integration						A	B	C	D	
Synchronization						A		B		C
Data availability				A		B		C		D
Data Updates				A	B	C	D	E		
Data granularity				A		B		C		
IT infrastructure				A	B	C	D	E		
Environments					A		B		C	
Meta data					A	B	C	D		
Data completeness				A					B	
Data validity				A					B	
Data consistency				A					B	
Data traceability				A					B	
Data accuracy				A					B	
Data access security for BI solution			A		B		C		D	
BI analyze tool				A	B	C	D	E		
BI products				A	B	C	D	E		

4.6 Develop assessment instrument

4.6.1 Questionnaire for case study

To be able to use the BI Environment Maturity Model as an instrument to assess the current maturity of the BI environment, measures must be defined for each capability. Steenbergen et. al. (2010) proposes that this can be done by formulating control questions for each capability. In the questionnaire are the control questions formulated for each sub-focus area. The formulization of the questions is based on the description of the focus areas and on experience and practice. The original questionnaire and the questionnaire after reviewing can be found in Appendix A and Appendix B.

The questionnaire of the BI Environment Maturity Model is evaluated by interviewing seven BI experts. After the evaluation with the BI experts another evaluation on the questionnaire takes place by conducting a case study in which the BI environment of academic hospital is assessed. The results of the expert interviews are processed in the questionnaire, which is used for the

case study. In the next chapter are the expert interviews and the results described. The case study is described in chapter 9.4.

4.6.2 Expert interviews

Multiple interviews were conducted with BI experts to evaluate BIEMM. The original questionnaire of the BIEMM was used during this evaluation. For the evaluation were seven BI experts interviewed. The goal of the evaluation is to research if the maturity model is complete, consistent and correct. To research if the assessment method was consistent and correct, the interviewees were asked if they could look at and criticize the questionnaire and its questions and answers. The interviewees were asked if they understood the questions, if they could explain in their own words by what is meant with the questions, and if the proposed answers were representative to determine the maturity of the sub-focus areas. To determine if the questionnaire was complete the interviewees were asked if the question were representative for measuring the sub-focus areas, and if the questionnaire covers all aspects of the BI environment.

Seven BI experts were selected through various BI forums in LinkedIn connections. The selection of the BI experts was based on their experience in an academic hospital and on their experience with BI solutions. All experts should at least work in an academic hospital and have at least 2 year experience with BI. Table 4 shows the experiences of the five participants.

A protocol is used for the interviews. First an introduction was given on the subject, second the assessment instrument of the BIEMM was introduced. Third, for each question was determined if the respondent understands the questions and if the appropriate answer was available. After the assessment, some additional questions were asked to research if the assessment method was complete and to research what the opinions of the respondents were on the use of BI to improve quality of care. All questions were open questions to reduce the risk of bias and to capture all (unexpected) insights. The protocol and associated questions can be found in Appendix F.

Participant	Position	Experience with BI
1	BI Advisor	2,5 years
2	BI Advisor process improvement and innovation.	5 years
3	Senior BI-specialist	6 years
4	BI-coordinator	28 years
5	BI-specialist	2 years
6	Head Business Intelligence	9 years
7	BI Platform developer	4 years

Table 4: Experiences BI Experts

4.6.3. Results Expert Interviews

The goal of the expert interviews was to evaluate the BI Environment Maturity Model. The results should determine if the maturity model was complete, consistent and correct. Almost all experts were enthusiastic about the questionnaire and most of them give feedback that existed out of comments, suggestions and recommendations to improve the questionnaire, the results are described below for each expert. All sub-focus areas are made bold and all questions in the questionnaire are made cursive, so, the results are easier to read.

BI advisor

The first interview was with a BI advisor which supports BI users in their information needs. He researches together with the information management-department of the hospital which information-possibilities are available.

The BI advisor understood all questions and thought that the questionnaire was complete and very detailed. He suggested that it would be useful to add the sub-focus area **business rule availability** and commented that some questions did not provide and answer for the lowest maturity level. The BI advisor also thought that the provided answers were representative. He had one suggestion, the questionnaire exists out of four main focus area and he mentioned that he missed the focus area innovation.

BI advisor process improvements and innovation

The second interviewee was a BI advisor in process improvement and innovation. The BI advisor understood all questions and thought that the questionnaire was very useful. The BI advisor also thought that the provided answers were representative. He had one comment for the future. He thought that external information could also become a part of the BI solution.

Senior BI specialist

The third interviewee was a Senior BI specialist who had also some suggestions about the content and on some typing and grammatical errors. He mentioned that it would be useful to explain that only one answer can be chosen for each question.

The BI specialist mentioned that they were unable to select only one answer for the question '*To what degree is the BI solution been tested?*' since they did unit testing, integration testing and systems testing, however they did not execute it in a standardized manner. Therefore another question has been added '*To what degree are the BI solution tests documented and standardized?*'. In which it is able to measure if the tests are documented and standardized regardless of the test that have been executed. The options 'documentation' and 'standardizations' in the provided answers are erased. The provided answers for the question '*To what degree are the BI products been tested?*' was unclear. Therefore the provided answers were changed and clarified.

For the sub-area **Data quality** it was necessary to reorganize the questions and provided answers because multiple answers were possible. Also data validity was not explained.

The focus area **BI-users** also needed to be reorganized because multiple answers were possible. He also mentioned there are three kinds of management levels that use the BI solution.

For the questions about **BI developers** and **BI developers expertise** it was suggested that it would be better to use numbers to determine the size of a group instead of 'small', 'medium' and 'big'.

BI – coordinator

The fourth interviewee was a BI coordinator which suggested some minor changes in the provided answers because of typing and grammatical errors. The BI coordinator understood all questions and thought that the questions and provided answers were representative to measure the BI environment of and academic hospital. He also thought that the questionnaire covers all aspects of the BI environment.

BI-specialist

The fifth interviewee was a BI-specialist who had also some suggestions about the content of the questionnaire. He suggested that the distinction between the maturity levels for the question '*What is the highest level in which the BI strategy is aligned with the overall business strategy?'* represented by the provided answers was unclear and that the documentation of the BI strategy was also something that should be asked. Therefore one of the provided answers needs to be adjusted and an additional question about the documentation should be asked.

The BI-specialist also mentioned that the alignment of changes between systems is also a form of maturity in change management. Therefore changes should be made in the provided answers of the questions '*To what extend are changes managed for the BI solution?*' and the question '*To what extend are changes managed for the BI products?*'

For the sub-focus area **Housing of data** he mentioned that the title is unclear. And the title should be changed into **BI solution architecture**. Furthermore he mentioned that it was also able to have a centralized data warehouse without data marts.

For the sub-focus area **Data availability** it was suggested that the provided answers for the question '*How often is the data warehouse updated?*' is changed into one option. For example one of the current provided answers was 'Quarterly to monthly' which is changed into 'Quarterly'.

For the question '*Are the requirements/standards for the BI solution documented and available?*' he suggested that the question should be split into one question about the documentation and one question about the availability. At last, he suggested that the documentation of requirements could be done for three levels of management.

Head Business Intelligence

The sixth interviewee was head business intelligence and had some grammatical and content suggestions. He also mentioned the distinction problem of the provided answers for the question '*What is the highest level in which the BI strategy is aligned with the overall business strategy?*' However this has already been resolved.

Another suggestion was about the sub-focus area **BI solution developer's expertise** for which isn't explained that it also determines the amount of BI solution developers that work on the BI solution. The same problem was mentioned for the sub-focus area **BI solution developers**. An additional text has been added for both sub-focus areas for clarification.

He also suggested that the purpose of the sub-focus area **Information culture** was unclear. Therefore an extra text has been added in the explanation and the provided answers were described with more words to emphasize the gradations between the maturity levels.

For the sub-focus area **ETL** he mentioned that the question *'What kind of ETL is used to transfers data into the data warehouse?*' should be changed into '*What is the highest maturity level that applies to the ETL that is used to transfer data into the data warehouse?*' because the provided answers did not exclude each other. For the question '*What type of data source supports the BI solution at the highest level (in which option c is the highest level)?*' he suggested that the provided answers needed to be reorganized because most ETL processes support operational database, some support CSV files and almost none support unstructured data.

As last comment he gave that, the questions should be rephrased and should be more hospital specific. So, 'organization' should be changed into 'hospital' and 'business processes' into 'care processes.'

BI Platform developer

The last interviewee was a BI platform builder which also had some suggestions about the content of the questionnaire. For the question sub-focus area BI strategy he mentioned that it would be useful to ask if it is also documented.

For the question '*To what degree are BI processes done manually or automatic?*' he suggested that 'manually' should be explained by referring to ad-hoc processes.

He also suggested that 'C-level' need to be explained for the sub focus area **C-level involvement**. Therefore 'C-level involvement' should be changed into 'Chief level involvement'. This is also changed for the sub-focus area **C-level management understanding the importance of data-integrity**.

For the sub-focus area **Training** he suggested that the provided answers did not exclude other provided answers. Therefore the question should be rephrased into '*What is the highest degree at which the BI users are trained to derive value from the BI environment?*'

For the sub-focus area **Data management/governance** he mentioned that it should be changed into 'Data management'. Also the explanation text should be adjusted. At last, he suggested that he misses a focus area that determines maturity of storage of historical data over time.

There were no contradictions in the opinions of the BI experts, there were however some agreements between them, as mentioned above. On almost all suggestions are included in the changes except for the suggestions that contained new research. The suggestions that are not included in the changes are described in the conclusion and further research.

4.7 Define improvement actions

For each of the sub-focus areas improvement suggestions are defined to evolve to a higher capability within that sub-focus area. These suggestions are based on the highest capabilities of the focus areas and describe the actions and conditions that must be met to reach the highest maturity level. These improvement actions and conditions can be used as advice to evolve to a higher maturity level for a specific sub-focus area. The sub-focus areas are made cursive.

BI strategy: To evolve to the highest maturity level in the *BI strategy* focus area, the hospital should be sure that the BI strategy is aligned with the Business strategy. The BI strategy should describe the current and the future processes and goals.
BI strategy documentation: To evolve to the highest maturity level in the *BI strategy documentation* focus area, the hospital should document the BI strategy and the alignment with the Business strategy in a report in which the objectives and goals are described.
BI governance: To evolve to the highest maturity level in this focus area, the hospital should standardize and document their successful BI efforts. These best practices should be available through the whole hospital so that reoccurrences of mistakes will not happen again.
Business rule documentation: To evolve to the highest maturity level in this focus area a hospital should document all business rules.
Business rule availability: To evolve to the highest level of business rule availability the hospital should make all documentation about the business rules available.
Business rule usage: To evolve to the highest level of business rule usage, a hospital should make all business rules available and check if business rules are understood and used.
BI solution requirement documentation: To evolve to the highest maturity level in this focus area, the hospital should document all requirements of the BI solution and reports for strategic, tactical and operational management.
BI solution requirements availability: To evolve to the highest maturity level in this focus area, the hospital should make all documentation about the requirements available for strategic, tactical and operational management.
BI solution requirements method: To evolve to a higher maturity level this focus area, the hospital should document and use a standardized methodology for the elicitation of the requirements, which is reviewed regularly and eliminates causes of bottlenecks.
BI solution used in Care processes: The use of Business Intelligence depends on many other focus areas. To evolve to a higher maturity level in this focus areas depends on the maturity of the information culture, data availability, the BI analyze tool and the BI products. If these focus areas evolve, so will the use of BI in the care processes increase.
Business benefits of BI solution: To evolve to a higher maturity level in this focus area, the hospital depends on the maturity of other focus areas like the BI analyze tool, the BI reports and the availability and integration of data. To

realize a full business value, BI processes and metrics should come together into a set of assets and capabilities that directly target business improvements.

Manual vs. automatic activities: To evolve in this focus area to the highest maturity level, the hospital should have automated all BI processes except for specific requests.

BI users: To evolve to the highest maturity level in this focus area, the hospital should make it possible for all management levels to use the BI solution.

BI solution developers: To evolve to the highest maturity level in this focus area, the hospital should have specialists who have specific knowledge about a certain BI service/activity or subject.

BI developers' characteristics: To evolve in this focus area to the highest maturity level, the company should have pro-active creative thinkers with a venture-capitalist mentality. These creative thinkers should focus on moving the business forward while always considering new ways.

Chief level involvement: To evolve in this focus area to the highest maturity level, C-level management of the hospital should embrace BI as a strategic lever for the business. This will open doors for investment in manpower and capital.

BI developers' expertise: To evolve to the highest maturity level in this focus area, the company should have in-house resources and know-how.

Information Culture: To evolve to the highest maturity level in this focus area, the hospital should focus on enterprise objectives. They also should think outside-the-box together to invent new ideas.

Chief-level understanding the importance of data-integrity: To evolve in this focus area to the highest maturity level, the hospital should have standardized procedures to achieve the highest level of data integrity and management of the departments should feel responsible for the quality of the information.

Training: To evolve to the highest maturity level in this focus area, the hospital should have a comprehensive training plan, the program should be scheduled and organized and all employees have access to the training program.

Service level management for BI solution: To evolve in this focus area, the hospital should document all service level agreements of all customers and review these with the customer and monitor them for improvement.

Change management for BI solution: To evolve in this focus area to the highest maturity level, the hospital should follow a standardize procedure to approve, verify, prioritize and schedule changes. By making use of reports, the hospital can analyze trends about the incident occurrence, customer satisfaction and value perception of provided services.

Incident management for BI solution: To evolve n this focus area to the highest maturity level, the hospital should follow as standard procedure and use a ticket handling system to classify and asses the incidents. By making use of reports, the hospital can analyze trends about the incident occurrence, customer satisfaction and value perception of provided services.

Release management for BI solution: To evolve in this focus area to the highest maturity level, the hospital should follow and document a standard procedure in which the conventions are named and numbered. By making use of reports, the hospital can analyze trends about the releases, customer satisfaction and value perception of provided services.
Resource management: To evolve in this focus area to a higher maturity level, the hospital should document and follow a standard procedure in which resources are managed. By making use of reports, the hospital can analyze trends about the resource performances.
Availability management: To evolve in this focus area to a higher maturity level, the hospital should be able to ensure availability according to the service level agreements. To ensure the availability risks assessment should be done to determine the critical elements and possible problems. By making reports the hospital can analyze the problems and plan activities to ensure that the applications are available.
Knowledge management: To evolve to a higher maturity level in this focus area a hospital should document and share all knowledge as much as possible. By making use of training the knowledge base will become bigger, it is important that all knowledge is gathered, available and improved.
Data management: To evolve in this focus area to a higher maturity level, the Chief-level management of the hospital should be involved in the data quality issues. If C-level management understands the importance of data integrity, more resources like preventive measures and a robust data quality system become available which enforces data policies and standards. At the highest maturity level data quality problems should be fixed at the source and data stewards are identified who are responsible for a certain data-part.
Testing BI solution: To evolve in this focus area to the highest maturity level, the BI developers should test the BI solution with unit tests, integration tests, system tests, acceptance tests and regression test.
Documentation of BI solution test method: To evolve in this focus area to the highest maturity level, the hospital should document all test methods.
Evaluation of the BI requirements: To evolve in this focus area to the highest maturity level, the BI developers, key-users and care managers should evaluate the BI solution requirements.
Documentation of BI requirements evaluation method: To evolve in this focus area to the highest maturity level, the hospital should document all evaluation methods.
Data source support: To evolve in this focus area to the highest maturity level, the ETL should support all possible data sources.
ETL: To evolve to the highest maturity level in this focus area, the company should have a standardized ETL tool which makes use of meta data and produces real-time data.
Monitoring of ETL: To evolve in this focus area to the highest maturity level, the hospital should make use of an automatic restart, recovery system and real-time monitoring.
BI solution architecture: To evolve in this focus area to the highest level of maturity, the hospital should have a centralized data warehouse which

should be used across the whole company, and also contains structured and unstructured data.
Data model levels: To evolve to the highest maturity level in this focus area, the hospital should have designed the conceptual, the logical and the physical level for the BI solution. In addition, enterprise wide standards should be defined.
Integration: To evolve in this focus area to the highest level, the hospital should have integrated all data by making use of an automated integration system. This integrated data should be available without regard to data source or integration technology used.
Synchronization: To evolve in this focus area to the highest level, the hospital should have synchronized all data automatically.
Data availability: To evolve to the highest maturity level in this focus area, the hospital should make the data available at any place where it is needed.
Data updates: To evolve to the highest maturity level in this focus area, the hospital should update the data daily and near real time.
Data granularity: To evolve in this focus area to the highest maturity level, the company should have the data granularity at its lowest level.
Environments: To evolve to the highest maturity level in this focus area, the company should have multiple separated environments in which the data is transferred automatically, one for production, one for development, one for acceptance and one for testing.
IT infrastructure: To evolve to the highest maturity level in this focus area, the hospital should have multiple separated servers for OLTP, BI solution and ETL processes.
Meta data: To evolve in this focus area to the highest maturity level, the hospital should have a central up-to-date meta data repository which is accessible via the web.
Data completeness: To evolve to the highest maturity level in this focus area, the hospital should have complete data.
Data validity: To evolve to the highest maturity level in this focus area, the hospital should have correct and reasonable data.
Data consistency: To evolve to the highest maturity level in this focus area, the hospital should have consistent data.
Data traceability: To evolve to the highest maturity level in this focus area, the hospital should have traceable data.
Data access security for BI solution: To evolve in this focus area to the highest level, the hospital should have an integrated companywide authorization security.
BI analyze tool: To evolve to the highest maturity level in this focus area, the company should have advanced analytic technologies with which predictive analytics and ad-hoc complex calculations are possible.
BI products: To evolve to the highest maturity level in this focus area, the company should make use of advanced reports that support frontline decisions making with real-time information.

4.8 Implement maturity model

The assessment instrument of the maturity model is implemented by conducting a case study at the academic hospital: 'Universitair Medisch Centrum Utrecht (UMCU)' in the Netherlands.

Before the implementation of the assessment instrument is described, first an organogram is shown with the hierarchy of UMC Utrecht. For each component is described where it stands for and what their role and activities are in the organization. After the organogram is described, the BI solution in UMC Utrecht is shown with its data warehouse processes. UMC Utrecht uses EZIS as electronic patient record. EZIS is called a Workflow Management System. It provides functionality to support patient centered treatment and registration processes, in which all processes within one workflow fit together seamlessly.

4.8.1 Organogram

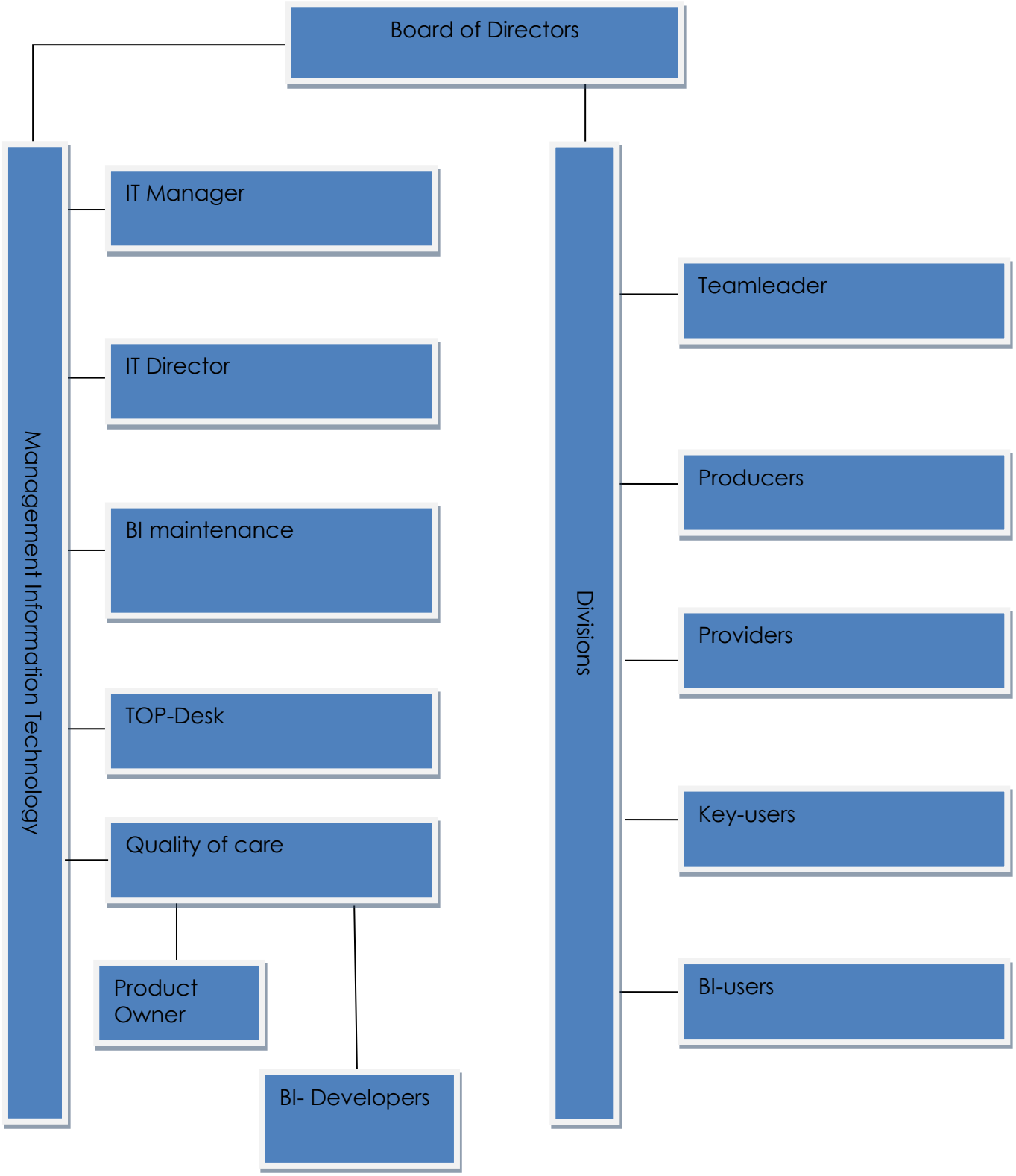


Figure 14: Organogram

Board of directors
A board of directors is a body of elected or appointed members who jointly oversee the activities of a company or organization. The Board of Directors determines the general policy of the UMC Utrecht. This involves the course and outline, the task and function, mission and ambition of the UMC Utrecht in relation to social, political and financial developments.

Management Information Technology
The Management Information Technology (MIT) department supports care, research and education with innovative and reliable IT. Not only employees of the UMC Utrecht, but also patients, students, referrers and visitors use the IT. Reliable IT is essential for patient safety and UMC Utrecht assigned the highest priority to it. Therefore, MIT has renewed and improved IT which supports care, research, education and business. To goal is to search for new innovate IT solutions to support all users. MIT developed the Business Intelligence solution and maintains the software and hardware. They also develop new information products by making use of the BI solution.

IT Manager
The IT Manager is primarily responsible for the qualitative and quantitative services provided by the IT department of a company. All products and services an organization that have to do with automation, application and IT infrastructure are delivered from this section and managed. The Manager is fully responsible, set budgets and manages the department budgets.

BI solution/product maintenance
The BI Product Manager is accountable for maintaining the BI solution/product. He makes sure that the solution is optimally used once it is implemented. BI maintenance is activity that includes error correction, enhancements of capabilities, deletion of obsolete capabilities, and optimization. Because change is inevitable, mechanisms must be developed for evaluation, controlling and making modifications.

TOP-DESK
Call Management is one of TOPdesk's processes. This makes it easy to register, organize and safeguard incoming calls, and assign them to operators or operator groups. The Call Management process supports daily tasks and helps to process calls more efficiently. These calls are for example changes and incidents that occur within a BI product/solution. TOPdesk's Call Management helps the organization register and process all complaints, wishes, requests for information and malfunctions. The front office processes the calls that can be resolved quickly. If a call requires a specialist, it can be forwarded to the back office or one of the suppliers.

Product owner
The product owner is responsible for the success of the BI product and for maximizing the return on investment (ROI). He determines what BI product is being built and where the priorities lie. The product owner knows who need the BI product and consults the board of members if there are not enough resources to realize the BI product. A well-functioning product owner is essential to the success of the BI environment.

BI Developers
Are the providers of the BI-products and the users of the BI solution. BI developers are analysts that understand the care processes, the information processes and the BI processes, which they use to improve the efficiency of the hospital. The BI developers analyze the care processes and their underlying information processes. The information is used to measure the quality indicators of the care processes. The information about these care processes are shown in a BI report. The BI developers determine who has access to these reports and who don't.

Divisions
UMC Utrecht has multiple divisions in which care is provided, within each division there is a decentralized information provision. However the information about quality of care is provided central and de-central. Some BI producer make new BI product out of the centralized information product.

Team leader: This is the team leader of the division. The team leader leads a team and is responsible for coordination and communication between unit- and team level. The team leader is responsible for providing the agreed quality of care to clients. The team leader has delegated powers and responsibilities in the field of personnel management. The team leader uses the BI products to see how well his team is performing on the quality of care.

BI producers: This central group has besides access to the centralized standard information products (BI-products) via the information portal also access to group tables, configuration database, source control and development tools (Visual Studio). The BI producers are able to make their own decentralized-BI products with new information from other sources. They can also provide access to the BI-products.

BI providers:
All employees that provide information. This group has access to the standard centralized information products (BI- products) via the information portal. The BI providers use centralized standard information products and provide this information in a suitable format (decentralized).

Key-users
Each division has key users. This group has access only to standard centralized information products (BI-products) via the information portal. They test the information product before it is used by the BI users. The feedbacks from the key-users are taken first into account by the BI developers when putting a BI product into production.

BI users:
Are all employees who decline information. This group has access only to standard centralized information products (BI-products) via the information portal. These users are for example the team leaders.

4.8.2 EZIS BI solution Environment UMC Utrecht

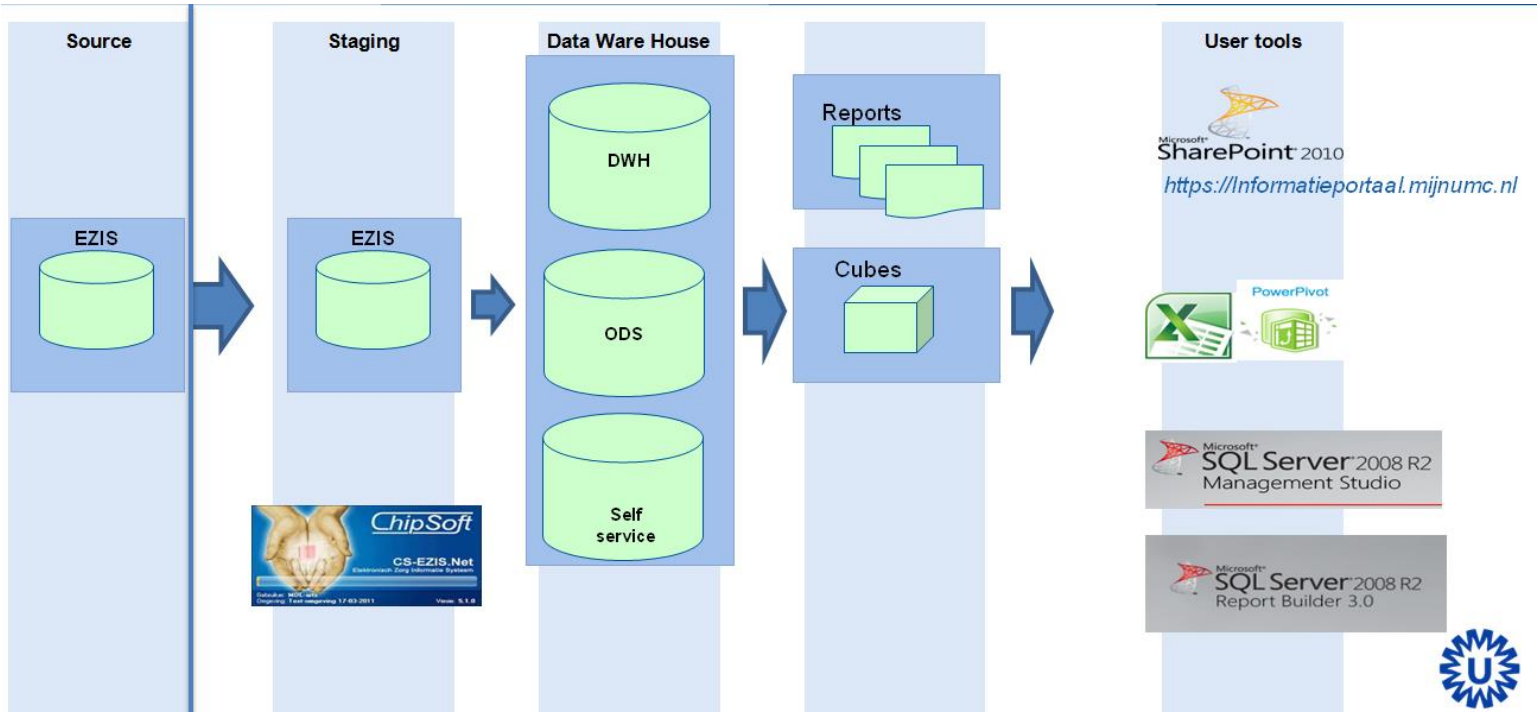


Figure 15: BI solution environment UMCU

EZIS DWH exists out of data that is extracted, transferred and loads by Chipsoft from the operational EZIS databases into a DWH. Because the DWH that is provided by Chipsoft does not contain all the information that is needed for the analysis of care processes, extra operational data stores (ODSs) are provided which are made by UMCU. The ODS databases contain extra information that is registered in EZIS but is not available in the DWH that is provided by Chipsoft. These databases function as data marts because ODSs normally contain only very recent information and the ODSs of UMCU stores long-term information and it is specified for a single subject area. The information that is stored in the DWH is used for reports and cubes. The reports are accessible via an information portal which is a webpage.

4.8.3 Evaluation of the BIEMM

4.8.3.1 Case study

Another evaluation of the BIEMM took place by conducting a case study at UMCU. The case study is conducted to capture knowledge from practitioners and to test and validate the assessment method of the maturity model. The results of the case study will determine if the maturity model was applicable in UMCU and should give valuable input for the improvement of the assessment method and the maturity model. The results of the case study will also determine the maturity level of the BI environment in UMCU. UMCU will be given an advice on which focus area needs to be improved to evolve to a higher maturity level. The case study was conducted in UMC Utrecht. Different employees were interviewed from Top-management until BI developers. For the interviews, was the questionnaire used as instrument and protocol to access the current maturity of the BI environment in UMC Utrecht. Interviewees had to answer questions about the same focus areas, if the answer was different than that of other participants. I decided to take the answer that was given most, as true. If the answers occurred equally, I decided to take the answer from the person with the most specific knowledge about that focus area, as true.

Table 5 shows the positions of participants which work in the academic hospital and the kind of questions that were asked.

Participants	Positions	Questions about focus areas
1	Board of directors	Business Alignment People
2	Product owner	Business Alignment People
3	BI solution/product developer	Business Alignment Technology People Processes
4	BI solution/product developer	Business Alignment Technology People Processes
5	BI solution/product maintenance	Technology Processes
6	BI solution/product maintenance)	Technology Processes
7	BI product provider/ Key user	Business alignment People Processes
8	BI product provider/Key-user	Business alignment People Processes
9	Care manager	People Processes
10	Care manager	People Processes

Table 5: Respondents UMCU

4.8.4 Results

4.8.4.1 Results Case study

This chapter will depict the maturity score that has been obtained regarding the BI environment in UMCU. The maturity score will be depicted in the capability matrix that has been developed in chapter 4.5. The focus areas are given in the left column; the capabilities per focus area are depicted by the letters A to F, which stand for progressively maturity capabilities. The actual maturity of the UMCU is depicted by coloring the cells until the next capability that has not been implemented yet. The rightmost column that is completely colored indicates the maturity scale of the UMCU. The highest capability that has been implemented has been made bold.

The capability matrix in with the results of the assessment is depicted below:

Maturity scale Sub-Focus areas	0	1	2	3	4	5	6	7	8	9
BI strategy		A		**B**		C		D		
BI strategy documentation			**A**			B				
BI governance				**A**	B		C		D	E
Business rule documentation		A			**B**			C		
Business rule availability			A			**B**			C	
Business rule usage				A		B		**C**		D
BI solution requirement documentation				A		**B**		C		D
BI solution requirement availability					A	B	C	D	**E**	F
BI solution requirement method		A		**B**		C		D		E
BI solution used in care processes					A	**B**	C	D	E	
Business benefits of BI solution		A			B	**C**		D		E
Manual vs. automatic activities		A		B		C		**D**		
BI users		A			B			**C**		
BI developers		A			**B**			C		
BI developers characteristics			A		B		**C**		D	E
Chief level involvement		A		B		C		D		**E**
BI developers expertise		A			**B**			C		
Information culture		A		**B**		C		D	E	F
Chief level understand importance of data-integrity		A			B			**C**		

Training		A		**B**		C		D		
Service level management for BI solution					A	B	**C**	D	E	
Change management for BI solution					A	B	C	**D**	E	
Incident management for BI solution					A	B	C	D	**E**	
Release management for BI solution					A	B	C	**D**	E	
Resource management		A		B		**C**		D		E
Availability management BI solution					**A**	B	C	D	E	
Knowledge management			**A**		B		C		D	E
Data management				A		B		**C**		D
Testing of BI solution				A		B		**C**		D
Documentation of testing BI solution					**A**		B		C	
Evaluation BI requirements					A		B		C	**D**
Documentation of BI requirements evaluation method						**A**	B	C		
Data source support			**A**			B		C		
ETL		A		B		**C**		D		
Monitoring of ETL			A		B		**C**		D	
BI solution architecture			A	B	C	**D**	E	F		
Data model levels					**A**		B		C	
Integration					A		B	C		D
Synchronization						**A**		B		C
Data availability				A		B		**C**		D
Data Updates				A	B	**C**	D	E		
Data				A		B		**C**		

granularity										
IT infrastructure				A	B	C	D	**E**		
Environments					A		B		**C**	
Meta data					A	**B**	C	D		
Data completeness				**A**					B	
Data validity				A					**B**	
Data consistency				A					**B**	
Data traceability				**A**					B	
Data accuracy				A					**B**	
Data access security for BI solution			A		B		**C**		D	
BI analyze tool				A	B	**C**	D	E		
BI products				A	B	C	**D**	E		

The current maturity score of the BI environment in UMCU is scale 3. Three sub-focus areas need improvement to evolve to a higher level of maturity. The first sub-focus area is **BI governance,** the second sub-focus area is **Knowledge management** and the third is sub-focus area **Integration.**

The goal of the maturity model is not only to measure the current maturity of the BI environment but also to provide the academic hospital with some feedback and the necessary steps to reach a higher maturity stage.
The maturity of the BI environment is 3 because the maturity level of the sub-focus areas **BI governance** and **Knowledge management** score maximal 3. To reach a higher maturity level it is necessary for the UMCU to start with the improvement of those sub- focus areas. To improve the sub-focus areas the hospital can use the advice that has been given for these sub-focus areas in chapter 4.7. These improvement actions and conditions can be used as input to evolve to a higher maturity level.
To evolve to the highest maturity level in the sub-focus area **BI governance,** the hospital should standardize and document their successful BI efforts. These best practices should be available through the whole hospital so that reoccurrences of mistakes will not happen again. To evolve to a higher maturity level in the sub-focus area **Knowledge management** a hospital should document and share all knowledge as much as possible. By making use of training the knowledge base will become bigger, it is important that all knowledge is gathered, available and improved. To evolve in the sub-focus

area **Integration** to a higher maturity level, the hospital should have integrated all data by making use of an automated integration system. This integrated data should be available without regard to data source or integration technology used.

The results show also that the maturity model was applicable in an academic hospital. By interviewing the respondents, it was possible to determine the maturity of the BI environment and at the same time to test if the respondents understood the questions and were able to answer the questions for their situation with the provided answers. Besides measuring the maturity of the BI environment it was also possible to give UMCU advice on which sub-focus areas need the most attention and on how to evolve in that sub-focus area. After the assessment, the respondents were also asked for their findings and opinions about the assessment instrument. They were asked if the questionnaire covers all aspects of the BI environment in an academic hospital, if the questions are representative for measuring the sub-focus areas, and if the answers are also representative for measuring the maturity of the sub-focus areas.

4.8.4.2 Suggestions/Comments on Questionnaire

The suggestions/ comments of the respondents and the changes that were proposed are described for each respondent:

Board of directions
The first interview was conducted with the chairman of the Board of directions. He had to answer questions about the focus areas **Business alignment** and **People**. The chairman understood the questions in the questionnaire and had no additional suggestions to improve the assessment instrument.

Director Quality and Patient safety/ BI product owner
The second interview was conducted with the Director of quality and patient safety. This is also the BI product owner for BI products that contain information about the quality of care. He had to answer questions about the focus areas **Business alignment** and **People**. The interviewee mentioned for the sub-focus area **BI governance** that they did not document the best practices of BI but that they were shared by making use of networking. This is something that was not mentioned as a maturity level in the questionnaire. An additional answer 'No best practices documented, but best practices are shared through networking' was added to the question: '*To what degree are the overall BI best practices being maintained?*' For the same question it was unclear what the link was between the explanation that was given for the current topic and the question that was asked. Therefore the explanation was extended with the following sentence: '*The approach and BI efforts are often described in best practices'*. After the explanation, the interviewee was able to answer the question.

The interviewee also mentioned that sponsoring of BI also takes place through centralized sponsoring and through decentralized sponsoring in a hospital. The central sponsoring is through C-level sponsoring from the IT department and de-centralized sponsoring takes place through sponsoring from the different departments/wards that uses the BI solution/ products. Therefore the question *'To what degree are the BI solution/products sponsored?' is changed into 'To what degree are the BI solution/products sponsored through centraliCzed and decentralized management?'* In addition, the possible answers were adjusted.
As last comment the interviewee mentioned that the information in their information culture was used for the improvement of collaboration and interdependency between departments on a project basis. This was not an option, so the possible answers for the question '*How mature is the information culture that uses the BI products?*' were adjusted here too.

Care managers
The third interview was with two care managers of different divisions. The first care managers worked at the division Heart and Lung and the other Care manager worked at the division Internal medicine and Dermatology. The interviewees understood all questions and were able to provide and answer, however they mentioned that it was important to measure if the care managers know what the purposes are of the BI products of the BI solution. Especially, the relation with the business rules from which they are derived. An additional sub-focus area was added to the main focus-area Business alignment, which is called *BI product understanding*. The following question is asked: '*To what extent do Care managers know what the relation is between the business rules in the protocols and the BI products?'* The Care managers proposed the possible answers that can be given.

Key-users
The fourth interview was with two key-users/information analysts of the BI solutions. The first key-user is an information analyst at the division Vital Functions the second key-user is also an Information analyst at the division Internal medicine and Dermatology. They use the BI products of the BI solution as input for new information products. These new information products for example contain only information about a specific department or contain some additional detailed information that was not available in the BI products of the BI solution. These products are used often locally (decentralized information products). The key-users had to answer questions about the focus areas Business alignment, Processes and People. The interviewees understood all questions and were able to provide and answer, however they had some comment about not mentioning the 'information lines'. With which they were aiming on the organizational structure in the hospital to obtain information products. According to them it was necessary for management to know where to go to if they needed information products. This was not measured in the questionnaire. An additional sub-focus area should be added to the main focus area People. Which is should be called *Information network.* In which

the following questions is can be asked: '*How well does management of departments know the network?'*. Additionally proposed answers were given by the key-users. The interviewee also mentioned that setting a norm for each business rule was important for the improvement of care processes. According to the interviewees the norm should become a goal, and they suggested if there are no norms set that the health workers are less motivated to reach that level. Therefore a sub-focus area should be added to the main focus area Business alignment, which is can be called *'Business rules Norms'*. In which the following question can be asked: '*Do de BI products contain norms?*' Additionally proposed answers were also given by the key-users.

BI maintenance
The fifth interview was with two employees of BI maintenance. The interviewees were working for the IT department, they make sure that the BI solution is up and running and performs the ETL processes. They had to answer questions about the focus areas Technology and Processes. Both employees understood the questions in the questionnaire and had no additional suggestions to improve the assessment instrument.

BI developers
The sixth interview was with two BI developers. Both developers worked for the IT department. The developers had to answer questions about the Business alignment, Processes, People and Technology. The BI developers understood all questions and were able to provide and answer, however they mentioned that it would be useful to measure the use of the BI products of the BI solution. By measuring the use of the BI products it is possible to research if certain BI reports were slow, if it was used enough or if it should be changed. Therefore a sub-focus area should be added to the main focus area Business alignment, which is called *'monitoring BI usage'*. In which the following question can be asked: '*Is the use of BI products been monitored?*'. Additionally proposed answers were also given by the BI developers.

Based on this feedback some additional changes were made in the questionnaire and in the sub-focus areas. The four sub-focus areas that are added are:
- Business rules norm, introduced by the key-users
- BI product understanding, introduced by the care managers
- monitoring BI usage, introduced by the BI developers
- Information network, introduced by the key-user

If the norm for the business rules is known, they can be depicted in the BI product. And if the BI users know how to use the BI product, the performances and the norm that needs to be reached can be followed. Low usage of a BI product can be a consequence of not understanding the BI product.
These four sub-focus areas are described below. The final version of the questionnaire and the corresponding maturity matrix can be found in

Appendix D and Appendix E.

4.8.4.2 Sub-focus areas that have been added to the model

Business rules norm

Determines if norms are set for the performance of executing or following the business rules. Each business rule contains elements that can be measured. To find out if all business rules are performed or are followed the way they should, one can measure the performance of executing the business rule or following the business rule by making use of the information processes that support the business rule.

Business rule norm	Some norms for the performance indicators	All performance indicators contain norms if possible.

BI product understanding

BI product understanding determines if the provided BI products are known by the Care managers and if they understand the relation between the business rules that are described in the protocols to keep quality of care processes high and the BI products that represent the data about the performances of the quality of the care processes.

BI product understanding	Care managers have no idea where the BI products are useful for.	Care managers measure the performances of the quality of care processes but do not know why.	Care managers measure the performances of the quality of care processes and know the purpose.	Care managers measure the performances of the quality of care processes and understand that the quality indicators are derived from the business rules that are described in protocols.

Monitoring BI usage
Monitoring BI usage refers to the process in which is monitored if BI products are used enough. By no usage one should consider to change the report so it will be used.

Monitoring BI usage	Monitoring ad-hoc	Standard monitoring, results are fed back to the Care managers of the departments.	Self-service monitoring. Care managers are given access to the reports to monitor the usage in their department.

Information network
Refers to the organizational structure/network of people in a hospital that enables the creation of new information products.

Information network	Organizational structure is unknown, people reuse other information products.	Some know who does what; they get information products from providers out of their own network if possible.	The organizational structure is known, everybody knows who to go to for a particular information product, and who is responsible for the quality of the information products.

4.9 Improve matrix iteratively

If enough assessments have been collected quantitative evaluation becomes possible. To evaluate how the model assists in incremental improvements interventions it must be tracked longitudinally, a repository must be kept to collect assessment results. However, for this research there was only one academic hospital to access and there was not enough time to track the model longitudinally.

4.10 Communicate results

To further the field the results of the maturity model are communicated to the practitioners of the community as well as to the scientific community because the results are available in this thesis if it is produced.

5. Conclusion & Future research

The main research question that needed to be answered with this research was:

"To what extent can a BI solution in Dutch hospitals be configured to situationally assess and incrementally improve the quality of care?"

To assess the quality of care I developed and Business Intelligence care process assessment method (BICPAM) that can be used to assess the quality of care. For this model I used parts of the Six Sigma model and combined them with the BI solution/methods. By conducting a case study on three care processes, I determined that the method was applicable in an academic hospital. The method was used for the assessment of three care processes. For all three care processes were the quality of the care processes been assessed. Since the method is only tested in one academic hospital it would be unwise to generate the findings to other academic hospitals. The method can however be used as starting point when an academic hospital would like to use a BI solution to assess the quality of their care processes. It is important that the BI solution is used in a mature BI environment. Evolving in the maturity level of a BI environment can contribute in a better assessment of quality of care processes

To research how mature the BI environment of an academic hospital is, another model has been developed. The maturity model contains four main focus areas and several sub-focus areas which determine the maturity of a BI environment. To determine the level of maturity an assessment instrument was developed. The assessment instrument (a questionnaire) was evaluated by reviewing seven BI experts and by conducting a case study in an academic hospital.

The goal of the expert interviews was to evaluate the BI Environment Maturity Model (BIEMM). The results should determine if the maturity model was complete, consistent and correct. Almost all experts were enthusiastic about the questionnaire and most of them give feedback that existed out of comments, suggestions and recommendations to improve the questionnaire. The suggestions of the BI experts were almost all included in the changes that were made on the assessment instrument. A case study was conducted to research if the capture knowledge from practitioners and to test and validate the assessment method of the maturity model. The results of the case study showed that the maturity model was applicable in an academic hospital and gave valuable input for the improvement of the assessment method and the maturity model. The results of the case study also determined the maturity level of the BI environment in the academic hospital. The academic hospital was given advice on which sub-focus areas needed to be improved to evolve to a higher maturity level and on how to improve those sub-focus areas. However, also this case study took place in one academic hospital, so the results cannot be generated to the other academic hospitals. The

method and the model can however be used as starting point if an academic hospital would like to use a BI solution to assess the quality of their care processes and would like to improve the environment in which it is used. If the hospital does not use a BI solution yet, I can use BIEMM to guide the usage of the BI solution, and it can use BICPAM to assess the care processes in the hospital. This way, can the BI solution be used more efficient and can the care processes be assessed to improve the quality of care.

Future research
Some of the suggestions that were made by the BI experts and by the respondents of the academic hospital were not included in the changes of the questionnaire and focus areas because they needed further research and were not mentioned in the maturity models that were researched.

One of the sub-focus areas that was missing according to a BI expert was 'Innovation', this is however an interesting topic to research. That is in how a BI solution influences the innovation of a company. If new information becomes available, can hospitals use it to support new innovations and to lead the market?
Another suggestion form a BI expert was that external information could become a data source for the BI solution. It is very interesting to research how external data is going to influence the maturity of a BI environment.
The last BI expert suggested that he misses the focus area that determines the maturity of storing historical data over time. This should be useful because most BI solutions store often the data of the last setting, which means that data is lost at the moment that it is changed.

This thesis provides a method which can be used to guide an academic hospital with the assessment of the quality of care processes and provides a maturity model which can also be used as guide to determine the maturity of the focus areas. The maturity of these focus areas are visualized in a matrix and show how well the BI processes and BI solution in a BI environment are executed or managed. The maturity model provides also the ability on how to evolve from one level to another. The method and the model were both applicable in an academic hospital. However, because it was only evaluated in one academic hospital, it is necessary to evaluate it in other academic hospitals so that the results of the case studies can be generated. I think that other evaluations will contribute in the improvement of the method and maturity model. By doing multiple evaluations there can be given insights in even more aspects that are related to the method or the maturity model. These aspects need to be researched so that the method and the maturity model becomes generic and applicable in multiple institutes were BI is used to assess quality of care processes. Since BI is becoming a valuable asset for the improvement of quality of care, more possibilities with BI will be developed and can be included in the method or model.

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Appendices

Appendix A: Original Focus Areas and capabilities

Appendix B: Original Questionnaire

Appendix C: Questionnaire for Case Study (incl. answers)

Appendix D: Final Questionnaire

Appendix E: Final Maturity Matrix

Appendix F: Expert interview

Appendix A: Original Focus Areas and capabilities

Business Alignment

BI strategy

A BI strategy is driven by business objectives, which enables stakeholders with better decision making capabilities and helps enterprises in achieving the desired goals. Effective BI strategy should ensure that enterprise objectives, business strategy, investments and BI are aligned. Enterprise that are able to connect BI to overall enterprise objectives become intelligent enterprises. BI strategy should include a broad set of processes, technologies and stakeholders for collecting, integrating, accessing and analyzing information for the purpose of helping enterprise make better business decisions. BI strategy should have a comprehensive approach in describing the current and future behavior of the processes, technology, people and other components to ensure that they align with the goals and strategic direction of the enterprise. (Deloitte, 2009).

It is vital to establish a BI vision to ensure that implementation of specific components fits in the overall BI strategy. BI strategy should state and document the needs as identified by the stakeholders, highlighting how BI fits in the broader enterprise vision. BI vision should be to help drive better business performance by enabling all decision makers essentially empowering all employees, customers, and external parties to be able to play their roles effectively as a result of the BI adaption (Deloitte, 2009).

BI strategy/ vision	There is a business intelligence strategy but it is not aligned with the overall business strategy.	There is a business intelligence strategy and it is aligned with some parts of the business strategy.	BI strategy aligned with business strategy and enterprise objectives	BI strategy current and future behavior of the processes, technology, people and other components.

BI governance
The most mature companies have moved towards developing a business intelligence competency center (BICC). A BICC enables companies to adopt an enterprise wide approach, standardize and co-ordinate their BI efforts. This enables companies to leverage their experiences and best practices while at the same time limiting reoccurrence of mistakes. Establishing a BI competency center will help in integrating BI best practices with the on-going BI work and the BI environment of the enterprise (Deloitte, 2009).

BI governance	Best practices are not documented but are standardized.	IT best practices are documented and standardized, to develop and maintain the BI solution.	IT and analytical best practices are documented and standardized, to design the BI solution based on the information needs.	BI competency Centre developing, alignment of BI strategy with Business strategy	Enterprise wide BI governance with business leadership

Business rules
Business rule documentation
Determines if the business rules are documented. Business rules describe the operations, definitions and constraints that apply to an organization. Business rules can apply to people, processes, corporate behavior and computing systems in an organization, and are put in place to help the organization achieve its goals.

Business rule documentation	Some business rules are defined and documented	Most business rules are defined and documented	All business rules are documented

Business rule usage
Determines if the business rules are known, and if the business rules are also used in the care processes.

Business rule usage	Some health workers know that the business rules exist, but do not execute them.	They know they exist but do not understand how to use them or how they contribute in the improvement of quality of care.	They know they exist and why to use them, most of the health workers use the rules.	All health workers that needed to know the business rules know them and try to improve the quality of care.

BI requirements
BI Requirement documentation
Refers to the requirements that are described in a document. The document is written by a company which defines a product they are making, or the requirements for one or more new features for an existing product. The requirements documentation of a product exists out of functional requirements and technical requirements. It is important to define, classify and document the functional requirements and the technical requirements of the BI product/solution. It is also important to categorize the requirements as essential, important and desired. (Documentation of data models)

BI solution requirement documentation	Purpose of BI solution is described. The main objective which the BI solution will support is described	Functional requirements are described. Access requirements are documented.	Functional and Technical requirements are described	All requirements are documented and available

BI Requirements method

Encompasses how requirements definition is done. In a DW, users' business requirements represent the most powerful driving force as they impact virtually every aspect of the project.

BI solution Requirements method	Ad-hoc requirements definition, no methodology.	Methodologies differ from project to project; interviews with business users for collecting the requirements.	Standard methodology for all the projects; interviews and group sessions with both business and IT users for collecting the requirements.	Qualitative assessment and measurement of the methodology, the requirements are documented and published.	Causal analysis meeting to identify common bottlenecks causes and subsequent elimination of these causes.

Business intelligence used in Business processes

Refers to how BI is used to support the business processes. The level that needs to be reached is where BI is used as a strategic and competitive asset and provides useful information to improve processes and decision making.

Business intelligence used in business processes	Limited use, BI has to evolve. Local use. Users build awareness and understanding of business (historical data)	BI is used to in the business processes to follow trends, to save time and increase useful information. Users build awareness and understanding of business (historical data)	Business improvement decision making through broad based use of BI More useful information. BI is used as a strategic and competitive asset Users build awareness and understanding of business (historical data)	BI is used to predict outcomes BI is used to prohibit corporate strategy, BI is used to redesign business processes Users exploit right-time information to work proactively to solve problems and optimize performance	BI is fully embedded in all levels of the organization to promote and enable strategic agility and to support corporate objectives organizations automate decisions using statistical models embedded in applications.

Business benefits of Business Intelligence
Refers to the benefits that arise when an organization makes use of business intelligence. It is important to meet the level where the focus is on improving business and not on improving the BI solution. The Business value of BI is being realized when metrics are defined and when the BI processes are in place and are coming together into a set of assets and capabilities that directly target business improvements through broad-based us of BI (Stock, 2013).

Business benefits of BI investment	Vague, mostly costs. BI is a cost center. Time is spent on quality.	Some benefits are identified, New and better information. BI informs executives better. Time is spent on quality.	Business values increase by making use of complex analytics. Make better decisions BI empowers the employees and processes can be monitored. Time is spent on quality and improving business.	Business benefits are realized by making use of operational, tactical and strategically BI. BI helps the organization to drive the business. Time is spent on business processes. Users have access to insights that help them work more effectively and optimize care outcomes.	Business benefits improve through predictive analytics. BI helps the hospital to drive the market. Time is spent on improving business processes.

People

Manual versus Automatic activities
Determines if most of the activities are done by hand or if the activities are done automatically. At the beginning most activities will be done manually. Automating processes improves the BI processed and the availability of data. It makes it also able for BI suppliers to focus on new products that can contribute in the improvement of quality of care.

Manually vs. Automated	Some activities are done manually (analyzing, ETL, integrating, cleansing of data and reporting)	Most activities are automated (ETL, quality checks and reporting).	All most all activities are automated except for specific requests.

BI users

Are the users that make use of the Business Intelligence products. The BI products can really make a difference when they are used by frontline-employees. The frontline-employees can improve the care processes by making use of the information that is provided via a BI product. Executives and managers can also track trends in the care processes. They can analyze how long a certain trend occurs and what causes it. If it is an unfavorable trend there can be found a way to prevent it next time, if it was a favorable trend there can be analyzed what caused it and how to continue this trend. BI users describe the type of users and the location of the users (Watson, 2001).

BI users	Executives and managers	Executives, managers, and frontline employees/key users.	Empowerment of frontline users

BI developers

Are the providers of the BI solution. The BI solution developers can have different roles in the beginning because they have to do different tasks. How mature the BI solution becomes the more specific a task become and how more specialized the assigned role is.

BI solution developers	Everybody knows something about every BI process.	Some developers get specific roles, they know a lot about a particular BI process.	Specialists know everything about one specific part of the BI process.

BI developer's characteristics

Are the providers of the BI-products and the users of the BI solution. The BI developers are analysts that understand the processes of the business and the BI processes, which they use to improve the efficiency of the company.

BI product developers	People, who prize autonomy, work well in unstructured environments and are fairly outgoing and risk tolerant.	People who support departmental rather than individuals or enterprise agendas. Charismatic leaders, but are more likely to select and align themselves with team players rather than individuals	People who collaborate well within their peer group, but they also think outside their functional unit about the greater good of the enterprise	People are driven, diverse and adaptable, and they thrive one challenge. They prefer creative challenges to predictable tasks and are not afraid to take risks. They bring diverse intellectual skills to the table and use historical and predictive analysis to increase the effectiveness of their organization.	People are proactive creative thinkers with a venture-capitalist mentality. They hold various roles within the organization. They focus on moving the business forward while always considering new ways their expertise might create value.

Chief level involvement
Globalization is putting pressure on C-level executives to make better informed decisions, and on the CIO to provide accurate, consistent and timely information from a dynamic organization. Chief level involvement refers to the extent of organizational support and sponsorship for the BI environment. Strong support and sponsorship from senior business management is critical for a successful BI initiative (Logica, 2009). The visibility that management support brings will open the door for investments in both manpower and capital ((Stock, 2009).

C-level involvement in BI investment	Support from IT-manager, No C-level involvement.	Limited Some savvy C-level managers are interested in BI Single Sponsorship from business unit or department.	C-level management is enthusiastically engaged in BI. C-level management sees quantitative impact on the business. Multiple sponsorship from multiple business units or departments.	C-level sponsors the BI portfolio C-level supports data management processes and standards. Sponsorship from multiple business units or departments.	C-level embraces BI as a strategic lever for the business. Chief analytics officer. Top level management sponsorship.

BI developers' expertise:
Determines how broad the Business Intelligence expertise is within an organization. It shows which skills are available. It is important to have in-house knowledge about BI. In-house resources are more willing to share knowledge than consultancy companies. There needs to be knowledge about data warehousing, business analytics, business performance management and user interfaces. In the beginning there skills are focuses on IT-skills and analytical skills for setting up the BI solution, while later on the focus is on analytical skills and business skills to provide the right information in the BI products.

BI developers expertise	Few talented individuals Knowledge comes from doing.	Broader base of BI-talent. Skills of technical employees.	Substantial BI knowledge or a consulting partner.	In-house resources and know-how, Knowledge is rewarded.

Information Culture
Shows how information is used and how it is improved and shared. The information that is provided via a BI product can be used for individual objectives and for enterprise objectives. At the highest level most is used for enterprise wide objectives.

Information culture	Individual objectives, 'everyone for himself' Measure what is happening.	Department objectives, 'us versus them' How to monitor the business.	Enterprise objectives, Information-quality improvement.	Enterprise objectives Collaboration & interdependency	Enterprise objectives, 'outside-the-box' thinking, new ideas. Think strategically.

C-level understanding the importance of data-integrity
Determines if C-level management understands the importance of a high level of data–integrity. It is important that chiefs understand why a high level of integrity is important. If they understand what the consequences are if the integrity is low, than they are more willing to provide more personnel and resources to reach a high level of data-integrity.

C-level understanding the importance of data-integrity	Limited corporate management buy-in to the data integrity.	Receive executive and management approval to improve the data. The data improvement initiatives receive personnel and resources to create high-quality data.	Procedures help the enterprise to achieve the highest levels of data integrity. Department-head is responsible for information-quality.

Training:
Education and communication regarding BI initiatives is necessary to help the frontline employees derive value from the BI environment. As the data/report is introduced in the BI environment, trainings sessions, data forums, and metadata need to be made available to the BI community (Deloitte, 2009).

Training	Company develops skills with extern-training programs	Employees gain information skills through formal intern training.	Intern information skill training programs are available through email and portal.	Comprehensive training plan program is scheduled and organized. All level of employee has access to the training.

Processes

Service level management:
Describes the service level agreements between suppliers and customers. The service level agreements need to be documented and formalized. BI application management service is based on clear service level agreements, and by making use of blended delivery models. By ensuring the service level agreements, BI product developers can use the BI solution/application to produce BI products. The BI products are used by the BI users (health-workers). There are also service level agreements for the BI products, like refreshing/updating the data; I refer to it as the BI product management service. By monitoring the agreements, BI users can focus on their job to provide the best care possible. When information is delivered via a service oriented framework BI application and product suppliers have to ensure that agreements are met by continual monitoring and reviewing. When service levels are discussed, set and measured consumers and users will know what to expect. As a result, they will develop confidence in the BI solution/BI product and the BI providers.

Service level management for BI solution	Customer needs are documented ad-hoc.	Some of the customer's needs are documented and formalized. SLA's.	All the customer's needs are documented and formalized SLA's.	SLA reviewed with the customer on periodic and event-driven base.	Actual service delivery is continuously monitored and evaluated for continuously improvement.

Change management:
Aims to ensure that standard methods and procedures are used to handle changes as soon as possible and in an efficient way. It is important to use a standard procedure and a change management system to store, approve, verify, prioritize and schedule changes. This way there is a good overview of what has changed and what still needs to be changed. Also the quality of BI solution/product will go up because errors are documented or solved.
Changes occur in the BI solution and in the BI product.
A standard procedure enables a quick change when necessary. A quick change is necessary when a BI product is used for improving the quality of care but shows the wrong data, or when the way of registering data in the application has changed. It is also important to track changes in BI solution a product requirements, by tracking them you can see the progress of the BI solution and the BI product that supports the improvement of quality of care.
Changes occur in requirements, BI product and BI solution

Change management for BI solution	Change request are made and solved in an ad-hoc manner	A change-management system is used for storing the request for change	A standard procedure is used for approving, verifying, prioritizing and scheduling changes	Standard reports concerning the change status are regularly produced for all the involved teams	Trend analysis and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them.

Incident management

'*An incident is an event which does not belongs to the standard operation of a service and which causes or may cause interruption or reduction in the quality of that service*.'

Incident management refers to the activities of an organization that identify analyze and correct hazards to prevent future re-occurrence. It is important to report incidents into a ticket handling system and to assess and classify the incidents by following a standard procedure. By following a standard procedure the most necessary incident are treated first. By classifying the incidents one can measure how much the BI product contributes in the improvement of the quality of care. For example an incident may cause that a health worker can't access multiple reports which he/she needs to provide a high quality of care, but an incident can also cause that a health worker can't download a report but can see the results she needs. The former incident is more crucial than the last incident, because the health worker cannot provide the best care possible. Solving incidents improves the productivity of the consumers/ users, improves process monitoring, higher customer/user satisfaction.

Incident management for BI solution	Ad-hoc , No specialized ticket handling system or service desk.	A ticket handling system.	A service desk, Incidents assessments and classification is done following a standard procedure.	Standard reports are regularly produced, An incident management database is established.	Trend analysis in incident occurrence, in customer satisfaction, and value perception of the service provided to them.

Release management

'*A release is a composition of one or more changes*'

A release exists out of different categories:

- Major Release (major roll-out new hardware / software, significant new functionality, often takes several Known Errors way, including Quick Fixes and workarounds)
- Minor release / hardware upgrade (minor improvements in Fixes Known Errors, last good basic configuration is updated)

Release management refers to the process of managing releases from development stage to the actual release. Release management ensures the use of high quality software and hardware, and less implementation. Releases take place in BI solutions and BI products. Release management should be documented and be done by following a standard procedure. By documenting the releases, users of the reports can see what has changed and what the new possibilities are. Therefore the users can fully exploit the BI product.

Release management for BI solution	Ad-hoc releases, No release naming and numbering conventions.	Release naming and numbering conventions.	Release management Is documented and done following a standard procedure.	Standard reports concerning release management.	Release management trend analysis.

Resource management

The purpose of resource management is to maintain control of the necessary hardware and software resources needed to deliver the agreed DWH service level agreements. Before commitments are made to BI product developers, resources are checked. If not enough resources are available, either the commitments are adapted or extra resources are installed. It also involves monitoring the ETL and the BI applications in order to see if the current resources are enough for the desired data warehouse performance (Sacu., 2010).

Resource management	Ad-hoc resource management activities	Resource management following some procedures	Resource management following documented standardized procedures	Resource management following documented standardized procedures and standard reports concerning performance	Resource management following documented standardized procedures and standard reports concerning performance and trend analyzing.

Availability management
The goal is to address the issue of a cost effective and established level of availability of the BI solution/products. Availability management is responsible for ensuring application systems to be up- to -date and available for use according to the conditions of the service level agreements. Availability management ensures that new product and services meet the agreed availability requirements and standards with the customers.

Availability management BI solution	C-level understanding the importance of data-integrity	C-level understanding the importance of data-integrity	C-level understanding the importance of data-integrity	C-level understanding the importance of data-integrity

Knowledge management
The primary role of Knowledge Management is to improve the quality of decision making by ensuring that accurate, reliable and trustworthy information is available throughout the Service Lifecycle. The process responsible for gathering, analyzing, storing and sharing knowledge and information within an organization. The primary purpose of knowledge management is to improve efficiency by reducing the need to rediscover knowledge.
Knowledge management encompasses all the knowledge activities and the way they are implemented. To exploit the use of BI fully, knowledge need to be shared and documented. By sharing the knowledge about BI, people understand what the possibilities are by making use of BI solution. BI can be used as an asset to enable strategic agility. It is important to share the BI knowledge, for example when crucial people in the care process don't know what the possibilities are with BI or they don't know how to use it, useful and available information will not be used and the quality of care will not improve.

Knowledge management	Ad-hoc knowledge gathering and sharing.	Organized knowledge sharing through written documentation and technology and also through training and mentoring programs.	Knowledge management is important to top level management, knowledge creation and sharing through brainstorming, training and mentoring programs	Central business unit knowledge management; quantitative knowledge management control and periodic knowledge gap analysis	Continuously improving inter-organizational knowledge sharing.

Data management/governance

Key in achieving accountable, consistent and traceable information in a business intelligence solution is the presence of data management processes. To achieve high quality data it is important to governance the quality of the data and to have preventive measures. If data is not managed well increasing amounts of time may be spent on corrective activity. Assigning explicit responsibility for looking after data, documenting and applying procedures for data handling. Ensuring data is classified, stored safely and properly backed up will reduce the amount of time spent dealing with data-related problems. Data governance provides for an enterprise-wide data governance body, a policy, a set of processes, standards, controls, and an execution plan for managing the data. It promotes data quality, data integrity, data consistency and thus increases the information usability and reliability. Data governance should include identification of data stakeholders, such as data owners, data stewards and their roles in handling enterprise data. The data governance program encourages the understanding and management of the data from both business and technical perspectives, plus it promotes the importance of the data as a valuable resource, allowing the enterprise to use the data confidently to satisfy business needs. Data governance improves information quality, and confidence in decision making, lowers the cost of managing the data, designates accountability for data quality, and makes the best use of the data to achieve the overall enterprise objectives. The realization that the data is a valuable and manageable enterprise asset is one of the main business benefits of a data governance initiative (Deloitte, 2009).

Data management	Efforts are ad-hoc and manual. Mainly ETL-based cleansing. Problem correction Enterprise realizes data management is valuable Enterprise is not willing to provide time and money	Data quality and governance are becoming more important. Ownership of data, data stewards are identified, Preventive measures are in place to ensure high-quality data. Documentation about data management policies.	Robust data quality system is in place. Standards & policies are enforced, data quality problems are fixed at the source (no) cleansing , Preventive measures are in place to ensure high-quality data.

Evaluation of the BI product

An investigation conducted to provide stakeholders with information about the quality of the product or service. Testing can be stated as the process of validating and verifying that a product meets the requirements that guided its design and development, that the product works as expected and that the product satisfies the needs of stakeholders. Testing the BI solution/product reduces risk of failure and ensures that the users are able to operate productively. Testing is important because it verifies that a report shows the information that it actually should show. The tests should be documented and executed by following standard procedures. Requirements and the reports are mostly tested by key-users in the healthcare, or by verifying with old existing reports. It is increasingly common to see that controlled test sets and formal test projects are used. The functionality, features and the fit of the BI product should be evaluated.

BI solution Evaluation	Technical test, executed by BI product developers	Functional and technical test executed by BI product developers. Documented and standardized technical test	User test executed by key-user Documented and standardized functional and technical test	Documented and standardized functional technical and user tests (care managers)	
BI solution Testing	Unit testing.	Unit testing is documented and executed in a standard way. Integration testing and system testing take place but not in a standard way and without documentation	Unit testing, integration testing, and system testing is documented and executed in a standard way, and acceptance testing takes place but not in a standard way and without documentation.	Unit testing, integration testing, system testing, and acceptance testing is documented and executed in a standard way and regression testing takes place but not in a standard way and without documentation.	Unit testing, integration tests, system testing, acceptance testing and regression testing takes place and is documented and executed in a standard way. All testing is done by the provider of the BI solution.
Documentation of BI requirements evaluation method	No documentation, but some of the tests are standardized	Some tests are standardized and documented.	All tests are standardized and documented.		

Technology

ETL

An ETL tool is responsible for data transfer, from operational or transaction systems to data warehouses. Usually ETL processes are not very complex when a company uses ETLs that are written by hand. This shows a low level of maturity regarding ETL capabilities. It is very useful when a hospital uses standardized ETL-tools and ETL –scripts this will provide better performances. The more standardized an ETL is the less manual work needs to be done.

Data source support	CSV files	Operational databases	Unstructured data sources		
ETL	Hand coded ETL Simple ETL processes No meta data for ETL	Hand coded ETL and standard scripts Basic ETL-processes Business and technical metadata for some ETL	ETL tool for all the ETL design and generation Advanced automated ETL Business and technical metadata for all ETL	Standardized ETL-tool and some ETL Scripts for better performance More advanced ETL Process metadata is also managed for some ETL.	Complete ETL generated from metadata Real-time ETL capabilities All types of metadata are managed for all ETL
Monitoring of ETL	Simple monitoring.	Manual restart and recovery system, simple monitoring, and a start in advanced monitoring.	Manual and Automatic restart and recovery system, simple monitoring, and advanced monitoring.	Automatic restart and recovery system, advanced monitoring, and real-time monitoring.	

Housing of data
Shows how the data is stored that is used to analyze. It is very useful to have at least a centralized data warehouse this way a single view of the truth can be provided.

Housing of data	Desktop data marts (EXCEL)	Multiple independent data marts	Multiple independent data warehouses	Centralized data warehouse with multiple dependent data marts which contains structured data.	A centralized data warehouse with multiple data marts which contains structured and unstructured data.

Data models levels
Data models for the subject areas of the core functions of the enterprise should be defined in the BI solution. Conceptual, logical and physical data models should be drawn to provide the foundation for overall data architecture goals. Conceptual data models lays out business entities and their relationships. Logical data model defines detailed attributes of business entities. Physical data model provides for the actual implementation of the logical model. Data architecture acts as a key artifact to help in developing and implementing processes to support a data management strategy leading to effective BI governance (Deloitte, 2009).

Data models	Logical and physical levels designed for BI solution	Logical and physical levels designed for BI solution. Solution-dependent standards.	Logical, physical and conceptual levels designed for BI solution. Enterprise wide standards.

Integration
Integration of data involves combining data residing in different sources and providing users with a unified view of these data. Data integration is required to process data into information. Enriching and aggregating data to support the different control levels within an organization should not lead to a lack of traceability of information. It is important to have the data stored in an integrated IT system, so there is a single version of the truth across the organization addressing multiple subject areas.

Within one source system data will not be stored redundantly in most cases. However, multiple source systems often do store the same data redundantly. In those cases the leading source system for that specific data element must be determined. A rule of thumb is to choose the source system that is first to store the data element in question, and in doing so limiting the chain of data transfers and possible loss of quality.

The data integration process can be optimized by documenting it, making it repeatable, easy to define and easy to use.

Integration	No integration between or within subject areas. Multiple data views on single subject.	Integration within the same subject area. No integration between different subject areas. Single data view on a single subject	Integration across subject areas and business unit solutions. Single view on one or two data subjects. Provides historical detail.	Data is stored in an integrated IT system. Semi-automated integration system. Single consistent version of the truth across the organization addressing multiple subjects. Provides historical detail. Automatic synchronization on all of the data models.	Integrated information is available seamlessly without regard to data source or integration technology used.
Synchronization	No synchronization between data models.	Manual synchronization.	Manual and Automatic synchronization depending on the data models.	Automatic synchronization on all of the data models.	

Data availability
Determines if data is available when needed and if there are no constraints. It is important to have the data in the data warehouse and the reports up-to-date. This way trends can be followed and decisions in the care process can be made near real-time. In the ideal situation the information is available when needed where it's needed, this way the best possible decision can be made. A BI solution should be available 24 hours a day to access and reporting applications. The loading of the BI solution should therefore not interfere with the ability to report and analyze the available information in the BI solution (Roekel et al., 2009).
In some cases the required data is not available in any source system. In these cases research is performed to establish whether this data can be derived from available data based on transformation rules. In some cases missing pieces of data are available externally and can be purchased.

Data availability	Systems constraints,	Data is available, but not at the place where it is most useful.	Data is available when it is needed where it is needed (at a computer).	Data is available to the right person at the right time in the right place (at a tablet).
Updates	Quarterly to Monthly.	Monthly to Weekly.	Weekly to daily update.	

Data granularity
Refers to the size in which data fields are subdivided. It is useful to have the granularity level as low as possible to really understand what the data means and to discover causal relationships. In general, source systems contain data with a lower level of detail than needed for the BI solution.
Aggregation to the desired level in the BI solution is not a problem in those cases. It is even advised to store the lowest level of detail also in the data warehouse to assure that any time integration with other data sources is possible.

Data granularity	Summary data. Few fact tables have their granularity at the lowest level possible.	Aggregated. Most fact tables have their granularity at the lowest level possible.	Lowest level. All fact tables have their granularity at the lowest level possible.

Environments
Refers to the environments that are available to set up a report. Development, testing, acceptance and production environments are used for different purposes to support the development phases. For the development of a BI product it is useful to have at least two different environments so the production environment doesn't get disturbed.

Environments	Two separate environments. Manual transfer	Three or more environments. Some separation. Manual transfer	Three or more environments. Some separation. Automatic transfer	All environments are separated. Automatic transfer	
IT infrastructure	No specialization, desktop platform	Shared OLTP and data warehouse server	Separated OLTP servers and data warehouse server, manual transfer.	Separated OLTP servers and data warehouse server, automated transfer.	Separated servers for OLTP, data warehouse, ETL and BI applications. Automated transfer.

Meta data
Meta data is an essential part of the BI strategy as metadata explains how, why, and where he data can be found, retrieved, stored and used in an information management system. Technical metadata is used for data lineage and impact analysis. Technical meta data should include source system information, entity and attribute definitions. Operational meta data provides information regarding change and update activity, archiving, back-up and system usage information. Business metadata provides context to the data and thus it makes the meaning of the data explicit and provides definitions of data elements in business terms from the business point of view. The meta data repository contains all the metadata information about source, target, transformations, mappings, workflows, sessions and business terms. Architecture of a meta data repository should be centralized, distributed or hybrid. In a centralized architecture, meta data from all sources is stored in a central repository and all users can access it (Deloitte, 2009).

Meta data	Non-integrated metadata	Multiple central metadata repositories separated by tools, the metadata is not up-to-date.	Central up-to-date metadata repository.	Web-accessed central metadata repository with integrated, standardized, up-to-date metadata.

Data quality
The state of completeness, validity, consistency, timeliness and accuracy that makes data appropriate for a specific use.

Data traceability
Results from analysis and reporting applications are often used for strategic decision making and must often comply with regulatory demands. Traceability and an audit trail of the data from a report back to the source become very important in those cases. The BI architecture must be well equipped to support these capabilities (Roekel et al., 2009).
An enterprise should be able to trace the data as it flows from data entry systems, transactional systems, data staging environments, data warehouses and data marts to the means of information delivery used for business analysis. Meta data enables the tracking and monitoring of the data through the entire data flow.

Data consistency:
Means that data across the enterprise should be in synchronized with each other.

Data accuracy: the degree to which data correctly reflects the real world object or an event being described.

Data reliability: The data stored is trustable, i.e., it can be taken as true information.

Data completeness: the extent to which data is not missing and is sufficient breadth and depth for the task at hand.

Data Quality	Redundant data may exist in multiple files and databases. Data quality varies.	Inaccuracy of data through the enterprise Inconsistency between data sources across departments. Data is not up-to-date	Data is more standardized, consistent, complete, accountable and accurate. Data is current with the world that it models. But it is not up-to-date.	Data is consistent, accurate, complete and reliable and measurable. Data is current with the world that it models. But it is not up-to-date.	Highest level of data integrity, data is consistent, accurate, complete and reliable. Data is up-to-date.

Data access security
Information from different sources is integrated in a BI solution, creating a valuable and highly confidential integrated data collection. This often encompasses strategic information that should not reach unauthorized people, not within and definitely not outside the organization (Logica, 2009). For a high security level a company uses an integrated companywide authorization security. Tools and methods also offer remedies to mask production data in an efficient way so that confidentiality is guaranteed and an effective test set is created. By masking the production data an unauthorized person cannot trace information back to the patients.

Data access security for BI solution	Authentication security (one password for multiple people to one report)	Independent authorization for each tool.	Role level security at database level.	Integrated companywide authorization security.

BI analyze tool
Determines how advanced the BI tool is that is used to analyze data. For analyzing historical data a basic analyze tool complies however for predictive analytics there must be used an advanced analytics technology.

BI analyze tool	Spreadsheets. Tools are client based. Analyzing history. Ad-hoc queries.	Basic analyze tool of ERP-vendor. For departmental needs. Ad-hoc queries. Trend analyzing.	Strategic BI partner Basic analyze tool of ERP-vendor For organization needs OLAP, predefined queries. Supports historical comparison. Trend analyzing.	Advanced analytic technologies, Predictive analytics (data and text mining).	Advanced analytic technologies, Ad-hoc complex calculations at report level/ cube level.

BI products
Determines how advanced the BI tool is that is used to visualize performance. For following trend a basic report is enough however for frontline decision making is an event centric decision support system necessary.

BI products	Spreadsheets. Static and parameter	Web based interactive reports with	Basic dashboards and	Integrated reporting and balanced	Reports for frontline decisions

	driven reports	adjustable parameters.	scorecards. Ad-hoc reporting.	score cards and KPI's. Reports are made for frontline employees to enable frontline-decision making.	making (real-time) , Operational BI/ event centric decision support system

Appendix B: Original Questionnaire

A BI solution is a database used for reporting and data analysis. A BI solution can be used to access the quality of care processes. By assessing the quality of care processes it is possible to improve the quality of care processes. To do so, it is important that a mature BI environment support the assessment. The goal of evolving to a higher BI environment maturity is to improve the BI environment in which the BI solution supports the assessment of quality of care processes. Improving the BI environment can contribute in a better assessment of quality of care processes. If the BI solution is mature and data is used by the right people in the right way and in alignment with the quality of care goals of the academic hospital it will return more relevant and accurate information about the current status of quality of care processes. To measure the maturity of a BI environment in an academic hospital a questionnaire is used. The questionnaire is also divided into four main focus areas: Business Alignment, Service processes, Technology and People. To determine the maturity level, each focus area is divided in multiple sub-focus area. For each sub-focus area one or more questions need to be answered to determine the maturity level. The questionnaire exists out of 57 questions. For each question the respondent need to choose out of the given answers. The answers represent different maturity levels to determine the maturity of a sub-focus area. Answer 'A' represents the lowest maturity level as the last letter (e.g. 'E') represents the highest maturity level.

Business Alignment

BI Strategy

BI strategy state and document the needs as identified by the stakeholders of a hospital, highlighting how BI fits in the broader enterprise vision (business strategy).

What is the highest level in which the BI strategy is aligned with the overall business strategy?

A) There is no business intelligence strategy.
B) There is a business intelligence strategy but it is not aligned with the overall business strategy.
C) There is a business intelligence strategy and it is aligned with some parts of the business strategy.
D) There is a business intelligence strategy and it aligned with the overall business strategy and the enterprise objectives.
E) There is a business intelligence strategy and it is aligned with the overall strategy, which describes not only the current BI behavior and processes but also the future BI behavior and processes.

BI governance

BI governance enables companies to adopt an enterprise wide approach, standardize and coordinate their BI efforts.

To what degree are the overall BI solution/ product being maintained?

A) No documentation or standardization of BI best practices.
B) Best practices are not documented but are standardized.
C) IT best practices are documented and standardized, to develop and maintain the BI solution.
D) IT and analytical best practices are documented and standardized, to design the BI solution based on the information needs.
E) The best practices of IT, analytical and business processes are documented and standardized in a Business Intelligence Competence Center for some part of the organization, which is done to manage and align the Business Intelligence strategy with the Business strategy.
F) Enterprise wide BI governance (best practices of IT, analytical and business), to manage and align the Business Intelligence strategy and the Business strategy, managed by hospital management.

Business rule documentation

Business rules describe clear and unambiguous business definitions; business rules in healthcare describe rules that are documented as best practice to keep the quality of care as high as possible.

To what degree are the business rules which are used to improve the quality of care defined and documented in protocols?

A) No business rules defined or documented
B) Some of the business rules are defined and documented
C) Most of the business rules are documented.
D) All business rules are documented.

Business rule usage

Business rule usage determines if the documented business rules are known by the health workers and if they are used to keep the quality of care are high as possible.

To what extent are the health workers aware of the business rules and do they follow the business rules?

A) Health workers had no idea they exist.
B) Some health workers know that the business rules exist, but do not execute them.
C) They know they exist but not how to use them or how they contribute in the improvement of quality of care.
D) They know they exist and why to use them, most of the health workers use the rules.
E) All health workers that needed to know the business rules know them and try to improve the quality of care.

BI requirement documentation

BI requirements describe the requirements for one or more features of the BI solution/product.

Are the requirement/ standards for the BI solution documented and available?

A) No documentation
B) The main objective is described, which the BI solution will support.
C) Functional requirements are documented.
D) Technical requirements are documented.
E) All requirements are documented and available.

BI requirements method

The BI requirements method describes which method is used to gather the requirements for the BI solution.

How mature is the method for gathering the requirements for the BI solution?

A) Ad-hoc requirement definition, no methodology
B) Methodologies differ, interviews with business users.
C) Standard methodology, interviews and group sessions with business and IT-users.
D) Standard methodology, interviews and group sessions with business and IT-users, requirements are documented and published.
E) Standard methodology, interviews and group sessions with business and IT-users, requirements are documented and published. Causal analysis meeting to identify common bottlenecks causes and subsequent elimination of these causes.

Business Intelligence used in Business processes

Here is described where the BI solution/BI product is used in the business processes to improve the efficiency.

To what extent is the business intelligence solution used in the enterprise?

A) Limited local use, BI has to evolve. Users build awareness and begin to understand the quality of care by looking at historical data.
B) BI is used for some business processes to follow trends and to improve the provided information that is used by management.
C) Business processes improve through analysis by making use of BI. More useful information.BI solution is used as a strategic and competitive asset. BI users understand how BI can be used to assess the business processes.
D) BI solution is used to predict outcomes by making use of analytical tools. BI solution is used to support corporate strategy; BI solution is used to redesign business processes. BI-users exploit right-time information to work proactively to solve problems and optimize business processes.
E) BI solution is fully embedded in all levels of the hospital to promote and enable strategic agility and to support decision making.

Business benefits of using Business Intelligence

Business benefits describe the benefits as result of using BI in the business processes.

To what degree results BI in business benefits?

A) Vague no business benefits, BI is a cost center. Time is spend on data quality
B) Some benefits are identified, such as new and better information. Mainly care managers are informed better by using BI. Time is spent on data quality.
C) Quality of business processes increases by making use of complex analytics. Make better decisions BI empowers the care managers and care processes can be monitored. Time is spent on data quality and improving quality of care processes.
D) Business benefits are realized by making use of operational, tactical and strategically BI. BI helps the organization to drive the business. Time is spent on improving quality of care processes. Users have access to insights that help them work more effectively and optimize care outcomes.
E) Business benefits improve through predictive analytics. BI helps the hospital to drive the market. Time is spent on improving business processes.

People

Manual vs. automatic activities

Determines if most of the activities are done by hand or if the activities are done automatically.

To what degree are activities done manually or automatic?

A) All activities are done manually.
B) Some activities are done automated.
C) Most activities are automated.
D) All most all activities are automated.

BI-users

Refers to the users that make use of the Business Intelligence products

Who are the main users of the BI product?

A) Management and executives
B) Executives, management and employees
C) The focus is on improving processes/decisions by empowering frontline employees.

BI developers

Are the providers of the BI solution

How mature are the roles that are assigned to the BI solution developers?

A) Small group of BI providers, all BI providers know something about everything.
B) Bigger group of BI providers, certain roles are assigned however BI solution developers are not specialized in their roles.
C) Big group of BI providers, each BI enabler has been assigned a specific task. The BI enablers are specialized in their task.

BI developers characteristics

Refers to the providers of the BI-solution.

What are the characteristics of product developers?

A) Prize autonomy, work well in unstructured environments, risk tolerant.
B) Support departmental agendas, charismatic leaders, align themselves with team players.
C) Collaborate well within their peer group; think outside their functional unit about the greater good of the enterprise.
D) Driven, diverse and adaptable, and thrive one challenges. They prefer creative challenges to predictable tasks and are not afraid to take risks. They bring diverse intellectual skills to the table and use historical and predictive analysis to increase the effectiveness of their organization.
E) Proactive creative thinkers with a venture-capitalist mentality. They hold various roles within the organization. They focus on moving the business forward while always considering new ways their expertise might create value.

C- Level involvement.

C- Level involvement refers to the extent of organizational support and sponsorship for the BI environment

To what degree is the BI solution sponsored?

A) No sponsor.
B) IT-director.
C) Single sponsor from business unit or department, limited C-level involvement.
D) Multiple sponsors from multiple business units or departments, C-level are engaged in BI.
E) Multiple sponsors from multiple business units or departments, C-level sponsors BI portfolio.
F) Top level management sponsorship, C-level embraces BI as a strategic lever for the business.

BI developers expertise

Determines how broad the Business Intelligence expertise is within an organization.

How high is the BI expertise of the developers of the BI solution?

A) Few talented individuals, focus is on IT skills to develop the BI solution.
B) Small group of BI talent, focus is on IT skills to develop the BI solution.
C) Substantive BI knowledge or BI consulting partner, focus is on IT and analytical skills.
D) In-house resources and know-how of BI, focus is on analytical and business skills.

Information Culture

Determines how information is used and how it is improved and shared.

How mature is the information culture that uses the BI solution?

A) Information is used for individual objectives
B) Information is used for departmental objectives
C) Information is used for enterprise objectives, to improve information quality.
D) Information is used for enterprise objectives, to improve collaboration and interdependency.
E) Information is used for enterprise objectives, to come up with new ideas to improve strategy.

C-level management understanding the importance of data-integrity

Determines if C-level management understands the importance of a high level of data–integrity.

To what degree does C-level management understand the importance of the data-integrity?

A) Limited corporate management buy-in to the data integrity.
B) Receive executive and management approval to improve the data.
C) Procedures help the enterprise to achieve the highest levels of data integrity.

Training

Refers to education and communication regarding BI initiatives.

To what degree are the BI users trained to derive value from the BI environment?

A) No training
B) Company develops skills with extern-training programs.
C) Employees gain information skills through formal intern training
D) Information skill training programs are available within the company through email and portal.
E) Comprehensive training plan program is scheduled and organized. All level of employee has access to the training.

Processes

Service level management

Service level management refers ensuring that service level agreements are met, by continual monitoring and reviewing.

To what extent are the service level agreements managed for the BI solution?

A) Customer and suppliers service needs are documented in an ad-hoc way.
B) Some of the customer's needs are documented and formalized in SLA's by making use of a standardized procedure.
C) All the customer's needs are documented and formalized in SLA's by making use of a standardized procedure.
D) SLA reviewed with the customer on periodic and event-driven base.
E) Actual service delivery is continuously monitored and evaluated for continuously improvement.

Change management

Change management refers to ensuring that standard methods and procedures are used to handle changes as soon as possible and in an efficient way.

To what extend are changes managed for the BI solution?

A) Change request are made and solved in an ad-hoc manner.
B) A change-management system is used for storing the request for change.
C) A standard procedure is used for approving, verifying, prioritizing and scheduling changes
D) Standard reports concerning the change status are regularly produced for all the involved teams.
E) Trends and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them are analyzed.

Incident management

Incident management refers to the activities of an organization that identify analyze and correct hazards to prevent future re-occurrence.

To what degree are incidents managed for the BI solution?

A) Ad-hoc incident management, no specialized ticket handling system or service desk.
B) A ticket handling system.
C) A service desk is available. Incidents assessments and classification is done following a standard procedure.
D) An incident management database is established. Standard reports are regularly produced.
E) Trends and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them are analyzed.

Release management

Release management refers to the process of managing releases from development stage to the actual release. Release management ensures the use of high quality software and hardware, and less implementation.

To what extent are releases for the BI solution been managed?

A) Ad-hoc releases, no release naming and numbering conventions.
B) Release naming and numbering conventions.
C) Release management is documented and done following a standard procedure.
D) Standard reports concerning release management.
E) Release management trend analysis.

Resource management

The purpose of resource management is to maintain control of the necessary hardware and software resources needed to deliver the agreed BI solution/product service level agreements.

To what degree are resources for the BI solution been managed?

A) Ad-Hoc resources management activities.
B) Resource management by following some procedures.
C) Resource management following documented and standardized procedures.
D) Resource management following documented and standardized procedures, there is also a report about the performance of the resources.
E) Resource management following documented and standardized procedures, there is also a report about the performance of the resources and trends in the performance are analyzes.

Availability management

Availability management is responsible for ensuring application systems to be up- to -date and available for use according to the conditions of the service level agreements.

To what extent is availability been managed for the BI solution?

A) Ad-hoc availability management.
B) Availability management for the whole organization.
C) Risk assessment to determine the critical elements and possible problems.
D) Availability management, trend analysis and planning to ensure that all elements are available for the agreed service level targets.

Knowledge management

The primary purpose of knowledge management is to improve efficiency by reducing the need to rediscover knowledge.

To what degree is knowledge about BI managed?

A) Ad-hoc knowledge gathering and sharing
B) Organized knowledge sharing through written documentation and technology and also through training and mentoring programs.
C) Knowledge management is important to top level management, knowledge creation and sharing through brainstorming, training and mentoring programs
D) Central business unit knowledge management; quantitative knowledge management control and periodic knowledge gap analysis
E) Continuously improving inter-organizational knowledge sharing.

Data management/ governance

Data governance provides for an enterprise-wide data governance body, a policy, a set of processes, standards, controls, and an execution plan for managing the data.

To what extent is quality of data managed?

A) No quality management activities.
B) Ad-hoc quality management activities, ETL-based cleansing.
C) Preventive measures are in place to ensure high-quality data, documentation about data management policies.
D) Robust data quality system is in place, standards and policies are enforced, and data quality problems are fixed at the source.

Evaluation of the BI solution/ product

Evaluating/testing can be stated as the process of validating and verifying that a product meets the requirements that guided its design and development, that the product works as expected and that the product satisfies the needs of stakeholders

To what degree is the BI solution been tested?

A) Only unit testing, this is not executed in a standard way and there is no documentation.
B) Unit testing is documented and executed in a standard way. Integration testing and system testing take place but not in a standard way and without documentation.
C) Unit testing, integration testing, and system testing is documented and executed in a standard way, and acceptance testing takes place but not in a standard way and without documentation.
D) Unit testing, integration testing, system testing, and acceptance testing is documented and executed in a standard way and regression testing takes place but not in a standard way and without documentation.
E) Unit testing, integration tests, system testing, acceptance testing and regression testing takes place and is documented and executed in a standard way. All testing is done by the provider of the BI solution.

To what degree are the BI requirements been evaluated?

A) The technical and functional requirements are not tested.
B) The technical requirements of the BI product are tested by the BI product developers.
C) The technical and functional requirements of the BI product are tested by the BI product developers.
D) The technical requirements are tested by the BI product developers and the functional requirements of the BI product are tested by BI product developers and the key-users.
E) The technical requirements are tested by the BI product developers and functional requirements of the BI product are tested by BI product developers, key-users and/or care managers (BI product user).

To what degree is the BI requirements evaluation method been documented or standardized?

A) No documentation or standardization
B) No documentation, but some of the tests are standardized.
C) Some tests are standardized and documented.
D) All tests are standardized and documented.

Technology

ETL

An ETL tool is responsible for data transfer, from operational or transaction systems to data warehouses

What type of data source supports the data warehouse at the highest level?

A) CSV files
B) Operational databases
C) Unstructured data sources

What kind of ETL is used to transfer data into the data warehouse?

A) Hand-coded ETL
B) Hand-coded ETL and some standard scripts
C) Standardized automated ETL tool and some standard scripts
D) Optimized ETL tool, with real-time capabilities.

To what degree is the ETL managed/monitored?

A) No monitoring.
B) Simple monitoring*
C) Manual restart and recovery system, simple monitoring, and a start in advanced monitoring**.
D) Manual and Automatic restart and recovery system, simple monitoring, and a start in advanced monitoring.
E) Automatic restart and recovery system, advanced monitoring, and real-time monitoring

*Simple monitoring: (statistics regarding ETL execution such as pending, running, completed and suspended jobs; MBs processed per second; summaries of errors)
**Advanced monitoring:(statistics on infrastructure performance like CPU usage, memory allocation, database performance, server utilization during ETL; job scheduler; time or event based ETL execution, events notification, data lineage and analyzer systems)

Housing of data

Housing of data refers to how the data is stored.

How is the data in the current data warehouse stored?

A) Desktop data marts (EXCEL)
B) Multiple independent data marts
C) Multiple independent data warehouses
D) Centralized data warehouse with multiple dependent data marts which contains structured data.
E) A centralized data warehouse with multiple data marts which contains structured and unstructured data.

Data model levels

Data model refers to the objects (of a certain subject area) represented in a BI system together with their properties and relationships. The conceptual data model level lays out business entities and their relationships. The logical data model level defines detailed attributes of business entities. The physical data model provides for the actual implementation of the logical model.

To what degree are the levels of the data models defined?

A) No levels designed at all.
B) Logical and physical levels designed for BI solution
C) Logical and physical levels designed for BI solution. Solution-dependent standards.
D) Logical, physical and conceptual levels designed for BI solution. Enterprise wide standards.

Integration of data

Integration of data involves combining data residing in different sources and providing users with a unified view of these data. Data integration is required to process data into information.

To what degree is the data integrated?

A) No integration between or within subject areas.
B) Integration within the same subject area.
C) Integration across subject areas and business unit solutions.
D) Data is stored in an integrated IT system.

To what degree is the data synchronized?

A) No synchronization between data models.
B) Manual synchronization between some of the data models.
C) Manual and automatic synchronization between data models.
D) Automatic synchronization of all data models.

Data availability

Data availability determines if data is available when needed and if there are no constraints

How often is the data warehouse updated?

A) Quarterly to monthly update.
B) Monthly to weekly update.
C) Weekly to daily update.
D) Real-time.

To what degree is the data available?

A) Systems constraints
B) Data is available when it is provided.
C) Data is available when it is needed (online) at a desktop.
D) Data is available to the right person at the right time in the right place (at a tablet).

Data granularity

Data granularity refers to the size in which data fields are subdivided.

What is the level of the granularity of the fact tables that are needed?

A) The data is summarized
B) The data is aggregated
C) All fact tables had their granularity at the lowest level possible.

Environments

Refers to the environments that are available to set up a report. Development, testing, acceptance and production environments are used for different purposes to support the development phases.

To what degree is IT infrastructure in het health institute specialized for a data warehouse?

A) No specialization, desktop platform.
B) Shared OLTP and data warehouse server.
C) Separated OLTP servers and data warehouse server, manual transfer.
D) Separated OLTP servers and data warehouse server, automated transfer.
E) Separated servers for OLTP, data warehouse, ETL and BI applications. Automated transfer.

To what degree is there a separation between the development, test, acceptance and deployment environments?

A) No separation
B) Separate environments with manual transfer.
C) Separate environments with manual transfer and automatic.
D) Separated environments with automatic transfer.

Meta-data

Meta data is an essential part of the BI strategy as metadata explains how, why, and where he data can be found, retrieved, stored and used in an information management system.

To what degree is the meta-data repository accessible?

A) There is no meta-data
B) There is meta-data, however the meta-data is not integrated.
C) In each tool there is a centralized meta-data repository, but they are still not integrated.
D) There is a central up-to-date meta-data repository
E) The central up-to-date meta data repository is accessible via the web.

Data quality

The state of completeness, validity, consistency and accuracy that makes data appropriate for a specific use.

What is the level of data quality?

A) Redundant data may exist in multiple files and databases. Data quality varies.
B) Inaccuracy of data through the enterprise. Inconsistency between data sources across departments. Data is not up-to-date.
C) Data is more standardized, consistent, complete, accountable and accurate. Data is current with the world that it models. But it is not up-to-date.
D) Data is consistent, accurate, complete and reliable and measurable. Data is current with the world that it models. But it is not up-to-date.
E) Highest level of data integrity, data is consistent, accurate, complete and reliable. Data is up-to-date.

***Data consistency**: means that data across the enterprise should be in synchronized with each other.*

- *Is data represented more than once?*

***Data traceability**: allows the lifecycle of data to track all access and changes to the data. It helps an enterprise demonstrate transparency, compliance and adherence to regulations. Data traceability, along with data compliance, can be considered part of a data audit process.*

- *Is the data traceable to the source?*

***Data accuracy**: the degree to which data correctly reflects the real world object or an event being described.*

- *Does the data represent the information in the real world?*

***Data completeness**: the extent to which data is not missing and is sufficient breadth and depth for the task at hand.*

- *Is data missing?*

Data access security

The data access security refers to the security that is necessary to prevent that unauthorized people can access valuable information.

How mature is the BI solution security that is implemented to prevent unauthorized people accessing valuable information?

A) There is no security implemented, everybody can access the data.
B) Authentication security, data can be accessed by using a username and password (Groups).
C) Authentication security, data can be accessed by using a username and password (Individual).
D) Independent authorization for each tool. A user with a specific role can get permission to access the data.
E) Integrated companywide security level with authorization at role level.

BI analyze tool

The BI analyze tool refers to how advanced the BI tool is that is used to analyze data.

How mature is the BI analyze tool that is used?

A) Spreadsheets are used as analyze tool.
B) A basic analyze tool of ERP-vendor with ad hoc queries, used for e.g. trend analysis.
C) A basic analyze tool of ERP-vendor with predefined queries and historical comparison, used for e.g. trend analysis.
D) Advanced analytic tool, for predictive analysis.
E) Advanced analytic tool, which also supports ad-hoc complex calculations at report level.

BI products

The BI products refers to how advanced the BI reports are that is used to visualize data.

How mature are the BI products?

A) Spreadsheets, parameter driven reports.
B) Web-based interactive reports with adjustable parameters
C) Ad-hoc reporting and basic dashboard and scorecards
D) Integrated reporting and balanced dashboard, scorecards and KPI's
E) Reports for frontline decision making (real-time). Operational event driven support system.

Appendix C: Questionnaire for Case Study (incl. answers)

A BI solution is a database used for reporting and data analysis. A BI solution can be used to access the quality of care processes. By assessing the quality of care processes it is possible to improve the quality of care processes. To do so, it is important that a mature BI environment support the assessment. The goal of evolving to a higher BI environment maturity is to improve the BI environment in which the BI solution supports the assessment of quality of care processes. Improving the BI environment can contribute in a better assessment of quality of care processes. If the BI solution is mature and data is used by the right people in the right way and in alignment with the quality of care goals of the academic hospital it will return more relevant and accurate information about the current status of quality of care processes. To measure the maturity of a BI environment in an academic hospital a questionnaire is used. The questionnaire is also divided into four main focus areas: Business Alignment, Service processes, Technology and People. To determine the maturity level, each focus area is divided in multiple sub-focus area. For each sub-focus area one or more questions need to be answered to determine the maturity level. The questionnaire exists out of 57 questions. For each question the respondent need to choose out of the given answers. The answers represent different maturity levels to determine the maturity of a sub-focus area. Answer 'A' represents the lowest maturity level as the last letter (e.g. 'E') represents the highest maturity level.

Business Alignment

BI strategy

BI strategy state and documents the needs as identified by the stakeholders of a hospital, highlighting how a BI solution fits in the broader hospital vision (business strategy).

What is the highest level in which the BI strategy is aligned with the overall business strategy?

A) There is no business intelligence strategy.
B) There is a business intelligence strategy but it is not aligned with the overall business strategy.
C) The business intelligence strategy is aligned with some parts of the business strategy.
D) The business intelligence strategy is aligned with the current business strategy and the hospital objectives.
E) The business intelligence strategy is aligned with the overall strategy. The business intelligence strategy describes not only the current BI processes and goals but also the future BI processes and goals.

BI strategy documentation

Defines if the BI strategy is documented.

Is the BI strategy been described and documented?

A) No documentation.

B) Some documentation in the business strategy.

C) Report on the vision and goals of the BI strategy.

BI Governance

BI governance enables companies to adopt an enterprise wide approach, standardize and coordinate their BI efforts.

To what degree are the overall BI solution/ product being maintained?

A) No documentation or standardization of BI best practices.

B) Best practices are not documented but are standardized.

C) IT best practices are documented and standardized, to develop and maintain the BI solution.

D) IT and analytical best practices are documented and standardized, to design the BI solution based on the information needs.

E) The best practices of IT, analytical and business processes are documented and standardized in a Business Intelligence Competence Center for some part of the organization, which is done to manage and align the Business Intelligence strategy with the Business strategy.

F) Enterprise wide BI governance (best practices of IT, analytical and business), to manage and align the Business Intelligence strategy and the Business strategy, managed by hospital management.

Business rule documentation

Business rules describe clear and unambiguous business definitions; business rules in healthcare describe rules that are documented as best practice to keep the quality of care as high as possible.

To what degree are the business rules which are used to improve the quality of care defined and documented in protocols?

A) No business rules defined or documented.

B) Some of the business rules are defined and documented.

C) Most of the business rules are documented.

D) All business rules are documented.

Business rule availability

Business rules availability determines if the business rules are available digitally either via a webpage or via shared documents.

To what degree are the business rules digitally available?

A) No business rules digitally available.
B) Some of the business rules are digitally available.
C) Most of the business rules are digitally available.
D) All business rules are digitally available.

Business rule usage

Business rule usage determines if the documented business rules are known by the health workers and if they are used to keep the quality of care are high as possible.

To what extent are the health workers aware of the business rules and do they follow the business rules?

A) Health workers had no idea they exist
B) Some health workers know that the business rules exist, but do not execute them.
C) Health workers know they exist but not how to use them or how they contribute in the improvement of quality of care.
D) Health workers know they exist and why to use them, most of the health workers use the rules.
E) All health workers that needed to know the business rules know them and try to improve the quality of care.

BI solution requirement documentation and availability

There are three management levels in which BI solutions can be used: Strategically management, Tactical management, Operational management.

For which management levels are the BI solution requirements documented?

A) No documentation.
B) Documentation for one level.
C) Documentation for two levels.
D) Documentation for all levels.

For which management levels is the documentation about the BI solution requirements available?

A) No availability
B) Some requirements are available for one level.
C) Some requirements are available for two levels.
D) Some requirements are available for all levels.
E) All requirements are available for one level.
F) All requirements are available for two levels.
G) All requirements are available for all levels.

BI solution requirements method

The BI requirements method describes which method is used to gather the requirements for the BI solution/ product.

How mature is the method for gathering the requirements for the BI solution?

A) Ad-hoc requirement definition, no methodology.

B) Methodologies differ, interviews with business users.

C) Standard methodology, interviews and group sessions with business and IT-users.

D) Standard methodology, interviews and group sessions with business and IT-users, requirements are assessed and published.

E) Standard methodology, interviews and group sessions with business and IT-users, requirements are assessed and documented and published. Causal analysis meeting to identify common bottlenecks causes and subsequent elimination of these causes.

BI solution used in Care processes

Here is described where the BI solution is used in the care processes to improve the efficiency.

To what extent is the business intelligence solution used in the enterprise?

A) No use of BI solution to improve care processes.

B) Limited local use, BI has to evolve. Users build awareness and begin to understand the quality of care by looking at historical data.

C) BI is used for some care processes to follow trends and to improve the provided information that is used by management.

D) Care processes improve through analysis by making use of BI. More useful information.BI solution is used as a strategic and competitive asset. BI users understand how BI can be used to assess the quality of care processes.

E) BI solution is fully embedded in all levels of the hospital to promote and enable strategic agility and to support decision making.

F) BI solution is used to predict outcomes by making use of analytical tools. BI solution is used to support corporate strategy; BI solution is used to redesign care processes. BI-users exploit right-time information to work proactively to solve problems and optimize care processes.

Business benefits of using BI solution

Business benefits describe the benefits as result of using BI in the care processes.

To what degree results BI in business benefits?

A) Vague no business benefits, BI is a cost center. Time is spend on data quality
B) Some benefits are identified, such as new and better information. Mainly care managers are informed better by using BI. Time is spend on data quality.
C) Quality of care processes increases by making use of complex analytics. Make better decisions BI empowers the care managers and care processes can be monitored. Time is spent on data quality and improving quality of care processes.
D) Business benefits are realized by making use of operational, tactical and strategically BI. BI helps the organization to drive the business. Time is spent on improving quality of care processes. Users have access to insights that help them work more effectively and optimize care outcomes.
E) Business benefits improve through predictive analytics. BI helps the hospital to drive the market. Time is spent on improving quality of care processes.

People

Manual vs. automatic BI processes

Determines if most of the BI processes are done by hand (ad-hoc) or if the BI processes are done automatically. BI processes are: analyzing, ETL, integrating, cleansing of data and reporting.

To what degree are BI processes done manually or automatic?

A) All BI processes are done manually.
B) Some BI processes are done automated.
C) Most BI processes are automated.
D) All most all BI processes are automated.

BI-users

Refers to the management levels that make use of the Business Intelligence products. There are three levels for which BI can be used: Strategically management, Tactical management, Operational management.

How many levels make use of the BI product?

A) None
B) One level
C) Two levels
D) All levels

BI developers

Refers to the amount of providers of the BI solution and the extensiveness of their roles.

How mature are the roles that are assigned to the BI solution developers?

A) No BI developers.
B) 1-3 BI solution developers, all developers know something about all BI processes and data products.
C) 3-5 BI providers, certain roles are assigned however BI solution developers are not specialized in their roles.
D) Five or more BI providers, each BI enabler has been assigned to a specific task and is specialized in their task.

BI developers characteristics

Refers to the characteristics of the developers of the BI solution

What are the characteristics of BI developers?

A) Prize autonomy, work well in unstructured environments, risk tolerant.
B) Support departmental agendas, charismatic leaders, align themselves with team players.
C) Collaborate well within their peer group; think outside their functional unit about the greater good of the enterprise.
D) Driven, diverse and adaptable, and thrive one challenges. They prefer creative challenges to predictable tasks and are not afraid to take risks. They bring diverse intellectual skills to the table and use historical and predictive analysis to increase the effectiveness of their organization.
E) Proactive creative thinkers with a venture-capitalist mentality. They hold various roles within the organization. They focus on moving the business forward while always considering new ways their expertise might create value.

Chief level involvement.

Chief level involvement refers to the extent of organizational support and sponsorship for the BI environment

To what degree is the BI solution sponsored?

A) No sponsor.
B) Sponsoring by IT-director.
C) Single sponsor from business unit or department, limited C-level involvement.
D) Multiple sponsors from multiple business units or departments, C-level is engaged in BI.
E) Multiple sponsors from multiple business units or departments, C-level sponsors BI portfolio.
F) Top level management sponsorship, C-level embraces BI as a strategic lever for the business.

BI developers expertise

Determines how broad the Business Intelligence expertise is within an organization and how many people work on the BI solution. The bigger the group the bigger the knowledge and experiences.

How mature is the BI expertise of the developers of the BI solution?

A) No expertise.
B) 1-3 talented individuals, focus is on IT skills to develop the BI solution.
C) 3-5 individuals who have substantive BI knowledge or BI consulting partner.
D) In-house resources and 5 or more individuals who have knowledge about BI processes.

Information Culture

Determines how information is used and how it is improved and shared. The information that is provided via a BI product can be used for individual objectives and for hospital objectives. At the highest level most information is used for hospital wide objectives to generate new ideas.

How mature is the information culture that uses the BI solution?

A) Nu use of information.
B) Information is used for individual objectives.
C) Information is used for departmental objectives.
D) Information is used for enterprise objectives, to improve information quality (to produce new useful information products) on a project base.
E) Information is used for enterprise objectives, to improve information quality constantly and to improve collaboration and interdependency between departments on a project base.
F) Information is used for enterprise objectives, to improve collaboration and interdependency between departments constantly.
G) Information is used for enterprise objectives, to come up with new ideas to improve strategy constantly.

Chief level management understanding the importance of data-integrity

Determines if Chief level management understands the importance of a high level of data–integrity.

To what degree does Chief level management understand the importance of the data integrity?

A) No understanding.
B) Limited corporate management buy-in to the data integrity.
C) Receive executive and management approval to improve the data.
D) **Procedures help the enterprise to achieve the highest levels of data integrity.**

Training

Refers to education and communication regarding BI initiatives.

What is the highest degree at which the BI users are trained to derive value from the BI environment?

A) No training
B) Company develops skills and knowledge with extern-training programs.
C) Selected group of employees gain BI skills and knowledge through formal extern/intern training.
D) BI skill and knowledge-training programs are available within the company through email and portal.
E) Comprehensive training plan program is scheduled and organized. All level of employee has access to the training.

Processes

Service level management

Service level management refers ensuring that service level agreements are met, by continual monitoring and reviewing.

To what extent are the service level agreements (SLAs) managed for the BI solution?

A) No documentation of service level agreements.
B) Customer and suppliers service needs are documented in an ad-hoc way.
C) Some of the customer's needs are documented and formalized in SLAs by making use of a standardized procedure.
D) All the customer's needs are documented and formalized in SLAs by making use of a standardized procedure.
E) SLA reviewed with the customer on periodic and event-driven base.
F) Actual service delivery is continuously monitored and evaluated for continuously improvement.

Change management

Change management ensures that standard methods and procedures are used to handle changes as soon as possible and in an efficient way.

To what extend are changes managed for the BI solution?

A) No change management.
B) Change request are made and solved in an ad-hoc manner. No alignment between information system and BI solution
C) A change-management system is used for storing the request for change. No alignment between information system and BI solution
D) A standard procedure is used for approving, verifying, prioritizing and scheduling changes. Changes in the information system are aligned with changes in the BI solution.
E) Standard reports concerning the change status are regularly produced for all the involved teams. Changes in the information system are aligned with changes in the BI solution.
F) Trends and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them are analyzed. Changes in the information system are aligned with changes in the BI solution.

Incident management

Incident management refers to the activities of an organization that identify analyze and correct hazards to prevent future re-occurrence.

To what degree are incidents managed for the BI solution?

A) No incident management.
B) Ad-hoc incident management, no specialized ticket handling system or service desk.
C) A ticket handling system.
D) A service desk is available. Incidents assessments and classification is done following a standard procedure.
E) An incident management database is established. Standard reports are regularly produced.
F) Trends and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them are analyzed.

Release management

Release management refers to the process of managing releases from development stage to the actual release. Release management ensures the use of high quality software and hardware, and less implementation.

To what extent are releases for the BI solution been managed?

A) No release management.
B) Ad-hoc releases, no release naming and numbering conventions
C) Release naming and numbering conventions.
D) Release management is documented and done following a standard procedure.
E) Standard reports concerning release management.
F) Release management trend analysis.

Resource management

The purpose of resource management is to maintain control of the necessary hardware and software resources needed to deliver the agreed BI solution/product service level agreements.

To what degree are resources for the BI solution been managed?

A) No resource management.
B) Ad-Hoc resources management activities.
C) Resource management by following some procedures.
D) Resource management following documented and standardized procedures.
E) Resource management following documented and standardized procedures, there is also a report about the performance of the resources.
F) Resource management following documented and standardized procedures, there is also a report about the performance of the resources and trends in the performance are analyzes.

Availability management

Availability management is responsible for ensuring application systems to be up- to -date and available for use according to the conditions of the service level agreements.

To what extent is availability been managed for the BI solution?

A) No availability management.
B) Ad-hoc availability management.
C) Availability management for a specific group of people.
D) Availability management for the whole organization.
E) Risk assessment to determine the critical elements and possible problems.
F) Availability management, trend analysis and planning to ensure that all elements are available for the agreed service level targets.

Knowledge management

The primary purpose of knowledge management is to improve efficiency by reducing the need to rediscover knowledge.

To what degree is knowledge about BI managed?

A) Knowledge is not shared or documented.
B) Ad-hoc knowledge gathering and sharing.
C) Organized knowledge sharing through written documentation, technology, training and mentoring programs.
D) Knowledge management is important to top level management, knowledge creation and sharing through brainstorming, training and mentoring programs
E) Central business unit knowledge management; quantitative knowledge management control and periodic knowledge gap analysis
F) Continuously improving inter-organizational knowledge sharing.

Data management

Ensuring data is classified, stored safely and properly backed up will reduce the amount of time spent dealing with data-related problems.

To what extent is quality of data managed?

A) No quality management activities.
B) Ad-hoc quality management activities, ETL-based cleansing.
C) Preventive measures are in place to ensure high-quality data, documentation about data management policies.
D) Robust data quality system is in place, standards and policies are enforced, and data quality problems are fixed at the source.
E) Data management groups operate across the enterprise, data quality audits and data metrics to give insight into improvement.

Evaluation of the BI solution

Evaluating/testing can be stated as the process of validating and verifying that a BI solution meets the requirements that guided its design and development, that the product works as expected and that the product satisfies the needs of stakeholders

To what degree is the BI solution been tested?

A) No testing.
B) Only unit testing,
C) Unit testing, Integration tests and system testing take place.
D) Unit testing, integration tests, system and acceptance testing takes place.
E) Unit testing, integration tests, system testing, acceptance testing and regression testing takes place.

To what degree are the BI solution tests documented and standardized?

A) No documentation or standardization
B) No documentation, but some of the tests are standardized.
C) Some tests are standardized and documented.
D) All tests are standardized and documented.

To what degree are the BI requirements been evaluated?

A) The technical and functional requirements are not tested.
B) The technical requirements of the BI product are tested by the BI developers.
C) The technical and functional requirements of the BI product are tested by the BI developers.
D) The technical requirements are tested by the BI product developers and the functional requirements of the BI product are tested by BI developers and the key-users.
E) The technical requirements are tested by the BI product developers and functional requirements of the BI product are tested by BI product developers, key-users and/or care managers (BI product user).

To what degree is the BI requirements evaluation method been documented or standardized?

A) No documentation or standardization
B) No documentation, but some of the tests are standardized.
C) Some tests are standardized and documented.
D) All tests are standardized and documented.

Technology

ETL

An ETL tool is responsible for data transfer, from operational or transaction systems to data warehouses

What type of data source supports the BI solution at the highest level (in which option c is the highest level)?

A) No support.
B) Operational databases
C) CSV files
D) Unstructured data sources.

What is the highest maturity level that applies to the ETL that is used to transfer data into the data warehouse?

A) No ETL.
B) Hand-coded ETL.
C) Hand-coded ETL and some standard scripts.
D) Standardized automated ETL tool.
E) Optimized ETL tool, with real-time capabilities.

To what degree is the ETL monitored?

A) No monitoring.
B) Simple monitoring*
C) Manual restart and recovery system, simple monitoring, and a start in advanced monitoring**.
D) Manual and Automatic restart and recovery system, simple monitoring, and advanced monitoring.
E) Automatic restart and recovery system, advanced monitoring, and real-time monitoring

*Simple monitoring: statistics regarding ETL execution such as pending, running, completed and suspended jobs; MBs processed per second; summaries of errors
**Advanced monitoring: statistics on infrastructure performance like CPU usage, memory allocation, database performance, server utilization during ETL; job scheduler; time or event based ETL execution, events notification, data lineage and analyzer systems)

BI solution architecture

Housing of data refers to architecture in which the data is stored.

How is the data in the current BI solution stored?

A) Desktop data marts (EXCEL), no DWH architecture.
B) Multiple independent data marts
C) Multiple independent data warehouses
D) One centralized data warehouse which contains data from different applications
E) One centralized data warehouse with multiple dependent data marts which contains structured data.
F) One centralized data warehouse with multiple data marts which contains structured and unstructured data.

Data model levels

Data model refers to the objects (of a certain subject area) represented in a BI system together with their properties and relationships. The conceptual data model level lays out business entities and their relationships. The logical data model level defines detailed attributes of business entities. The physical data model provides for the actual implementation of the logical model.

To what degree are the levels of the data models defined?

A) No levels designed at all.
B) Logical levels designed for BI solution.
C) Logical and physical levels designed for BI solution. Solution-dependent standards.
D) Logical, physical and conceptual levels designed for BI solution. Enterprise wide standards.

Integration of data

Integration of data involves combining data residing in different sources and providing users with a unified view of these data. Data integration is required to process data into information.

To what degree is the data integrated?

A) No integration between or within subject areas.
B) Integration within the same subject area.
C) Integration across subject areas and business unit solutions.
D) Data is stored in an integrated IT system.

To what degree is the data synchronized?

A) No synchronization between data models.
B) Manual synchronization between some of the data models.
C) Manual and automatic synchronization between data models.
D) Automatic synchronization of all data models.

Data availability

Data availability determines if data is available when needed and if there are no constraints

How often is the data warehouse updated?

A) Quarterly update.
B) Monthly update.
C) Weekly update.
D) Daily update.
E) Real-time.

To what degree is the data available?

A) Systems constraints
B) Data is available when it is provided.
C) Data is available when it is needed (online) at a desktop.
D) Data is available to the right person at the right time in the right place (at a tablet).

Data granularity

Data granularity refers to the size in which data fields are subdivided.

What is the level of the granularity of the fact tables that are needed?

A) No details.
B) The data is summarized
C) The data is aggregated
D) All fact tables had their granularity at the lowest level possible.

Environments

Refers to the environments that are available to set up a report. Development, testing, acceptance and production environments are used for different purposes to support the development phases.

To what degree is there a separation between the development, test, acceptance and deployment environments?

A) No separation
B) Separate environments with manual transfer.
C) Separate environments with manual transfer and automatic.
D) Separated environments with automatic transfer.

To what degree is IT infrastructure in het health institute specialized for a BI solution?

A) No specialization, desktop platform.
B) Shared OLTP systems and BI solution environment.
C) Separated OLTP systems and BI solution environment, manual transfer.
D) Separated OLTP systems and BI solution environment, automated transfer.
E) Separated servers for OLTP, BI solution, and ETL processes. Automated transfer.

Meta-data

Meta data is an essential part of the BI strategy as metadata explains how, why, and where he data can be found, retrieved, stored and used in an information management system.

To what degree is the meta-data repository accessible?

A) There is no meta-data
B) There is meta-data, however the meta-data is not integrated.
C) In each tool there is a centralized meta-data repository, but they are still not integrated.
D) There is a central up-to-date meta-data repository
E) The central up-to-date meta data repository is accessible via the web.

Data quality

The state of completeness, validity, consistency, traceability, and accuracy that makes data appropriate for a specific use.

Data completeness: the extent to which data is not missing and is sufficient breadth and depth for the task at hand.

What is the level of data completeness?

A) Data is incomplete
B) Some of the data is complete
C) All data is complete

Data validity: is the process of ensuring that a program operates on clean, correct and useful data. It uses routines, often called "validation rules" "validation constraints" or "check routines", that check for correctness, reasonableness, and security of data that are input to the system. Reasonableness of data means that numeric data are all digits; dates have valid month, day and year and; and the spelling of names is proper.

What is the level of data validity?

A) Data is not validated
B) Some of the data is validated, correct and reasonable
C) All data is correct and reasonable

Data consistency: means that data across the enterprise should be in synchronized with each other.

What is the level of data consistency?

A) Data is inconsistent
B) Some of the data is consistent
C) All data is consistent

Data traceability: allows the lifecycle of data to track all access and changes to the data. It helps an enterprise demonstrate transparency, compliance and adherence to regulations. Data traceability, along with data compliance, can be considered part of a data audit process.

What is the level of data traceability?

A) Data is not traceable
B) Some of the data is traceable
C) All data is traceable

Data accuracy: the degree to which data correctly reflects the real world object or an event being described.

What is the level of data accuracy?

A) Data is not accurate
B) Some of the data is accurate
C) All data is accurate

Data access security

The data access security refers to the security that is necessary to prevent that unauthorized people can access valuable information.

How mature is the BI solution security that is implemented to prevent unauthorized people accessing valuable information?

A) There is no security implemented, everybody can access the data.
B) Authentication security, data can be accessed by using a username and password (Groups).
C) Authentication security, data can be accessed by using a username and password (Individual).
D) Independent authorization for each tool. A user with a specific role can get permission to access the data.
E) Integrated companywide security level with authorization at role level.

BI analyze tool

The BI analyze tool refers to how advanced the BI tool is that is used to analyze data.

How mature is the BI analyze tool that is used?

A) Spreadsheets are used as analyze tool.
B) A basic analyze tool of ERP-vendor with ad hoc queries, used for e.g. trend analysis.
C) A basic analyze tool of ERP-vendor with predefined queries and historical comparison, used for e.g. trend analysis.
D) Advanced analytic tool, for predictive analysis.
E) Advanced analytic tool, which also supports ad-hoc complex calculations at report level.

BI products

The BI products refers to how advanced the BI reports are that is used to visualize data.

How mature is the BI visualization tool?

A) Spreadsheets, parameter driven reports.
B) Web-based interactive reports with adjustable parameters
C) Ad-hoc reporting and basic dashboard and scorecards
D) Integrated reporting and balanced dashboard, scorecards and KPI's
E) Reports for frontline decision making (real-time). Operational event driven support system.

Appendix D: Final Questionnaire

To be able to use the BI Environment Maturity Model as an instrument to access the current maturity of the BI environment, measures must be defined for each capability. This is done by using a questionnaire. In the questionnaire are control question formulated for each sub-focus area. The formulization of the questions is based on the description of the capabilities and on experience and practice.

The questionnaire is divided into four main focus areas: Business Alignment, Service processes, Technology and People. The questionnaire is used to determine the maturity of the Business Intelligence Environment in an academic hospital. To determine the maturity level each focus area is divided in multiple sub-focus area. For each sub-focus area one or more questions need to be answered to determine the maturity level. In the questionnaire a distinction is made in a Business Intelligence solution and a Business Intelligence product. The Business Intelligence solution refers to the data warehouse in which the data is ordered. The Business Intelligence product refers to reports in which the data is visualized so it can be used by frontline employees. The questionnaire exists out of 57 questions. For each question the respondent need to choose out of the given answers. The answers represent different maturity levels to determine the maturity of a sub-focus area. Answer 'A' represents the lowest maturity level as the last letter (e.g. 'E') represents the highest maturity level.

Business alignment

BI Strategy

BI strategy state and documents the needs as identified by the stakeholders of a hospital, highlighting how a BI solution fits in the broader hospital vision (business strategy).

What is the highest level in which the BI strategy is aligned with the overall business strategy?

A) There is no business intelligence strategy
B) There is a business intelligence strategy but it is not aligned with the overall business strategy
C) There is a business intelligence strategy and it is aligned with some parts of the business strategy
D) There is a business intelligence strategy and it aligned with the current business strategy and the enterprise objectives.
E) There is a business intelligence strategy and it is aligned with the overall strategy, which describes not only the current BI processes and goals but also the future BI processes and goals.

BI strategy documentation

Defines if the BI strategy is documented.

Is the BI strategy been described and documented?

A) No documentation.
B) Some documentation in the business strategy.
C) Report on the vision and goals of the BI strategy.

BI Governance

BI governance enables hospitals to adopt an enterprise wide approach, standardize and coordinate their BI efforts. The approach and BI efforts are often described in BI best practices.

To what degree are the overall BI best practices being maintained?

A) BI best practices are not documented or used elsewhere.
B) BI best practices are standardized but not documented, best practices are however shared and used through networking to redevelop and maintain BI solution/products.
C) BI best practices are documented and standardized for some information products to redevelop and maintain BI solution/products.
D) BI best practices are documented and standardized for all information products, to redevelop and maintain the BI solution/products.
E) BI best practices are documented, standardized, and available for all information products in a Business Intelligence Competence Center (BICC), which is a central point in the hospital for all BI best practices.
F) There is a hospital wide approach for documenting and standardizing BI best practices which uses a BICC, for the alignment of the BI strategy with the Business strategy.

Business rule documentation

Business rules describe clear and unambiguous business definitions; business rules in healthcare processes describe rules that are derived from best practices. These business rules should improve the quality of care processes and are mainly described in protocols.

To what degree are the business rules which are used to improve the quality of care defined and documented in protocols?

A) No business rules defined or documented
B) Some of the business rules are defined and documented.
C) Some of the business rules are defined, documented and available.
D) Most of the business rules are defined, documented and available.
E) All business rules are defined, documented and available.

Business rule availability

Business rules availability determines if the business rules are available digitally either via a webpage or via shared documents.

To what degree are the business rules digitally available?

A) No business rules digitally available.
B) Some of the business rules are digitally available.
C) Most of the business rules are digitally available.
D) All business rules are digitally available.

Business rules norms

Refers to norms that have been set for executing or following the business rules.

Do the BI products contain norms?

A) No norms.
B) Some norms for the performance indicators.
C) All performance indicators contain norms if possible.

Business rule usage

Business rule usage determines if the documented business rules are known by the health workers and if they are used to keep the quality of care as high as possible.

To what extent are the health workers aware of the business rules and do they follow the business rules?

A) Health workers had no idea they exist
B) Some health workers know that the business rules exist, but do not execute them
C) They know they exist but not how to use them or how they contribute in the improvement of quality of care processes.
D) They know they exist and how he rules contribute in the improvement of quality of care processes, most of the health workers apply the business rules in the care process.
E) All health workers that needed to know the business rules knows them and tries to improve the quality of care by applying the rules wherever possible. All health workers also know how to register the information into the information system.

BI requirement documentation and availability

There are three levels in which BI products of the BI solution can be used: Strategically management, Tactical management, Operational management.

For which levels are the BI product requirements documented?

A) No documentation
B) Documentation for one level
C) Documentation for two levels
D) Documentation for all levels

For which levels is the documentation about the BI product requirements available?

A) No availability
B) Some requirements are available for one level
C) Some requirements are available for two levels
D) Some requirements are available for all levels
E) All requirements are available for one level
F) All requirements are available for two levels
G) All requirements are available for all levels

BI solution requirements method

The BI requirements method describes which method is used to gather the requirements for the BI solution/ product.

How mature is the method for gathering the requirements for the BI products of the BI solution?

A) Ad-hoc requirement determination, no methods
B) Methods differ, requirements are retrieved with interviews. Interviews with care managers for collecting the requirements.
C) Standard methodology, all requirements are retrieved the same way and are documented. Interviews with care managers for collecting the requirements.
D) Standard methodology, all requirements are retrieved the same way and are documented, assessed and published. Interviews with care managers and Top- management to align the requirements with the business strategy.
E) Standard methodology, all requirements are retrieved the same way, and are assessed, documented and published. Causal analysis meeting to identify common bottlenecks causes and subsequent elimination of these causes.

BI product understanding

BI product understanding determines if the provided BI products are known by the Care managers and if they understand the relation between the business rules and the BI products.

To what extent do Care managers know what the relation is between the business rules in the protocols and the BI products?

A) Care managers have no idea where the BI products are useful for.
B) Care managers do measure their performances in care processes but do not know why.
C) Care managers measure their performances and know the purpose.
D) Care managers measure their performances and know the purpose in relation with the business rules that are described in protocols.

Monitoring BI usage

Monitoring BI usage refers to the process in which is monitored if BI products are used enough. By no usage one should consider to change the report so it will be used.

To what extent is the use of BI products been monitored?

A) No monitoring.
B) Monitoring ad-hoc.
C) Standard monitoring, results are fed back to the Care managers of the departments.
D) Self-service monitoring. Care managers are given access to the reports to monitor the usage in their department.

Business Intelligence used in Care processes

Here is described how and where the BI products are used in the business processes to improve the care.

To what extent is the business intelligence solution used in the enterprise?

A) No use of business intelligence to improve care processes
B) Limited local use, BI has to evolve. Users build awareness and begin to understand the quality of care by looking at historical data.
C) BI is used for some care processes to follow trends and to improve the provided information that is used by management.
D) Care processes improve through analysis by making use of BI. More useful information. BI solution is used as a strategic and competitive asset. BI users understand how BI can be used to assess the quality of care processes.
E) BI solution is fully embedded in all levels of the hospital to promote and enable strategic agility and to support decision making.
F) BI solution is used to predict outcomes by making use of analytical tools. BI solution is used to support corporate strategy; BI solution is used to redesign care processes. BI-users exploit right-time information to work proactively to solve problems and optimize care processes.

Business benefits of using Business Intelligence

Business benefits describe the benefits as result of using BI in the care processes.

To what degree results BI in business benefits?

A) Vague, BI is a cost center. Time is spend on data quality
B) Some benefits are identified, such as new and better information. Mainly executives are informed better by using BI. Time is spend on data quality.
C) Business values increase by making use of complex analytics. Make better decisions BI empowers the care managers, and care processes can be monitored. Time is spent on data quality and improving quality of care processes.
D) Business benefits are realized by making use of operational, tactical and strategically BI. BI helps the hospital to drive the business. Time is spent on improving quality of care processes. Users have access to insights that help them work more effectively and optimize care outcomes.
E) Business benefits improve through predictive analytics. BI helps the hospital to drive the market. Time is spent on improving quality of care processes.

People

Manual vs. automatic BI processes

Determines if most of the BI processes are done by hand (ad-hoc) or if the BI processes are done automatically.

To what degree are BI processes done manually or automatic?

A) All processes are done manually.
B) Some BI processes are done automated.
C) Most BI processes are automated.
D) All most all BI processes are automated.

BI-users

Refers to the management levels that make use of the Business Intelligence products. There are three levels for which BI can be used: Strategically management, Tactical management, Operational management.

How many levels make use of the BI product?

A) None
B) One level
C) Two levels
D) All levels

Information network

Refers to the organizational structure/network of people in a hospital that enables the creation of new information products.

How well does management of departments know the network?

A) Organizational structure is unknown, people reuse other information products.
B) Some know who does what; they get information products from providers out of their own network if possible.
C) The organizational structure is known, everybody knows who to go to for a particular information product, and who is responsible for the quality of the information products.

BI developers

Refers to the amount of providers of the BI solution and the extensiveness of their roles.

How mature are the roles that are assigned to the BI solution developers?

A) 1-3 BI solution developers, all developers know something about all BI processes and data products.
B) 3-5 BI providers, certain roles are assigned however BI solution developers are not specialized in their roles.
C) 5or more BI providers, each BI enabler has been assigned to a specific task and are specialized in their task.

BI developers characteristics

Refers to the providers of the BI-products and the users of the BI solution

How mature are the characteristics of product developers?

A) Prize autonomy, work well in unstructured environments, risk tolerant.
B) Support departmental agendas, charismatic leaders, align themselves with team players.
C) Collaborate well within their peer group; think outside their functional unit about the greater good of the enterprise.
D) Driven, diverse and adaptable, and thrive one challenges. They prefer creative challenges to predictable tasks and are not afraid to take risks. They bring diverse intellectual skills to the table and use historical and predictive analysis to increase the effectiveness of their organization.
E) Proactive creative thinkers with a venture-capitalist mentality. They hold various roles within the organization and focus on moving the business forward while always considering new ways. Their expertise might create value.

Chief level involvement

Chief level involvement refers to the extent of organizational support and sponsorship for the BI environment. Sponsorship can take place through centralized management and decentralized management. The sponsoring via centralized management is provided via IT management which is top-down and the sponsoring via decentralized management is provided via management of different departments/wards that uses the BI solution/ products.

To what degree are the BI solution/products sponsored through centralized and decentralized management?

A) No sponsoring from centralized or decentralized management.
B) Sponsoring by IT-director via central management.
C) Limited sponsoring by C-level involvement via central management.
D) Decentralized sponsoring by management of multiple departments/wards, central sponsoring by C-level management which is engaged in BI.
E) Decentralized sponsoring by management of multiple departments/wards, central sponsoring by C-level management which sponsors the BI portfolio.
F) Top level management sponsorship, C-level management embraces BI as a strategic lever for the business and all C-level management of each department sponsors BI because they want to make use of BI information products.

BI developers expertise

Determines how broad the Business Intelligence expertise is within an organization and how many people work on the BI solution. The bigger the group the bigger the knowledge and experiences.

How mature is the BI expertise of the developers of the BI solution?

A) 1-3 talented individuals, focus is on IT skills to develop the BI solution.
B) 3-5 individuals who have substantive BI knowledge or BI consulting partner.
C) In-house resources and 5 or more individuals who have knowledge about BI processes.

Information Culture

Determines how information is used and how it is improved and shared.

How mature is the information culture that uses the BI products?

A) Nu use of information.
B) Information is used for individual objectives.
C) Information is used for departmental objectives.
D) Information is used for enterprise objectives, to improve information quality (to produce new useful information products) on a project base.
E) Information is used for enterprise objectives, to improve information quality constantly and to improve collaboration and interdependency between departments on a project base.
F) Information is used for enterprise objectives, to improve collaboration and interdependency between departments constantly.
G) Information is used for enterprise objectives, to come up with new ideas to improve strategy constantly.

Chief level management understanding the importance of data-integrity

Determines if C-level management understands the importance of a high level of data–integrity.

To what degree does C-level management understand the importance of the data-integrity?

A) No understanding.
B) Limited corporate management buy-in to the data integrity.
C) Receive executive and management approval to improve the data.
D) Procedures help the enterprise to achieve the highest levels of data integrity.

Training

Refers to education and communication regarding BI initiatives.

What is the highest degree at which the BI users are trained to derive value from the BI environment?

A) No training
B) Company develops skills and knowledge with extern-training programs.
C) Selected group of employees gain BI skills and knowledge through formal intern training
D) BI skill and knowledge -training programs are available within the company through email and portal.
E) Comprehensive training plan program is scheduled and organized. All level of employee has access to the training.

Processes

Service level management

Service level management ensures that service level agreements are met, by continual monitoring and reviewing.

To what extent are the service level agreements (SLAs) managed for the BI solution?

A) No documentation of service level agreements.
B) Customer and suppliers service needs are documented in an ad-hoc way.
C) Some of the customer's needs are documented and formalized in SLAs by making use of a standardized procedure.
D) All the customer's needs are documented and formalized in SLAs by making use of a standardized procedure.
E) SLA reviewed with the customer on periodic and event-driven base.
F) Actual service delivery is continuously monitored and evaluated for continuously improvement.

Change management

Change management ensures that standard methods and procedures are used to handle changes as soon as possible and in an efficient way.

To what extend are changes managed for the BI solution?

A) Change request are made and solved in an ad-hoc manner. No alignment between information system and BI solution
B) A change-management system is used for storing the request for change. No alignment between information system and BI solution
C) A standard procedure is used for approving, verifying, prioritizing and scheduling changes. Changes in the information system are aligned with changes in the BI solution.
D) Standard reports concerning the change status are regularly produced for all the involved teams. Changes in the information system are aligned with changes in the BI solution.
E) Trends and statistics regarding change occurrences, success rates and customer satisfaction and value perception of the services provided to them are analyzed. Changes in the information system are aligned with changes in the BI solution.

Incident management

Incident management refers to the activities of an organization that identify analyze and correct hazards to prevent future re-occurrence.

To what degree are incidents managed for the BI solution?

A) Ad-hoc incident management, no specialized ticket handling system or service desk.
B) A ticket handling system is used.
C) A service desk is available that uses the ticket handling system. Incidents assessments and classification is done following a standard procedure.
D) An incident management database is established, standard reports are regularly produced.
E) Trends and statistics regarding incident occurrences, success rates and customer satisfaction and value perception of the services provided to them are analyzed.

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Release management refers to the process of managing releases from development stage to the actual release. Release management ensures the use of high quality software and hardware, and less implementation.

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B) Ad-hoc releases, no release naming and numbering conventions
C) Release naming and numbering conventions.
D) Release management is documented and done following a standard procedure.
E) Standard reports concerning release management.
F) Release management trend analysis.

Resource management

The purpose of resource management is to maintain control of the necessary hardware and software resources, which is needed to deliver the agreed BI solution/product service level agreements.

To what degree are resources for the BI solution been managed?

A) No resource management.
B) Ad-Hoc resources management activities
C) Resource management by following some procedures
D) Resource management following documented and standardized procedures
E) There are reports about the performance of the resources.
F) Trends in the performances are analyzed.

Availability management

Availability management is responsible for ensuring application systems to be up- to -date and available for use according to the conditions of the service level agreements.

To what extent is availability been managed for the BI solution/products?

A) No availability management.
B) Ad-hoc availability management.
C) Availability management for a specific group of people.
D) Availability management for the whole organization.
E) Risk assessment to determine the critical elements and possible problems.
F) Availability management, trend analysis and planning to ensure that all elements are available for the agreed service level targets.

Knowledge management

The primary purpose of knowledge management is to improve efficiency by reducing the need to rediscover knowledge.

To what degree is knowledge about BI managed?

A) Knowledge is documented, gathered or shared.
B) Ad-hoc knowledge gathering and sharing
C) Organized knowledge sharing through written documentation and technology and also through training and mentoring programs.
D) Knowledge management is important to top level management. Knowledge is created and shared through brainstorming, training and mentoring programs
E) Central business unit knowledge management; quantitative knowledge management control and periodic knowledge gap analysis
F) Continuously improving inter-organizational knowledge sharing. Knowledge sharing is rewarded.

Data management

Data governance provides for enterprise-wide data governance a body, a policy, a set of processes, standards, controls, and an execution plan for managing the data.

To what extent is quality of data managed?

A) No quality management activities
B) Ad-hoc quality management activities, ETL-based cleansing
C) Preventive measures are in place to ensure high-quality data, documentation about data management policies.
D) Robust data quality system is in place, standards and policies are enforced, and data quality problems are fixed at the source.
E) Data management groups operate across the hospital, data quality audits and data metrics to give insight into improvement.

Evaluation of the BI solution

Evaluating/testing can be stated as the process of validating and verifying that a product meets the requirements that guided its design and development, that the product works as expected and that the product satisfies the needs of stakeholders

To what degree is the BI solution been tested?

A) No tests.
B) Only unit tests,
C) Unit tests, Integration tests and system tests take place.
D) Unit tests, integration tests, system and acceptance testing takes place.
E) Unit tests, integration tests, system tests, acceptance tests and regression tests takes place.

To what degree are the BI solution tests documented and standardized?

A) No documentation or standardization
B) No documentation, but some of the tests are standardized.
C) Some tests are standardized and documented.
D) All tests are standardized and documented.

To what degree are the BI requirements been evaluated?

A) The technical and functional requirements are not tested.
B) The technical requirements of the BI product are tested by the BI developers.
C) The technical and functional requirements of the BI product are tested by the BI developers.
D) The technical requirements are tested by the BI product developers and the functional requirements of the BI product are tested by BI developers and the key-users.
E) The technical requirements are tested by the BI product developers and functional requirements of the BI product are tested by BI developers, key-users and/or care managers (BI product user).

To what degree is the BI requirements evaluation method been documented or standardized?

A) No documentation or standardization
B) No documentation, but some of the tests are standardized.
C) Some tests are standardized and documented.
D) All tests are standardized and documented.

Technology

ETL

An ETL tool is responsible for data transfer, from operational or transaction systems to data warehouses

What type of data source supports the BI solution at the highest level (in which option c is the highest level)?

A) No support.
B) Operational databases
C) CSV files
D) Unstructured data sources.

What is the highest maturity level that applies to the ETL that is used to transfer data into the data warehouse?

A) No ETL.
B) Hand-coded ETL
C) Hand-coded ETL and some standard scripts
D) Standardized automated ETL tool.
E) Optimized ETL tool, with real-time capabilities.

To what degree is the ETL monitored?

A) No monitoring.
B) Simple monitoring*
C) Manual restart and recovery system, simple monitoring, and a start in advanced monitoring**.
D) Manual and Automatic restart and recovery system, simple monitoring, and advanced monitoring.
E) Automatic restart and recovery system, advanced monitoring, and real-time monitoring

*Simple monitoring: statistics regarding ETL execution such as pending, running, completed and suspended jobs; MBs processed per second; summaries of errors
**Advanced monitoring: statistics on infrastructure performance like CPU usage, memory allocation, database performance, server utilization during ETL; job scheduler; time or event based ETL execution, events notification, data lineage and analyzer systems)

BI solution architecture

BI solution architecture refers to architecture in which the data is stored.

How is the data in the current BI solution stored?

A) Desktop data marts (EXCEL), no DWH architecture.
B) Multiple independent data marts.
C) Multiple independent data warehouses.
D) One centralized data warehouse which contains data from different applications.
E) One centralized data warehouse with multiple dependent data marts, which contains structured data.
F) A centralized data warehouse with multiple data marts, which contains structured and unstructured data.

Data model levels

Data model refers to the objects (of a certain subject area) represented in a BI solution together with their properties and relationships. The conceptual data model level lays out business entities and their relationships. The logical data model level defines detailed attributes of business entities. The physical data model provides for the actual implementation of the logical model.

To what degree are the levels of the data models defined?

A) No levels designed at all.
B) Logical and physical levels designed for some data models.
C) Logical and physical levels designed for all data models. Solution-dependent standards.
D) Logical, physical and conceptual levels designed for some data models. Enterprise wide standards.
E) Logical, physical and conceptual levels designed for all data models. Enterprise wide standards.

Integration of data

Integration of data involves combining data residing in different sources and providing users with a unified view of these data. Data integration is required to process data into information.

To what degree is the data integrated?

A) No integration between or within subject areas
B) Integration within the same subject area
C) Integration across subject areas and business unit solutions.
D) Data is stored in an integrated IT system.

To what degree is the data synchronized?

A) No synchronization between data models.
B) Manual synchronization between some of the data models.
C) Manual and automatic synchronization between data models.
D) Automatic synchronization of all data models.

Data availability

Data availability determines if data is available when needed and if there are no constraints

How often is the data warehouse updated?

A) Quarterly update
B) Monthly update
C) Weekly update
D) Daily update
E) Real-time

To what degree is the data available?

A) Systems constraints
B) Data is available when it is provided.
C) Data is available when it is needed (online) at a desktop.
D) Data is available to the right person at the right time in the right place (at a tablet).

Data granularity

Data granularity refers to the size in which details about data fields available.

What is the level of the granularity of the fact tables that are needed?

A) No details.
B) The data is summarized
C) The data is aggregated
D) All fact tables had their granularity at the lowest level possible.

Environments

Refers to the environments that are available to set up a BI product. Development, testing, acceptance and production environments are used for different purposes to support the development phases.

To what degree is there a separation between the development, test, acceptance and deployment environments?

A) No separation
B) Separate environments with manual transfer.
C) Separate environments with manual transfer and automatic.
D) Separated environments with automatic transfer.

To what degree is IT infrastructure in the health institute specialized for a BI solution?

A) No specialization, desktop platform.
B) Shared OLTP systems and BI solution environment.
C) Separated OLTP systems and BI solution environment, manual transfer.
D) Separated OLTP systems and BI solution environment, automated transfer.
E) Separated servers for OLTP, BI solution, and ETL processes. Automated transfer.

Meta-data

Meta data is an essential part of the BI strategy as metadata explains how, why, and where the data can be found, retrieved, stored and used in an information management system.

To what degree is the meta-data repository accessible?

A) There is no meta-data
B) There is meta-data, however the meta-data is not integrated.
C) In each tool there is a centralized meta-data repository, but they are still not integrated.
D) There is a central up-to-date meta-data repository
E) The central up-to-date meta data repository is accessible via the web.

Data quality

The state of completeness, validity, consistency, traceability, and accuracy that makes data appropriate for a specific use.

Data completeness: the extent to which data is not missing and is sufficient breadth and depth for the task at hand.

What is the level of data completeness?

A) Data is incomplete
B) Some of the data is complete
C) All data is complete

Data validity: is the process of ensuring that a program operates on clean, correct and useful data. It uses routines, often called "validation rules" "validation constraints" or "check routines", that check for correctness, reasonableness, and security of data that are input to the system. Reasonableness of data means that numeric data are all digits; dates have valid month, day and year and; and the spelling of names is proper.

What is the level of data validity?

A) Data is not validated
B) Some of the data is validated, correct and reasonable
C) All data is correct and reasonable

Data consistency: means that data across the enterprise should be in synchronized with each other.

What is the level of data consistency?

A) Data is inconsistent
B) Some of the data is consistent
C) All data is consistent

Data traceability: allows the lifecycle of data to track all access and changes to the data. It helps an enterprise demonstrate transparency, compliance and adherence to regulations. Data traceability, along with data compliance, can be considered part of a data audit process.

What is the level of data traceability?

A) Data is not traceable
B) Some of the data is traceable
C) All data is traceable

Data accuracy: the degree to which data correctly reflects the real world object or an event being described.

What is the level of data accuracy?

A) Data is not accurate
B) Some of the data is accurate
C) All data is accurate

Data access security

The data access security refers to the security that is necessary to prevent that unauthorized people can access valuable information.

How mature is the BI solution security that is implemented to prevent unauthorized people accessing valuable information?

A) There is no security implemented, everybody can access the data.
B) Authentication security, data can be accessed by a group a BI users by using one username and password.
C) Authentication security, data can be accessed by one user by using a username and password.
D) Independent authorization for each tool. A user with a specific role can get permission to access the data.
E) Integrated hospital wide security level with authorization at role level.

BI analyze tool

The BI analyze tool refers to how advanced the BI tool is that is used to analyze data.

How mature is the BI analyze tool that is used?

A) Spreadsheets are used as analyze tool.
B) A basic analyze tool of enterprise resource planning (ERP)-vendor with which ad hoc queries can be written, used for e.g. trend analysis.
C) A basic analyze tool of ERP-vendor with predefined queries and historical comparison, used for e.g. trend analysis.
D) Advanced analytic tool, which also supports ad-hoc complex calculations at report level.
E) Advanced analytic tool, for predictive analysis.

BI products

The BI products refers to how advanced the BI reports are that is used to visualize data.

How mature is are the BI reports?

A) Spreadsheets, parameter driven reports.
B) Ad-hoc reporting and basic dashboard and scorecards
C) Web-based interactive reports and dashboards with adjustable parameters
D) Integrated reporting and balanced dashboard, scorecards and KPI's
E) Reports for frontline decision making (real-time). Operational event driven support system.

Appendix E: Final Maturity Matrix

Maturity scale Sub-Focus areas	0	1	2	3	4	5	6	7	8	9
BI strategy		A		B		C		D		
BI strategy documentation			A			B				
BI governance				A	B		C		D	E
Business rule documentation		A			B			C		
Business rule availability			A			B			C	
Business rule usage				A		B		C		D
Business rule norm			A				B			
BI solution requirement documentation				A		B		C		D
BI solution requirement availability					A	B	C	D	E	F
BI solution requirement method		A		B		C		D		E
BI solution used in care processes					A	B	C	D	E	
Business benefits of BI solution		A			B	C		D		E
Manual vs. automatic activities		A		B		C		D		
Information network		A				B				C
BI users		A			B			C		
BI developers		A			B			C		
BI developers characteristics			A		B		C		D	E
Chief level involvement		A		B		C		D		E
BI developers expertise		A			B			C		
Information culture		A		B		C		D	E	F
Chief level		A			B			C		

understand importance of data-integrity										
Training		A		B		C		D		
Service level management for BI solution					A	B	C	D	E	
Change management for BI solution					A	B	C	D	E	
Incident management for BI solution					A	B	C	D	E	
Release management for BI solution					A	B	C	D	E	
Resource management		A		B		C		D		E
Availability management BI solution					A	B	C	D	E	
Availability management BI product						A	B	C	D	E
Knowledge management			A		B		C		D	E
Data management				A		B		C		D
Testing BI solution				A		B		C		D
Documentation of testing BI solution					A		B		C	
Evaluation of the BI requirements					A		B		C	D
Documentation of BI requirements evaluation method						A	B	C		
Data source support			A			B		C		
ETL		A		B		C		D		
Monitoring of ETL			A		B		C		D	
BI solution architecture			A	B	C	D	E	F		
Data model					A		B		C	

levels										
Integration						A	B	C	D	
Synchronization						A		B		C
Data availability				A		B		C		D
Data Updates				A	B	C	D	E		
Data granularity				A		B		C		
IT infrastructure				A	B	C	D	E		
Environments					A		B		C	
Meta data					A	B	C	D		
Data completeness				A					B	
Data validity				A					B	
Data consistency				A					B	
Data traceability				A					B	
Data accuracy				A					B	
Data access security for BI solution			A		B		C		D	
BI analyze tool				A	B	C	D	E		
BI products				A	B	C	D	E		
BI products understanding					A	B	C	D		
Monitoring BI usage						A		B		C

Appendix F: Expert interview

A BI solution is a database used for reporting and data analysis. A BI solution can be used to access the quality of care processes. By assessing the quality of care processes it is possible to improve the quality of care processes. To do so, it is important that a mature BI environment support the assessment. The goal of evolving to a higher BI environment maturity is to improve the BI environment in which the BI solution supports the assessment of quality of care processes. Improving the BI environment can contribute in a better assessment of quality of care processes. If the BI solution is mature and data is used by the right people in the right way and in alignment with the quality of care goals of the academic hospital it will return more relevant and accurate information about the current status of quality of care processes. To measure the maturity of a BI environment in an academic hospital a questionnaire is used. The questionnaire is also divided into four main focus areas: Business Alignment, Service processes, Technology and People. To determine the maturity level, each focus area is divided in multiple sub-focus area. For each sub-focus area one or more questions need to be answered to determine the maturity level. The questionnaire exists out of 57 questions. For each question the respondent need to choose out of the given answers. The answers represent different maturity levels to determine the maturity of a sub-focus area. Answer 'A' represents the lowest maturity level as the last letter (e.g. 'E') represents the highest maturity level.

1. Could you explain your role in the hospital?

2. Do you think that measuring quality of care is a way to improve quality of care processes?

To determine the maturity of the BI environment in a hospital different sub-focus areas are measured by making use of the questionnaire. For each sub-focus area one or two questions need to be answered.

3. Do you think that the questionnaire covers all aspects of the BI environment in an academic hospital?

4. Do you think that the questions are representative for measuring the sub-focus areas, and if not which changes would you make?

5. Can you explain in your own words were what is meant with each question?

6. Do you think that the answers are representative to determine the maturity of the sub-focus areas, and if not which changes would you make?