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An Analysis of the Process of Colorectal Surgery from an Organizational Perspective in Dutch Hospitals

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Summary

Background The total costs of health care are rising worldwide and become a greater part of the GDP. This can be ascribed to an aging population, higher life expectancy, technological development and a greater need for high care quality by society. Care processes therefore have to be investigated and their relation with efficiency and effectiveness have to be assessed. In the Netherlands colorectal cancer (CRC) is the third most common cancer among males (14%) and the second most common among females (13 %). The demand for colorectal surgery is rising and efficient use of capacity and resources, improving quality and reducing costs is desirable. Different methods to assess efficiency exist in health care. Lean Thinking is a process-based management philosophy to decrease waste and construct a more efficient process design. Leanness is referred to as a quantitative term but what exactly should be quantified is not standardized.

Objective/research question To design and investigate methods to quantify efficiency and process characteristics of the surgical colorectal cancer pathway in Dutch hospitals.

Methods The research was conducted from February until August 2011. An explorative study was used to construct a measuring method to assess efficiency of the CRC surgical care. Different calculation methods and inputs and outputs were investigated. Based on the specific CRC surgical process an efficiency measure was constructed. Interviews, process observations and site visits were part of the study.

Furthermore a mixed method design was used to assess Lean initiatives. First a framework was constructed using a literature review and on-site hospital visits. Relevant data was also available from earlier research. Five hospitals were visited during four days and data was collected using a retrospective (electronic) health record review, semi-structured interviews, and observations.

After construction of the framework, the framework was applied to the collected hospital data to evaluate the usefulness. Besides correlations using a bivariate non-parametric Kendall's tau test with efficiency measures as lead-times and number of hospital visits were analyzed.

Results Various efficiency measurement methods were investigated and a non-parametric calculation method was proposed. Also a first step is done using data available for a data envelopment analysis. Furthermore a framework was constructed for six lean categories, which are; operational focus, autonomous work cell, physical layout, multi-skilled team, pull planning and elimination of waste. In each category different items could be scores in order to get a quantifiable aggregated score per category. When applied to hospital data, differences and similarities between organizational and (design of) process characteristics were found. Furthermore some relations were found after the analysis of which a few are relevant. In further analysis on item-level more relevant relations were found.

Conclusion/discussion Different methods to measure efficiency in health care were found and a selection of methods and measures is proposed. Data Envelopment Analysis is a promising technique that can be used to assess efficiency using multiple inputs and outputs.

Related to the process characteristics, differences between hospitals were found in both lead-times and number of hospital visits, as well the organization and design of the care process were found. The framework can be used as a scorecard to compare hospitals on six domains of process design characteristics. Most important relations that were found were that a multidisciplinary team slows down

the care process, but quality can be high and the scoring high on the scorecard categories “pull planning” and “operational focus” proved a reduction of lead-times. A more detailed correlation analysis revealed that the availability of flow charts in an organization increased the speed of care delivery and the presence of a dedicated colon care nurse does not improve the lead-time and number of hospital visits.

Preface

This report is the result of my research project I performed to obtain my Master of Science degree in Health Sciences at the University of Twente. The research was carried out between February and August 2011.

After four years of studying Technical Medicine, it was time for broadening my horizon and although related to health care, learning completely new things. At the start of this year I had never heard of operations management, health economics, and care pathways, but after a year that felt like a ride in a rollercoaster I learned a lot about our health care system. My main interests are in the field of medical technology, but for this assignment I really wanted to do something new. This assignment helped me to unveil where my interests are and it confirmed that medical technology still draws my attention. Nevertheless I learned a lot, asked a lot of questions and eventually people expected me to answer their questions. This was a welcome transition from layman to a capable student. But by understanding the process better, the more complex it became. I searched and gathered more knowhow, and with this knowledge the problem became even more complicated. From a learners perspective the total process of this research was interesting and it has served as a major learning experience throughout my connected student career as a Technical Medicine intern and graduated Health Scientist. I will start as an intern at the traumatology department of the University Medical Center of Utrecht in September 2011 with a new medical problem to be solved (or more realistic; make steps in the right direction).

This project was completed under the guidance of Wim van Harten and Erwin Hans. I thank my supervisors for their support and discussions. Their advices remain valuable throughout my future study and work. This research was related to the Phd project of Dorine Pluimers and I hope it will not only be related, but my work also contributed to her research.

During this research project I got the opportunity to get insight in various hospitals and their organization of care. The research was focused on the colorectal cancer patient, which allowed me to visit various involved departments and get understanding of their different point of views. I express my gratitude to all specialists, nurses, health care managers and others from the institutions for their time, useful information, critical thinking and hospitality. Furthermore I am grateful to thank Prof. Terry Young and Victor Klemann for providing me their publication about improvement of health care.

I thank my fellow health science students, for working together in our “hok”, organizing the first Easter lunch at the department of HTSR and always standing by for advice, and keeping up the mood.

I further thank my friends. They cheered me up when things did not go as fast or efficient as I would like them to be. Too many to name them all, but I like to point out Remy, Wieke, Anique, Evelien, Daan, Tamar and Mark. In thank in particular Marlies, for being always optimistic, showing her interest, and providing me a boost of moral support. Last but not least I thank my parents for their trust, endless support, advice and of course their sponsorship for this extra year, which I am grateful for.

Martijn van Mourik

Enschede, August 2011

Contents

Chapter 1 Introduction

This report is about an analysis of the processes around colorectal surgery from a health services research point of view. A method to perform a quantitative analysis of efficiency of the colorectal cancer care path is proposed. In addition a scorecard is developed to quantify process improvement initiatives and is tested using hospital data of 18 Dutch hospitals.

In this chapter first a short introduction about the context of this research will be given. Hence the problem is described and the objective and research questions of the study are provided. An outline of the complete report is provided in the last section of this chapter.

1.1 Context

The costs of medical care are rising worldwide. This can be ascribed to an aging population, higher life expectancy, technological development and a greater need for high care quality by a modern society. (Koning, Verver, Heuvel, Bisgaard, & Does, 2006). At the current rate of healthcare expenditure growth, the total healthcare costs will become an undesired amount of gross domestic product (GDP). Research can help to reduce the increase of health care costs for society and enhance quality of care. Improvements are possible by making efficient use of resources and identify best practices. Care processes therefore have to be investigated and their relation with efficiency and efficacy have to be assessed.
A recent press release by PriceWaterhouseCoopers is illustrative for the attention health care costs get. In this release it is stated that the Dutch health care sector should spend less and has to improve care efficiency in order to derive sustainable health care (PriceWaterhouseCoopers, 2011). Furthermore the House of Representatives in the Netherlands and the minister of finance are worried about the cost increase of health care (de Jager, 2011). The Dutch Health Care Performance Report indicated that the annual nominal growth of collective health care expenditures have increased in a rate of 6% to 7% between 2007 and 2009 (Westert, G. P., van den Berg, M.J., de Jong, J.D., Verkleij, 2010). This was mainly due to an increase in health care services provided.
When hospital managers and physicians are provided with meaningful information, they are able to implement corrective action to further improve care delivery and efficiency. At the same time, useful information provided to consumers and purchasers will allow them to make more informed, value-based health care decisions that meet their needs.

1.2 Research description

1.2.1 Problem description

As can be concluded from the introduction the need to measure hospital efficiency and quality, and distillate best practices is necessary in order to deliver efficient care of high quality. Besides the demand for efficient healthcare is increasing, as is the pressure on health care to reduce cost increase of care.

Current measures mostly cover a single department, which is too narrow to be relevant for an individual patient with a certain disease. On the other hand outcomes measured on hospital level, such as infection rates are too broad to be relevant for a single patient. Similarly, costs are calculated for a single department rather than the full care cycle for an individual condition (Porter, 2010).

Lean initiatives are used to improve healthcare and the delivery of high quality care. Although measuring performance is part of the lean principles, most research and literature is focused on techniques and tools to

embed lean in an organization. Less research is done to assess the degree of leanness to track the progress and it lacks an integrated and quantitative score for the leanness level seen over the whole process.

1.2.2 Objective

To construct a method to quantify efficiency of the surgical colorectal cancer care pathway in Dutch hospitals, in order to enable a comparison between different institutions.

In addition, leanness and lean initiatives of the surgical colorectal cancer pathway in Dutch hospitals must be quantified in order to enable a comparison between different institutions and identify best practices in organizing efficient and timely care.

1.2.3 Research question

1. How can efficiency in the colorectal cancer surgical care pathway be measured and compared across hospitals using inputs, outputs and patient related outcomes?

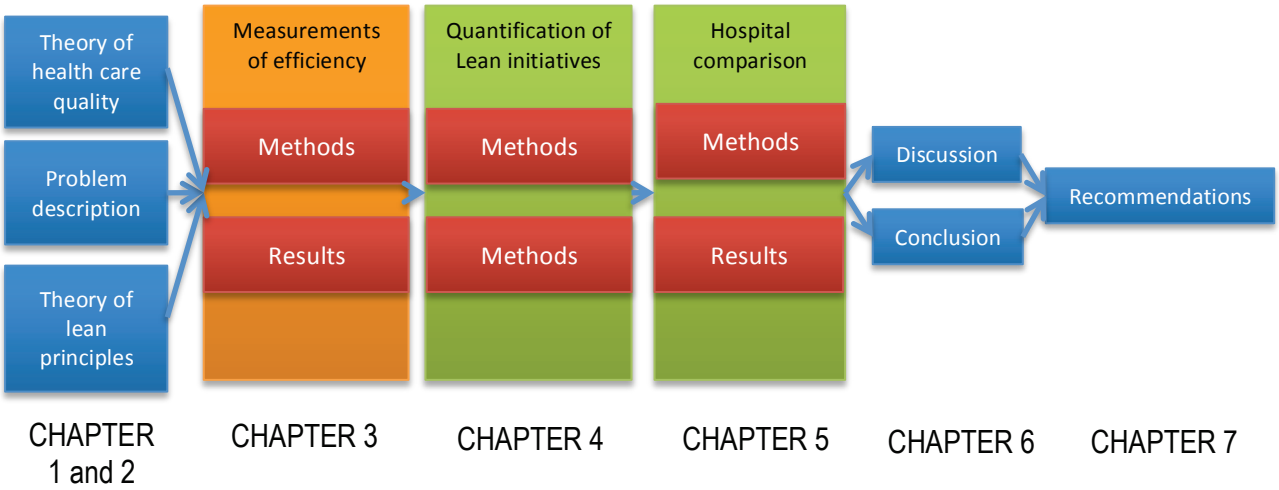
2. How can initiatives in becoming more efficient be quantified and how can it be operationalized for colorectal surgical care?

3. How can the process characteristics framework, initially developed by Van Vliet et al (2011), be adapted to the colorectal cancer care pathway in order to construct a quantifiable framework to determine "leanness" of a colorectal caner care pathway and see relations between lean initiatives and lean outcomes?

4. What are the results when comparing Dutch hospitals on their leanness using the developed framework and which relations can be found between the framework and lead-times and number of hospital visits?

1.3 Outline of the report / research framework

The first chapter of this report indicates our objective and gives an outline of the report. In the second chapter theory of health care quality and performance is provided. Besides theory and an explanation of Lean principles is specified. Chapter 3 focuses on the development of an efficiency measure for the CRC care. Chapter 4 and 5 focus on the implementation of Lean initiatives in Dutch hospitals for CRC care. Hence the report will continue with the discussion and conclusion (chapter 6). Finally recommendations will be given for further research or investigation (chapter 7).



Chapter 2 Theoretical framework

In this chapter the treatment of colorectal cancer is explained, a theoretical background about health care quality and performance is provided, and different management strategies used to improve health care, are explained. This chapter serves as a framework for Chapter 3 (quality and performance) and Chapter 4 (improvement strategies)

2.1 Colorectal cancer

In the Netherlands colorectal cancer (CRC) is the third most common cancer among males (14%) and the second most common among females (13 %). In total around 12.000 persons are diagnosed with CRC every year. In Tabel 1 more actual figures are provided. Due to the aging population, increase in incidence in male patients, and population growth it is expected that 14.000 - 15.000 will be diagnosed with CRC in 2015 (V. E. P. P. Lemmens, 2007). The demand for colorectal surgery is rising and efficient use of capacity, improving quality and reducing costs is desirable.

The therapy can consist of multiple treatments. This can be a curative or non-curative treatment. The treatment of colon cancer and rectal cancer are different and so are therefore the clinical guidelines (van de Velde, van Krieken, de Mulder, & Vermorken, 2005). This will result in a different care process.

Patients with CRC usually have complaints of abdominal pain, change in bowel habit, blood in stools, weakness anemia, weight loss or undefined gastroenterological complaints. These clinical symptoms however only show up

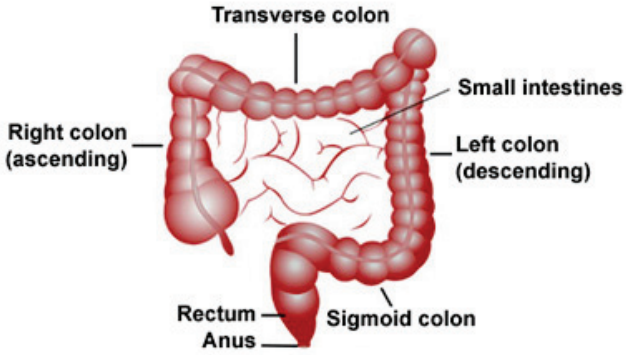


Figure 1. *An overview of the anatomical locations of CRC, from* (Cedars Sinai, 2011)

in a late or advanced stage of the disease. The early-detected cancers through e.g. screening do usually not have these symptoms yet (V. E. P. P. Lemmens, 2007). There is a wide variety of diagnostics that can be performed for the diagnosis and staging such as physical examination or a digital rectal exam. More advanced and complex diagnostics are sigmoidoscopy, colonoscopy (with both the ability to take a biopsy in order to get tissue to be analyzed by the pathologist), double-contrast barium enema, blood tests (hemoglobin and biological tumor markers), ultrasonography (of the abdomen and endorectal), computed tomography (CT), virtual endoscopy (CT-colonography), magnetic resonance imaging (MRI), chest X-ray (X-thorax) or positron emission tomography (PET-scan).

The cancer clinical practice guidelines in the Netherlands are published at www.oncoline.nl and one can find there for almost every common type of cancer the latest treatment and diagnostic paths that are advised by the Dutch Association of Comprehensive Cancer Centres (ACCC). Furthermore it facilitates the development, implementation and evaluation of guidelines for oncological and palliative care (Association of Comprehensive Cancer Centers - The Netherlands, 2011). The guidelines for colorectal cancer are written according to the specific location of the tumor, which could be roughly in the colon or in the rectum. The colon could be divided into left and right colon cancer since the treatment will differ. However the total process of diagnosing, staging and operation planning from organizational perspective will not differ for the different locations of the colon carcinomas. This was based on the clinical guidelines and verified during interviews with GE-surgeons.

In the Netherlands colorectal surgery is currently performed in almost every hospital. The Dutch Colorectal Cancer Group is a collaboration between medical disciplines that are relevant for the diagnosis and treatment of CRC. These are the specialists of surgical oncology, radiotherapy, medical oncology, pathology, radiology and gastroenterology (DCCG, 2008). They are involved in the Dutch Surgical Colorectal Audit, an audit to compare the results of CRC care in different hospitals in the Netherlands, which was initiated by colorectal surgeons. This audit was initiated following predecessors abroad such as national registries used in the UK or Scandinavian countries. This audit makes it possible to compare quality, identify learning points and is a first step in making care transparent.

2.1.1 Expected growth of care demand

In 2009 the Dutch health council advised the government to implement a colon cancer-screening program for people aged over 55. The reason is the evidence based proven decrease in mortality and morbidity when the malignancy or its predecessors (polyps) are detected. As CRC is relatively late detected and symptoms mostly show up when the disease is already in an advanced stage, screening will detect early CRC's. It also turned out that a screening program could be run cost-effectively (Gezondheidsraad, 2009). It is therefore likely that in the near future the screening for CRC will become a routine. The detection rate will therefore increase and related with the early detection of CRC the treatment will be started in an earlier phase of the disease.

Table 1: The Incidence of CRC in 2008 in the Netherlands (IKC-net, 2011)

Type of cancer	All ages Total
Invasive	
Colon, Sigmoid & Rectum	12117
Colon	8131
Rectum	3501
Recto sigmoid	485
Non-invasive / in situ	
Colon, Sigmoid & Rectum	300
Colon	192
Rectum	96
Recto sigmoid	12

In 2011 the minister of Health, Welfare and Sports announced that a national screening program for colorectal cancer is likely to start in 2013. The effects of this screening will be that there will be a rapid rise in patients needs to be treated since a lot of 'hidden' cancers will be found (Schippers, 2011). Eventually this incidence will drop, but still more patients than in 2011 will be operated but now in an earlier stage of the cancer at a lower age. This means that patients will need less extensive treatments, less comorbidity and less acute or urgent patients since the cancer is already detected before real complaints are present. The total number of patients diagnosed will however increase and so will the demand of surgical oncological care.

CRC is an accumulation of cancers in the colon, sigmoid and rectum. In broader terms we can distinguish colon cancer and rectum cancer. The clinical practice guidelines are different on a few points, which will be described in the next section.

2.1.2 Patient types

A clear distinction can be made between colon cancer (CC) and rectum carcinoma (RC) patients. In case of RC the patients often need additional treatment besides surgery in the form of preoperative radiotherapy or chemotherapy in order to decrease the size of the tumor before surgical resection. During the dissemination or additional diagnostics metastases can be found. In this case the patients will follow a different than standard pathway, based on the location and staging of the tumor.

Furthermore there is a patient group that is diagnosed very late and the tumor is already causing severe symptoms such as blocking the intestine or causing a perforation. These patients are admitted at the emergency department or seen at the outpatient clinic as urgent or acute patients.

To summarize, three main patient groups can be identified in the CRC care:

1. Colon cancer patients for elective (plan able) surgery
2. Rectum cancer patients for elective surgery
3. Acute or urgent patients

2.1.3 Treatment and diagnosis

The treatment of colorectal cancer is based on cancer clinical practice guidelines published by Oncoline and is a product of the Dutch Association of Comprehensive Cancer Centers (ACCC)(Association of Comprehensive Cancer Centers - The Netherlands, 2011). The focus of this research will be on the elective surgery since most patients fall in the elective surgery path. Besides the variation and complexity is less.

Based on the guidelines and by interviewing six GE-surgeons the process can be summarized in different phases or activities, however variations occur due to differences in types of patients, tumor localization and hospital preferences.

1. Patient has complaints and visits the general practitioner (GP).
2. GP decides on anamneses and physical examination if there is reason to suspect pathology. If not, the path ends here, if pathology is suspected, the GP will refer to the gastroenterologist or internist to perform a sigmoidoscopy or colonoscopy.
3. The gastroenterologist/internist will perform the endoscopy and in case of a suspected malignancy a biopsy will be taken that will be sent for examination to the pathologist. Virtual performed colonography by the radiologist is nowadays also a possibility, however because it is a relatively novel method to screen for malignancies and the inability to take a biopsy, it is not widely used. Only in cases when a full colonoscopy is not possible due to for example an obstruction by the tumor.
4. Hence the patient will be referred to the surgical outpatient clinic. In the meantime dissemination diagnostics such as abdominal-CT, thorax-CT, abdominal/pelvis-MRI (for rectal carcinoma), will be performed to stage the disease and find metastasis.
5. If all additional diagnostics are performed the results will be discussed in a preoperative Multi Disciplinary Team – meeting (MDT) to set up an individual treatment plan in cooperation with several disciplines such as the surgeon, oncologist, radiologist, radiotherapist, gastroenterologist and specialized nurse practitioners. In case of colon cancer this is not obliged to do preoperatively. For rectum cancer an obligatory MDT is required.

6. Hence the preoperative preparations can be done. The proposed treatment will be discussed with the patient during an outpatient clinic visit. For all patients a preoperative screening by the anesthesiologist will be conducted. The treatment differs per tumor type. For colon cancer usually no preoperative treatment is advised. For rectum cancer the treatment can vary from preoperative radiotherapy (short: 1 week (5 x 5 Gy.) , long: several weeks (45-50 Gy.) with a possible combination with preoperative chemotherapy. The decision between no, short or long radiotherapy is based on the pathology report and by assessing possible complications in relation with the preference by the patient.
7. After the preparations the actual surgery will take place and the patient will be admitted.
8. After surgery the patient will stay for several days at a nursing ward. Sometimes patients first stay at the ICU if no appropriate care can be given at the nursing ward.
9. Discharge of patient from hospital. Sometimes a postoperative MDT-meeting is done, but this can also take place after the discharge of the patient. In this MDT-meeting the final treatment plan and follow-up will be constructed. Additional treatment such as radiotherapy and/or chemotherapy will be discussed.

Metastases are mostly treated after the surgical resection and are therefore not included in this research to focus on colorectal surgery and the preoperative phase itself.

In the colorectal surgical care five different phases can be identified, which can be outpatient or inpatient. For parts of the process, which are in the outpatient, phase the patient is not admitted. The inpatient phases are all processes, which are done during the time the patient is admitted.

Outpatient
- **Diagnostic phase**, which is the time from the first visit to the hospital, which could be a colonoscopy or a visit to the outpatient clinic

Outpatient
- **Staging phase,** in this phase additional diagnostics are required to stage the disease, which is based on the possible metastasis, until the MDT meeting.

Outpatient
- **Preoperative phase**, which is the time between the decision which treatment will be provided and the treatment itself. In this phase a visit to the preoperative screening outpatient clinic is scheduled and besides additional visits to the colon care nurse or other medical professionals have to be done.

Inpatient
- **Admission phase,** which is the time the patient stays in the hospital from day of surgery until discharge. Actually in this patient group most patient are admitted one day before surgery but to reduce complexity length-of-stay (LoS) was taken as the time between surgery and discharge.

Outpatient
- **Follow-up phase,** the phase after surgery where adjuvant therapies can be given and patient remains under surveillance of their doctor

2.2 Health care quality: attributes

In this part several concepts and attributes of health care quality will be defined and explained in their relation with the colorectal care.

Healthcare quality and transparency becomes increasingly important in the world. Avedis Donabedian is one of the pioneers in understanding healthcare quality and in his vision there will never be a single comprehensive criterion to measure quality of medical care and quality is more a reflection of values and goals current in the medical system (Donabedian, 2005).

To measure quality of care Donabedian introduced the terms structure, process and outcome (Donabedian, 1988; E. R. Ransom, Joshi, Nash, & S. B. Ransom, 2008). The outcomes of medical care are frequently used as indicators for medical care quality. Examples are five-years survival, mortality rates or re-interventions. Donabedian questions using only outcomes to describe health care quality. One of the reasons for this is the relevance of the chosen outcome to assess the delivered care. A second argument is that outcome is influenced by multiple factors and not only by the quality of care provided. Furthermore outcomes measurement does not provide us with information about the nature and place of deficiencies or strengths to which the outcome might be attributed (Donabedian, 2005). To measure if the proper medical care is applied one can examine the process itself rather than its outcomes. The criteria should be based on the appropriateness and technical competence of care. However these measures are less clear than outcome variables and much attention should be paid to select the proper process variables from an almost infinite range since in a care process there are numerous process steps to analyze. A third approach Donabedian describes is to study the settings in which health care is provided. This is referred to as the structure domain and includes the adequacy of facilities and equipment, qualifications of staff. The assumption is made that when there is an appropriate structure, good medical care will follow. We see structure variables as the system properties of a care provider. An example is the presence of a radiotherapy center or a close cooperation. An example of a process indicator is the number of patients that are treated within a certain time in this radiotherapy center. An outcome example is the amount of tumor size shrinkage or the gained quality of life.

Although Donabedian was already describing these attributes in 1966 the modern thrive and focus on health care quality was boosted after publication of three major reports around 2000[1] a proven deficiency in healthcare quality became visible and the discussion of closing this gap started in the United States (E. R. Ransom et al., 2008).

The Institute of Medicine comes with a six-dimensional aim for quality of care and a high performing health care system which are summarized in an article by Berwick (Berwick, 2002):

- Safe: *"Care should be as safe for patients in healthcare facilities as in their homes"*
- Effective: *"The science and evidence behind healthcare should be applied and serve as the standard in the delivery of care."*
- Efficient: *"Care and service should be cost effective, and waste should be removed from the system."*
- Timely: *"Patients should experience no waits or delays in receiving care and service."*
- Patient centered: *"The system of care should resolve around the patient, respect patient preferences, and put the patient in control."*
- Equitable: *"Unequal treatment should be a fact of the past, disparities in care should be eradicated."*

In 2003 the Dutch minister of Health, Welfare and Sport requested from experts outside the health care setting to give advice about the Dutch health care regarding safety (Shell, Rein Willems), logistics (TPG, Peter Bakker), accountability (AEGON, Johan van der Werf) and innovation (KPN, Ad Scheepsbouwer).

In terms of efficiency and efficacy the report by Peter Bakker served as a catalyst for hospitals, government and the involved staff to focus more on patient flow, care logistics and quality of care. In order to do so the health care industry should focus more on care paths, standardizing care and make care processes transparent. Bakker identified three core logistic streams within health care, namely patient logistics, goods logistics and pharma

[1] A.) "The Urgent Need to Improve Health Care Quality" , IOM National Roundtable on Health Care Quality report (Chassin and Galvin 1998)
B.) To Err is Human (Kohn, Corrigan and Donaldson 2000)
c.) Crossing the Quality Chasm (IOM 2001)

logistics. In the scope of this report patient logistics is most important. Besides this groups accounts for most costs. Bakker defines patient logistics, as the total trajectory the patient has to deal with according to a specific care demand.

2.2.1 Units of analysis

When analyzing efficiency the boundaries of the analysis should be clearly defined. The general term Decision making units (DMU) is to indicate an institute, in this case the hospital, involved in the transformation of inputs into outputs. The term Health DMU used is used by the WHO (World Health Organization, n d). Besides it must have an organizing function to have influence on the production process since the DMU is considered to have control over factors that are influencing the performance. Measurement should be done in order to improve care provided by hospitals and based on decisions they make; a certain set of inputs will produce a certain sets of outputs. Furthermore the DMU sets the objectives.

DMU's should be comparable to each other. It is obvious that it is not possible to compare a general practitioner with an emergency department. The choice of units to be compared is that they are pursuing to deliver the same set of health care outputs, which in this care would be a surgical treatment for CRC. Choosing the proper DMU is not always sincere especially in complex care situations as the colorectal care. Multiple departments are involved in the care process and one department "buys in" outputs from other departments that serve as an input for the own department. There is a difference in integration of these departments between hospitals. More integration would lead to a focused factory, in which all care is dedicated to a specific disease.

When not analyzing and comparing a certain department such as the surgery or radiology department, but analyzing a complete care process with joint production.

According to Jacobs et al. (2011) larger aggregations of teams are more appropriate for the analysis of a care process because of the joint production and resource sharing, because it may be difficult to determine accurately what proportion of the shared input is related to each team (Jacobs, Smith, & Street, 2011).

2.2.2 Efficiency

According to the report "Crossing the Quality Chasm" in 2001 by the Institute of Medicine, efficiency is one of the key principles of quality of care and should therefore be defined and measured (E. R. Ransom et al., 2008). It is however defined as "avoiding waste", which is not a real quantitative measure. Defining efficiency is limited to a working definition but no uniform definition is yet available. When asking 6 gastro-intestinal surgeons three of them answered on the question " what does efficiency in healthcare mean for the colorectal pathway" that appropriate care of high quality should be delivered at a minimum of costs. The other three GE-surgeons answered that the care should be delivered fast, with as less diagnostics, delay and patient visits to the hospital as possible. When asking more providers about their thoughts about efficiency it is even said that a care process is efficient if care is properly adapted to the individual needs for the patient. This illustrates that among surgeons and health care providers there is no consensus regarding efficiency. It seems that efficiency is often confused with timeliness (care should be without unnecessary delay) and patient centeredness.

Efficiency refers to how well resources are used in achieving a given result. This can have a financial focus or more in general, a resource focus. Time and personnel are examples of resources. Inefficient care is related with waste. According to Donabedian, wasteful care is directly harmful to health or indirectly harmful by use up resources, which could be used to provide more useful care (Donabedian, 1988).

From a more operations management or business administration perspective efficiency is defined as how much output can be achieved with a certain sets of inputs. A hospital can become more efficient by decreasing the level

of inputs to create the same output or increase the level of outputs by remaining the same level of inputs. More economical would be to get maximum value out of minimal economical inputs.

Efficiency is a percentage that aggregates the relation between inputs used to deliver a certain output. The transforming process (or the throughput) will together with resources transform will transform the inputs into an output. According to Ozcan et al. (2008) there is no clear difference between productivity and efficiency. We do not agree since when comparing two hospitals on both efficiency and productivity a hospital with a high productivity is not necessarily efficient.

A definition of efficiency in operations management perspective is:

$$Efficieny = \frac{actual\ output}{effective\ capacity}$$

The actual output is compared with the effective capacity where effective capacity is the designed capacity minus the loss due to maintenance, market and technical demands (Slack, Chambers, & Johnston, 2007). This is a ratio, however using the formula above it is assumed that both the actual output and effective capacity have the same unit. This is not always needed or possible for ratio analysis. Therefore other ratio can also be calculated. It uses one input (such as costs, number of physicians) and one output (number of patients treated, number of outpatient clinic appointments).

The World Health Organization (WHO) constructed a performance assessment framework for hospitals. This framework focused on six categories, one of them being efficiency. According to this framework efficiency in hospitals is related to a hospital's optimal use of inputs to yield maximal outputs, given its available resources (Veillard et al., 2005). Also sub dimensions for efficiency were defined: appropriateness of services, input related to outputs of care and the use of available technology for best care. According to this study, efficiency could be analyzed using a corresponding organizational performance theory; an internal resource model and resource acquisition model.

Something is efficient according to the discipline of economics if the only way to make someone better off is to make someone else worse off (Romley et al., 2009). This is also described as Pareto-Koopmans efficiency (Zhu, 2009) or social efficiency (Greenberg & Campion, 2006). Since the care for colorectal cancer patients is not organized in focused factories one should deal with the shared use of resources for the CRC care.

Romley (2009) describes four important points for the assessment of efficiency from a practitioner's point of view. This are the importance of defining efficiency, the field of health economics can offer a framework for efficiency measurement, the perspective of the evaluator should be understood and health care inputs and outputs must be identified, and if there is a large variance in quality, a measure without adjustment for quality could lead to unintended consequences (Romley et al., 2009). Their aim of efficiency measures is to improve the use of health care resources. When implementing and assessing efficiency measures one should define the perspective of the evaluator, and health care inputs and outputs must be identified. Besides the assessment of quality should not be forgotten since if there if a substantial variation of quality is present in particular context efficiency should be related to this. Quality of care is closely related to efficacy. Efficiency and efficacy are closely related since very effective treatment may not be efficient (overuse of resources) or a very efficient treatment may not be effective (underuse of resources).

2.2.3 Productivity

Closely related to efficiency is productivity. Productivity is defined by Slack et al. as the "ration of what is produced by an operation or process to what is required to produce it, that is, the output from the operation

divided by the input to the operation. This is also described by (Saari, 2006). As already mentioned confusion can exist about the difference between efficiency and productivity. Productivity is defined as the ratio of the output(s) to the input(s) a DMU produces.

$$Total\ productivity = \frac{output\ quantity}{input\ quantity}$$

Sometimes productivity is used as a measure for efficiency and not difference is made in core definition (Bruce Hollingsworth & Peacock, 2008; Ozcan, 2008).

2.2.4 Effectiveness

Effective care is defined by the Institute of Medicine as how well evidence-based practices are followed (Berwick, 2002). Another definition is that a "clinical intervention or treatment is efficacious if it has been shown to produce a given outcome reliably when other, potentially confounding factors are held constant" (E. R. Ransom et al., 2008). Effictiveness is the relation between output and outcomes. Output can be a diagnosis or the provision of a treatment. When this is efficacious, there is high effictiveness and there is an increase in health benefits. Effectiveness is different from efficacy. Efficacy is the relation between output and outcome in a controlled-setting (such as a randomized controlled trial), whereas the effectiveness is the effect the treatment has in real life.

2.2.5 Performance

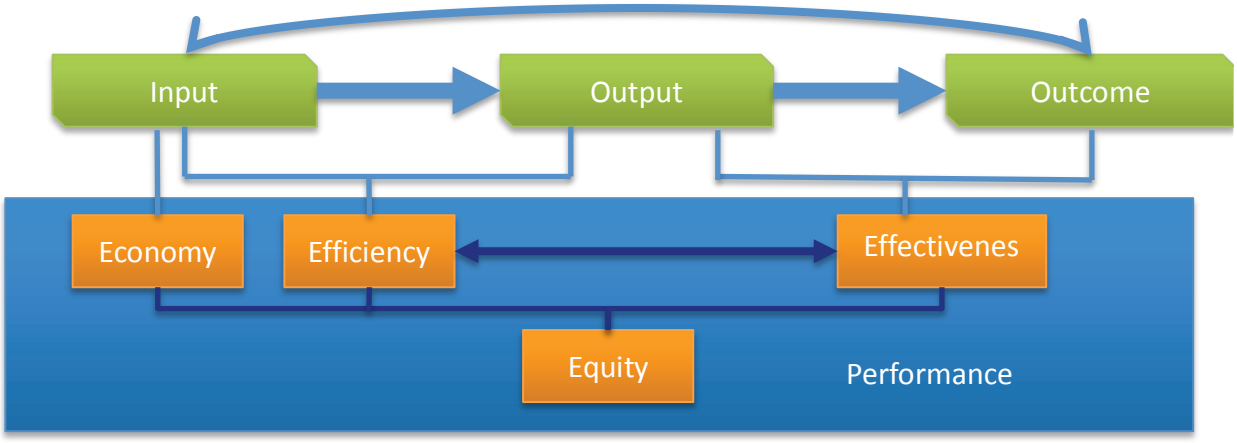


Figure 2. *Relationship overview about performance*

Figure 2 shows the relation between efficiency, effectiveness, economy and equity. Performance is closely related with efficacy and efficiency (Ozcan, 2008). A better term for efficacy in this case would be effectiveness, since this is more usual in management perspective. Traditional performance measurement focuses on financial analysis. However, when focusing primarily on financial indicators problems in quality, customer satisfaction, innovation and other intangibles remain hidden. According to Sanjay Bhasin (2008) instead of financial measures one should measure the performance of the customer service. This would also be better to do in the long term since it is assumed that emphasis on profit is short-term based (Bhasin, 2008). When measuring performance one should look at the inputs, outputs and the type of performance measurement should be based on a certain objective one wants to evaluate. The objective could be for example to have a low access time or to deliver fast

care. When evaluating the performance of such a DMU, it does not add much information about the performance when looking at costs. Although of course there could be a relationship between costs and lead-time.

Multiple performance measures are needed since a single measure ignores any tradeoffs among various performance measures. Since performance is related with efficiency and effectiveness, it is indirectly related to a set of given inputs, outputs, outcome and an objective set by a DMU. Furthermore equity and economy are included in the model. Economy is the financial performance and is related to the mix of inputs that can be bought or hired such as equipment, facilities and staff. Equity refers to the spread of resources and objectives. A hospital should not focus on only economy, efficiency or effectiveness. Well thought trade-offs between performances on these categories should be made.

In order to determine efficiency one should measure the inputs and outputs. Different examples for inputs are costs, number of doctors, number of nurses, beds, types of diagnostics and many more. Another approach would be to not use economic terms in inputs but rather state that economic quantities are needed to enable other inputs. Figure 4 shows the relations between inputs, throughput, output, and outcomes. We define inputs as the transforming resources (facilities, labor, equipment, materials) and the transformed resources (patient, information).

To conclude, efficiency and effectiveness are closely related. Efficiency is based on inputs (resources) and outputs (provision of care) and efficacy comprises the relation between outputs and outcomes (health benefits).

2.2.6 Design, planning and control

In a framework developed by Hans et al. (2011) health care design and planning is covered in four managerial areas: medical planning, resource capacity planning, materials planning and financial planning. Furthermore a distinction has been made between operations management (short term) and operations strategy (long term). Operations strategy is described as strategic decisions at a high level of a hospital organization. At level of operations management tactical, offline operational and online operational planning remain. Offline is all planning and decision making that can be done in advance whereas online operational deals with reactive planning and decision making. It is important to note that all managerial areas and hierarchical decompositions have influence on each other. This hierarchical framework enables us to demarcate the scope of our research and point out our focus.

Table 2 shows the application of the framework to the CRC care path.

Table 2. Application of planning and control framework by Hans et al. (2011)

	Medical planning	***Resource capacity planning***	***Materials planning***	***Financial planning***	
Strategic	Specialization on colorectal care	Cooperation with other facilities (diagnostics, surgery, radiotherapy), workforce planning	Supply chain and warehouse design	Investment plans, contracting care with insurance companies, cooperation with other facilities	↑ **Hierarchical decomposition** →
Tactical	Pathway construction	Block planning, staffing, admission planning	Supplier selection, tendering	Budget and cost allocation	
Offline operational	Diagnosis and treatment of an individual CRC patient	Appointments scheduling, workforce scheduling	Materials purchasing, determining order size	DRG billing, cash flow analysis	
Online operational	Emergency patients	Acute patients, complications,	Rush ordering: supply materials that run out of stock	Billing complications and changes	
← **Managerial areas** →					

In terms of patient logistics, use of resources, and care paths, the use of materials planning is least interesting. Materials planning addresses all materials used in the care provision, but are not renewable. More interesting are medical planning and resource capacity planning since they are directly related with patient flows and logistics and have a higher financial impact. Resource capacity planning addresses the management of renewable resources, such as an operating room, MRI-scanner or staff. This makes it an interesting factor of assessing efficiency of a care path.

Figure 3 shows that care for patients is influenced by planning and control and the system and processes themself. This will result in a certain activity, which could be a treatment or a diagnosis. Activity will lead to certain outputs, which are related to outcomes and performance. A hospital has control and can make decisions about planning and control and can make partly decisions about the system and processes. Some of these decisions such as the number of slots that are planned for CRC patients are established in “planning and control” but influence the “system”.

An example for looking at lead-time: a certain input (arrival of patients) come into the system and activity (in this example diagnosis) is performed. This will result in an output (*x* days); patient’s diagnoses and the time it took the hospital to finish their diagnosis. When looking at performance we can calculate the amount of patients that were really diagnoses within 20 days.

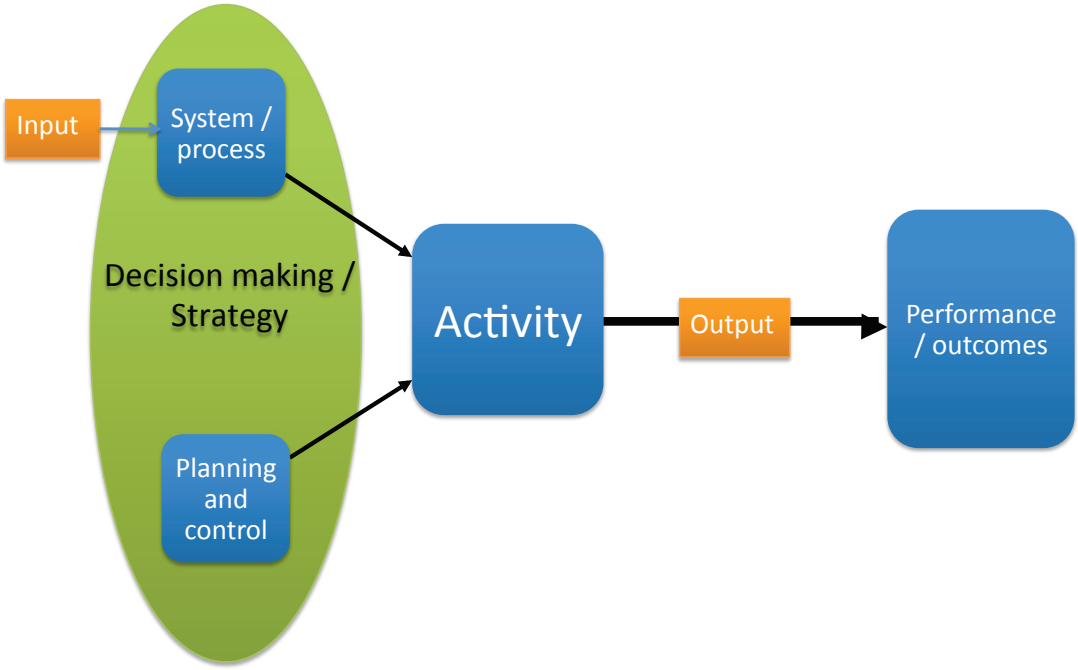


Figure 3. *Planning and control (management), system/process and performance relationship diagram*

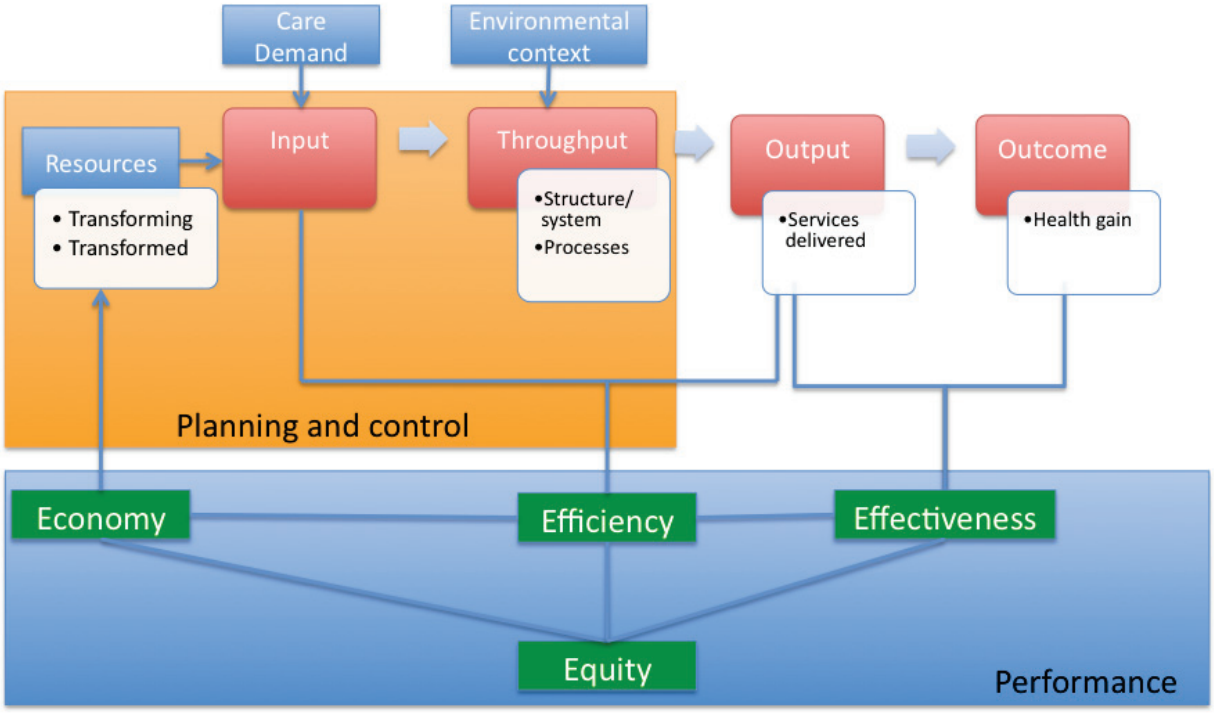


Figure 4: *Integration of 4Es of health care performance and planning and control*

The government, ministry of health or for example a national cancer network can establish quality norms and indicators. An example are the Dutch “Treeknormen”, which are acceptable access times and waiting times for Dutch hospitals (Busch, 2011) and deal with the performance factor timeliness. Patients want a service that is both efficient (without unnecessary delays and hospital visits) and effective, for example evidence-based practices are used (J. Vissers & Beech, 2005). This also stresses the different perspective of efficiency, which is actually timeliness.

2.2.7 Health care delivery

When looking at performance of a hospital care pathway one should understand the complexity of the delivering of health care services. Figure 4 shows an overview of this complexity. Healthcare is a service industry, which means that the customer is part of the production process. The patient going to a hospital for medical care is from that moment part of the production system. In production control approaches (in classic manufacturing organizations) the focus is on material flow. In healthcare services the core process is the flow of the patient through the care chain. Flow of materials (apparatus, instruments etcetera) is of secondary concern according to (J. Vissers & Beech, 2005). In our opinion both topics should be addressed when organizing efficient care since processes depend on availability of resources and it does not matter if this is the patient, information, facilities or equipment and materials. The IOM states that a hospital can be seen as a health care organization consisting of microsystems. A microsystem in this context is a team of people (staff) combined with their information system, materials, a client population and a set of processes (Berwick, 2002). This microsystems really deliver the care as the patient experiences it.

A production system can be seen as a system where inputs are transformed through a transforming process into outputs. The inputs mainly consists out of transformed resources and transforming resources (Slack et al., 2007). This is also applicable to health care. Transformed resources are for example materials, information and patients. Transforming resources are the facilities and employees. The manner the transformation is done can be referred to as the process.

The way inputs are combined in order to create outputs is called the production function. The production function is described by Saari et al. (2006) as a measure of productivity.

In terms of operations management mainly three different levels of operations analysis can be identified (Slack et al., 2007). This is summarized as:

- Supply network: flow between operations at an organizational level. This means that for example the care for colorectal patients is in hand of the hospital, consisting of several departments that are involved in the care process (operations).
- Operations: flow between processes. On a departmental level in an organization (such as the organization of care within the surgical department or the radiology department)
- Processes: flow between resources. On a single process level in an organization (such as the process of making a CT-scan or performing a surgery)

Slack et al. (2007) state that in operations management there are five main performance objectives: *quality*, *speed*, *dependability*, *flexibility* and *costs*. These categories fit well in performance measures of a hospital.

Quality could mean that patients will receive the most appropriate care in the correct manner, patients are consulted and kept informed, staffs are courteous, friendly and helpful and the patient satisfaction is high. *Speed* means that lead-times are short (diagnostic and therapeutic delay are short) and e.g. time for test results must be kept to a minimum. *Dependability* in a hospital setting could mean that appointments are not cancelled and patients do not have to wait for their appointments. *Flexibility* could mean that the hospital offers a mix of treatments and can adjust this to the type of patient or more flexibility regarding volume (variety in number of patients treated) or delivery flexibility (at the time the patient wants the care or to adjust to extern suppliers such as a radiotherapy center). The *cost* domain could mean to increase efficiency, productivity and reduce costs. In health care however this domain is not directly linked to the initial customer, the patient since the paying of care is through a third party, the insurance company (Slack et al., 2007).

When evaluating performance of health care it is important to note that health care itself is a derived demand (Bruce Hollingsworth & Peacock, 2008; Morris, Devlin, & Parkin, 2010). Patients, physicians, other staff and policy makers do not want two consults, three scans, one or two surgeries and 10 days of hospitalization. What they want is a health benefit or increase in wellness. It is therefore necessary to take into account what real health gain a certain care provider can establish

2.2.8 Chain logistics and care paths

The care process for the CRC patient can be seen as a care chain. Processes and chains can be seen as a sequence of operations with a need to be performed in order to establish a certain service or product. These operations often are performed in different units or departments such as the radiology department or operating rooms (J. Vissers & Beech, 2005). Homogeneity of patient's type (only CRC) allows the construction of a process chain or pathway to plan to increase efficiency and efficacy. This homogeneity implies that patients use the same type of resources. In the care process seen from operations management perspective the patient flow consists of activities (a series of operations in a certain sequence) and buffers or 'storage' in the form of waiting lines or queues. These times can be further assigned to access time (time between referral by general practitioner and first hospital visit), response time (time between first and second visit), waiting time (time between the last visit of the hospital and the treatment). When looking at the process itself, the cycle time is an interesting measure since this is the time resources are in use. We define cycle time as the time that is needed to complete one operation/activity. In the inpatient phase the length of stay is a valuable measure.

In health care research the focus is often on a single department without the complex relation with other departments. This approach fails in to get insight in the care process from an overall perspective, which is necessary to understand the complete care process and balance the production line. This will lead to longer lead-times, cycle time, more work-in-progress and inefficiencies. To standardize care and identify patient care trajectories effort been put in clinical pathways, lean/6-sigma projects, and focused factories. (P.T. Vanberkel & E.W. Hans, 2009). Furthermore effort has been put in total quality management, supply chain management and theory of constraints (Aronsson, Abrahamsson, & Spens, 2011; Kenagy, Berwick, & Shore, 1999; J. Vissers & Beech, 2005).

Lemmens et al. (2008) used a framework (the Leuven Clinical Pathway Compass) to assess the performance of colorectal care paths from multiple perspectives and beyond the scope of only a disease and help to assess a clinical pathway from multidisciplinary perspective and across department borders. Important is the service approach in which a total process from first contact to discharge (or even beyond) is evaluated (K. Vanhaecht & W. Sermeus, 2003). The compass addresses five domains: the *clinical*, *service*, *team*, *process*, and *financi*al domain. The *clinical domain* comprises patient related outcomes such as: number of complications, number of re-admissions on intensive care unit (ICU), time to restart defecation, time to return to enteral feeding, time to mobilize etc. The *service domain* is focused on patient satisfaction that could be measured using a standardized SF-36 questionnaire. The *team domain* involves team satisfaction. The *process domain* covers number of clinical examinations, completeness and quality of documentation, appropriate use of antibiotics and immunosuppressant. The *financial domain* is focused on the influence of the care path on (medical) costs, and length of stay since this influences the costs for postsurgical care greatly (L. Lemmens, van Zelm, Kris Vanhaecht, & Kerkkamp, 2008).

One can assess the (theoretical) efficiency of a care path, but the adherence to the care path should also be evaluated if hospitals are compared only on their designed care path. Adherence measurement of the pathway for the individual patient is interesting since this also reveals where the difficulties in implementation are (van de Klundert, Gorissen, & Zeemering, 2010).

2.2.9 Internal and external constraints

In the model showed in Figure 4, environmental context serves as external constraints for the throughput of the inputs. Outcomes leading from provision of health care are influenced by demographic differences between the populations that are served by the different hospitals. This is also referred to as the case mix. Other examples of external system constraints are the location or (mandatory) clinical guidelines.

Besides external system constraints there are also internal constraints. This can be the specific mix of surgeons that is present, physical layout in a hospital, which is hard to change, or agreements that have been made between departments.

2.2.10 Focused factories in health care

A focused factory is entitled to a specific operational process and should be designed to optimally support a certain homologous group of services. Traditionally hospitals are designed as an organization with functional departments instead of diagnosis or focused departments. In a functional department the customer demands are pooled, such as the demand for an X-ray at the radiology department for all patients of the hospital. In a diagnosis focused department patients with a similar diagnosis are pooled together, aggregated in a single department and the range of services is limited and adapted to the pooled group specific needs (Peter T. Vanberkel, Boucherie, Erwin W. Hans, Hurink, & Litvak, 2010). Advantages are that care is less interrupted by other types of care, it is easier to create flow, the care is provided in a patient centered manner, and quality is thought to be better since a focused factory offers dedicated physicians and processes are better aligned. However care should be provided in fewer hospitals to keep volumes high, which cause more travelling for patients. Furthermore this traveling could mean that a patient is treated in different hospitals for comorbidities. This is a risk since information sharing is not yet organized and physicians may be not up-to-date regarding the health status of the patient(Bredenhoff, van Lent, & van Harten, 2010; Casalino, Devers, & Brewster, 2003; Hyer, Wemmerlöv, & Morris Jr., 2009; Kumar, 2010)

2.2.11 Relation of timeliness on health outcomes

Since timeliness is often misinterpreted as efficiency it is important to not ignore the importance of timeliness from both clinical as managerial point of perspective. In terms of lead-times one can define the diagnostic delay and the therapeutic delay. The diagnostic delay is the time between first start of the symptoms and the diagnosis. The therapeutic delay is the time between the start of the symptoms and the appropriate therapy.

Earlier research has provided information about the relation between the therapeutic delay and the medical outcomes of care. A difference was found between colon carcinoma and rectal carcinoma. Whereas a long therapeutic delay is a negative prognostic factor for rectal carcinoma, this is not the case for colon carcinoma (Iversen, Antonsen, S Laurberg, & Lautrup, 2009; Korsgaard, Pedersen, Sørensen, & Søren Laurberg, 2006). Nevertheless a longer therapeutic delay causes more psychological stress (Klemann, Wolters, & Konsten, 2011).

2.3 Process improvement principles

We found in preliminary research different improvement strategies, which could be applied to health care:

- Lean
- Agile
- Six Sigma
- Supply Chain Management (SCM)
- Total Quality Management (TQM)

SCM and TQM can be seen as an umbrella term for lean, agile, Six Sigma and others since they all cover different parts within TQM and SCM. A literature review carried out in 2010 finds that 51% of the publications on 'Business Process Improvement Methodologies' were focused on ' Lean' and 35% of those were related to health care (Burgess & Radnor, 2007).

Womack and Jones introduced the term Lean Management or Lean Thinking in 1990 (Womack & Jones, 1990). Eiji Toyoda and Taihchi Ohno implemented the original Lean Thinking after the WW II as a reaction on Ford and General Motors mass production system (Seyedhosseini, Taleghani, Bakhsha, & Partovi, 2011). Lean Thinking is also referred to as the Toyota Production System (TPS). It was initially developed and proved for the manufacturing industry but there are parallels between pure manufacturing in a factory plant and the service industry such as healthcare, the basis of Lean Thinking could as easily be used in healthcare and hospital settings. Much literature is published about Lean in Healthcare and it becomes more and more popular to use Lean or Lean Six Sigma as a management tool/philosophy to drive improvement programs in healthcare (Boat, Chao, & O'Neill, 2008; Burgess & Radnor, 2007; DelliFraine, Langabeer, & Nembhard, 2010; Koning et al., 2006; Miller, 2005).

Lean Thinking is a process-based management philosophy to decrease waste and therefore get an efficient process design. Furthermore the timeliness of service delivery is assumed to increase since It could be summarized as an integrated system of practices, tools, instruments and techniques, which are focused on the reduction of waste of resources, synchronizing workflows and coping with variability in the service and creating flow of a product, customer or patient through the process (Liker & Morgan, 2006). There are several principles that characterize lean thinking and a lean system. The key principle is reducing lead times and costs (Ellen J Van Vliet et al., 2011). The core idea of lean thinking is to determine the value of each step in the process towards a final product and distinguish between activities adding value and activities not adding value. These non-value adding activities can be seen as waste of resources.

Womack and Jones defined Lean in five core principles, based on the assumption that an organization is built up on processes (Burgess & Radnor, 2007). The five core principles a lean organization should implement are:

1. Specify the real customer and specify value as is desired by the customer. Understand their requirements
2. Identify the value stream for the service provided and identify all wasted steps
3. Make the product or service flow continuously, standardize processes around best practices
4. Introduce pull between all steps where flow is impossible. In this way the process steps are focused on demand and inventory (or in service and healthcare terms, people waiting) and human activity is linked to the needs of the customer.
5. Manage towards perfection, continuous improvement of the process.

All principles of lean thinking are focused on decreasing waste. Every activity (specifically human activity) that use resources but add nothing to the real product or process can be seen as waste. Selected examples of waste for the CRC care are between brackets:

1. Overproduction; doing more work than is necessary to get the same quality or too much work is carried out before entering the next process step (require more diagnostics than necessary)
2. Motion: extra steps for the employee, movement of equipment (extra movement of patient or equipment does not have its own place)
3. Waiting: time that is passed waiting for the next step in the process to occur, a downstream activity that is waiting for an upstream activity (waiting for results, waiting for availability of operating room capacity)
4. Conveyance: moving materials or information around (like giving information to other physicians, patient files moving around)
5. Processing: non-value added steps in the work process (keeping patients unnecessary long at the ward until discharge)
6. Inventory: keeping excessive stockpiling or too little (how are materials for surgery managed)
7. Correction: mistakes which require rectification (rescheduling a patient for an outpatient clinic visit because the diagnostic results are not yet ready)

Operational inefficiency, which is affected by process design and is in control of healthcare professionals, can also be seen as waste (Koning et al., 2006). According to Slack et al (2007) lean thinking consists of two main themes: the 'just-in-time' (JIT) principle and ' jidoka' ("humanizing the interface between operator and machine"). The latter is a more manufacturing based definition but can be related to healthcare as giving insight in the process, and therefore early adaption can be made if a step in the process does not go as was intended. This could be a visual management system to see how many patients are waiting in the waiting room and if the outpatient clinic time is extended. Many more examples on different levels are possible.

The JIT principle is defined as the fast, smooth and coordinated movement of parts throughout the production system and supply network to meet customer demands (Slack et al., 2007). Converted to healthcare it would mean that the patient care is fast and is running smooth through the different process steps, such as outpatient clinic visits, diagnosis, treatment and possible follow up.

Womack and Jones (1996) make a distinction between two different types of waste. Type one: non-value adding activities necessary due to regulation, quality concerns or other waste the organization has little or no influence on. This could be described as the properties of the system element (see page 19). The second type of waste are the activities creating no value and are avoidable. This last type of waste is the type that needs attention since the process owner (a hospital, department or more general, the DMU) can make a difference by reorganizing/reengineering the process. This could be described as planning and control (see page 19).

Flow thinking is one of the key elements of Lean thinking. The opposite of flow thinking is batch thinking. In the latter first a certain process step is finished for all customers before continuing to the next step in the process. In healthcare for example the care for a patient can be seen as a flow where one department is responsible for all the different care activities rather than different departments specialized for their own job.

There are different levels one can look at when considering Lean principles. Lean principles can be used at the level of organizing a complete care pathway of a specific disease. The pathway than becomes a form of value stream. Another example could be the implementation of lean principles to restructure a department. It does matter what the exact objective is to choose the proper level to implement lean practices.

One can look at different levels towards Lean practices. Since it is a management philosophy and is not deals with a standard solution for every business it is more developing a certain mindset and evaluate processes. Lean can be used to look from a distant point of view at an organization, so looking at a whole process or a whole company. Another point of view would be the departmental level and therefore taking into account the process design (but not limited to) of the processes of a department. A narrower point of view would be to look at the design of a single process or task within a work cell of the department.

Figure 5 shows the differences between the different levels. In this visualization a distinction is made between hospital, strategic, tactical, operational and outcome level. At the top level of leanness is the "lean enterprise".

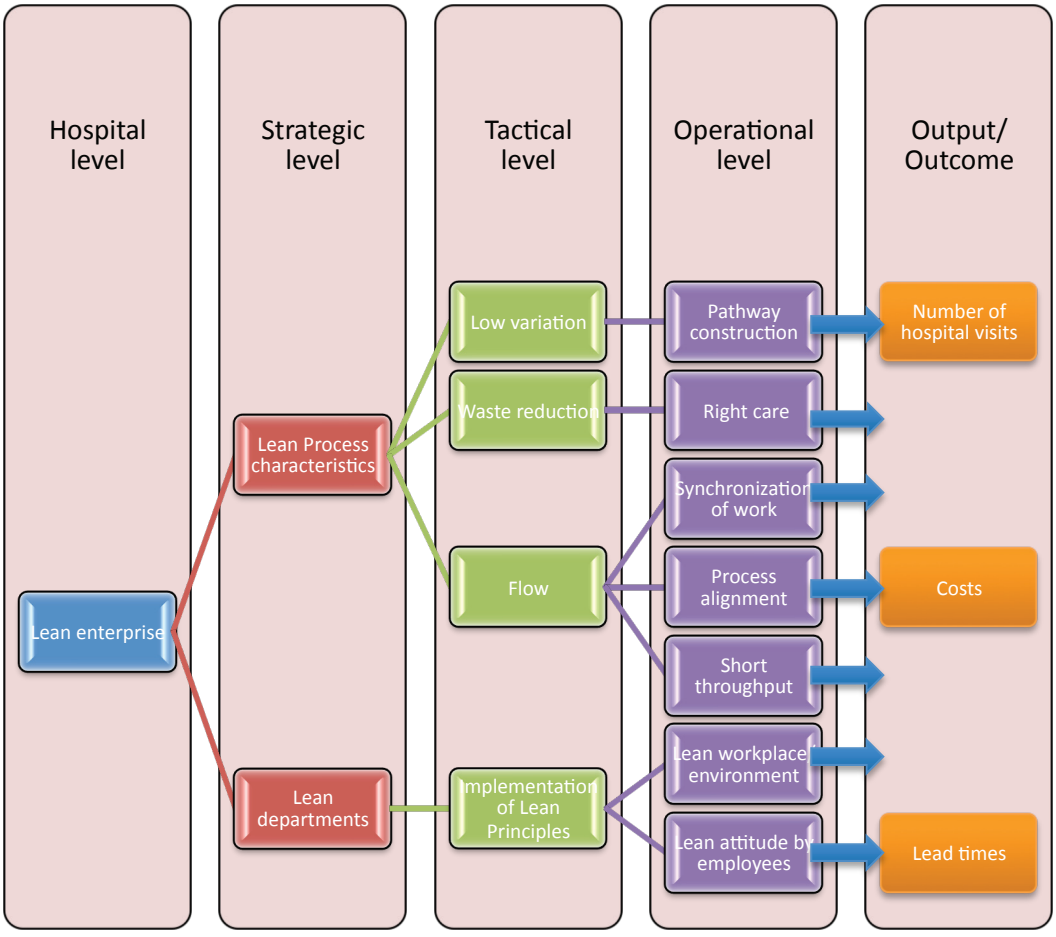


Figure 5. *Lean seen at multiple levels*

In relation with the terms efficiency, effectiveness, patient centeredness, timeliness, safety and equity, elements of lean can contribute to these. By decreasing unnecessary process and other waste, the process becomes more efficient. Furthermore timeliness can increase since the focus is on patient flow. Since value of the process is seen from a patient perspective, a lean process is patient centered. Because in the case of service industries the patient is part of the flow, this also attributes to patient centeredness.

In cataract surgery the lean framework was used to assess the relation between the design of the process and the organizational characteristics and the efficiency.

2.4 What is value in health care?

In lean thinking, but also in terms of efficiency, there is a strong focus on value. However it is yet unclear what is meant with value and it is difficult to quantify, especially in the healthcare context (McClean, Young, Bustard, Millard, & Barton, 2008). It is the customer/patient who should decide what value is and what is not. It is not up to the hospital, department or physician to decide what value is. Michael Porter (2010) describes value in healthcare by the health outcomes achieved per dollar spent. This goal is what matters for patients and unites the interests of all actors in the system (Porter, 2010). The patient and his or her medical condition define the needs. Health outcome cannot be seen as a single outcome but consists of multiple outcomes. Care for a patient can involve numerous medical personal and physical resources.

Value for the patient is created by multiple providers' effort combined over the full care cycle. This is especially the case for the surgical treatment of colorectal cancer where multiple specialties give care to the patient, such as the surgeon, radiotherapist or gastroenterologist. Furthermore multiple physicians and departments are involved in the diagnostic path such as radiology or the gastroenterologist.

Processes can be divided between primary and secondary processes. Primary processes are those steps that serve the external customer, in healthcare the patient. Secondary processes are internal process steps that serve employees, departments or other internal customers (Miller, 2005). In health care the internal processes will serve the primary process. An example of this could be the complementary diagnostics like a CT-scan after a first diagnosis through a biopsy during a colonoscopy.

Defining value is more difficult in services business, such as health care, compared to manufacturing industry. This is mainly because there is no clear monetary value for the outputs and outcomes of the care activities undertaken (Jacobs et al., 2011).

2.5 Lean framework

Womack et al. (2003) state several factors related to lean management. In an article Van Vliet et al. (2011) distilled six operational lean characteristics, used to evaluate a lean pathway in the cataract surgery and comparing different hospitals. Differences in process design and differences in the organization of care were measured using a model that consisted of items covering the six operational lean characteristics. After analysis of the original care path in an eye hospital they developed a lean pathway by removing waste and creating flow. They first evaluated efficacy and efficiency of the pathway. Efficacy was determined by measuring how many patients were treated according their lean pathway and different elements such as the number of patients using a one-stop pre-assessments, care plan formulated using patient record only, next-day telephone review and final review by an optometrist (Ellen Joan van Vliet, Walter Sermeus, van Gaalen, Sol, & J. M. H. Vissers, 2010).

Efficiency was defined by measuring the number of hospital visits per patient, amount of ophthalmologist's time spent per patient in minutes, and number of patients treated, related to ophthalmologist's time needed to treat one patient in the traditional pathway (Ellen Joan van Vliet et al., 2010). In a second paper by Van Vliet, efficiency was defined as a measure of average lead-times (split up in access time from first contact until consultation and waiting time, the time between consult and surgery), average number of hospital visits per patient (Ellen J Van Vliet et al., 2011). This is not in line with our definition of efficiency, which covers the relation between inputs and outputs. By measuring lead-times the timeliness of the process is addressed.

Costs were also included in this second paper, and were calculated using activity-based costing. Direct personnel costs to execute and coordinate a standard set of activities (eight activities were defined to be essential for the carepath) were calculated using a standard cost per team member, based on Dutch hourly wages. The number and type of team member involved per activity was determined by interviewing specialists. Costs per activity were

calculated by multiplying responsible team members with the allocated time. The total costs were calculated by defining at patient level the number and type of activities, and multiplying this with activity costs. The average costs per patient were hence calculated.

The process items that were operationalized are briefly explained (adapted from (Ellen J Van Vliet et al., 2011)):

Operational focus: operational focus in a lean pathway is to reduce lead-time by eliminating non-value added activities.

Autonomous work cell: when all resources (materials and human resources) are organized in an autonomous work cell, there are fewer interruptions from other type of patients. Besides the numbers of workstations is minimized and are arranged in the processing sequence to enhance flow.

Lean physical layout: the physical layout of the resources is adapted to the flow to prevent delays by crossing the physical boundaries of the autonomous work cell.

Multi-skilled team: a care team that works according Lean principles is multi-skilled to increase flexibility to conduct tasks interchangeably (according to regulations and competences) with a minimum transfer of information and responsibilities.

Pull planning: with pull planning it is meant that there are as less customer order decoupling points as possible and the patient flows through the whole process without many interruptions. A customer order decoupling point (CODP) is a point in the process when further actions are planned. In a care path with only one CODP all process steps are planned at the first call for an appointment. This could be achieved by directly planning all necessary appointments at the first decent suspect of a malignancy. The patient therefore does not have to wait until the resources become available again for the patient, but the resources already are prepared.

When the process flow is based on the needs of the customer/patient this is called a pulled process.

Elimination of waste: in the research by Van Vliet et al. the focus was on additional pre-assessment, not revisiting the hospital for a first review after the surgery by an ophthalmologist (this is seen as waste since this could also be done using a consultation by phone) and the number of coordination actions per patient. Each activity that was performed by a different member of the team was a coordination action.

To conclude, a framework was constructed to analyze process design characteristics of a care pathway and compare three different hospitals. An adapted version would be suitable for the colorectal cancer path since the six characteristics can be generally applied. Specific items, however, should be designed to fit in the CRC care setting.

2.6 Lean metrics and leanness

Leanness is a term for the degree how lean a certain process or enterprise is, however a clear definition of leanness and how the measure it is not available. Leanness is referred to as a quantitative term but what exactly should be quantified is not standardized.

Leanness could be the aggregate score of different (lean) objectives a company has. The different characteristics of lean (elimination of waste, flow, short throughput times etc.) can be measured as surrogates for leanness. Several lean metrics have been developed to evaluate the performance and tracking the improvements of a lean system. These metrics have been developed for both health care setting as other industries. Examples are the creation of a Lean index as a Lean metric for the woods products industry by calculating factors for use of

physical resources, production of by-products (waste) and turn-over times. A lean–index is created by linear regression analysis (Ray, Zuo, Michael, & Wiedenbeck, 2006).

Another approach is done by (Wan & Frank Chen, 2008) in the manufacturing industry. They use Data Envelopment Analysis (DEA) for the quantification of leanness and adoption of lean initiatives. DEA is explained in more detail later in this report. They used a slack-based approach since using only DEA manufacturers that are on the frontier of efficiency, not necessarily have to be completely efficient, or in their terms, has the highest leanness score. Figure 6, taken from their paper, illustrates these phenomena.

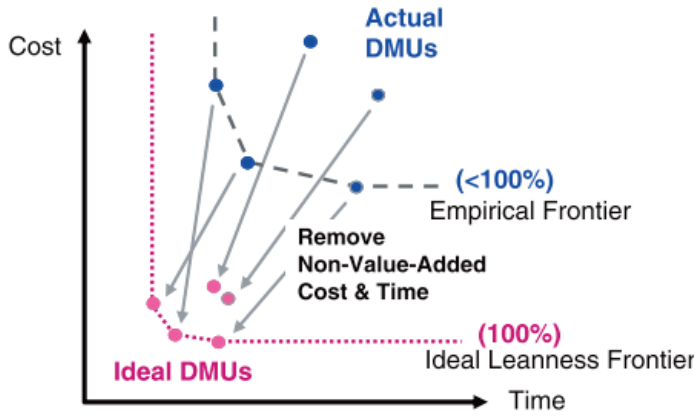


Figure 6: *relation between two inputs (time and costs) and a fictive output to show the difference between efficiency and super-efficiency. The Ideal DMUs can be seen as super-efficient DMUs. This example is taken from (Wan & Frank Chen, 2008)*

There is a difference between being Lean and *trying* to be Lean. Trying to be lean can be measured by looking at lean initiatives. Being lean can be measured by looking at the outcomes, results or performance. When assessing leanness one should look at 'being lean' since that is what eventually counts. Lean outcomes can be cost reduction, more flow (increase in timeliness), increase in capacity etcetera.

Chapter 3 How to assess efficiency?

In this chapter a method for efficiency measurement in colorectal surgery will be described. First an overview of efficiency measurements applicable to health care services is given. Different calculation methods are described and examples of inputs and outputs are provided. From this selection, a method to measure efficiency is proposed.

Research question:

1. How can efficiency in the colorectal cancer surgical care pathway be measured and compared across hospitals using inputs, outputs and patient related outcomes?

3.1 Methods:

We performed an explorative study to efficiency measurement in health care. To construct an efficiency measure or measures for the colorectal care path, literature has been searched for different types of efficiency measures used in healthcare. Hence a selection of criteria and methods is made which tend to be suitable to evaluate the efficiency at hospital/organizational level of the colorectal cancer care. Besides hospital visits were carried out to gain understanding of the care process for CRC patients. Without proper understanding of the process it is not possible to choose suitable performance indicators.

The Scopus database was searched for articles in English. Medical Subject Headings (MeSH) were used where possible and available. Search terms included: efficiency (MeSH), colorectal surgery (MeSH), productivity, healthcare, health care, organizational efficiency, surgery (MeSH), critical pathway (MesH). First reviews were searched.

"Reference mining" was used to retrieve possible additional articles by searching relevant articles in bibliographies of the already retrieved publications. Besides grey literature was used when possible efficiency measures were described. Grey literature is described by (Scroll & For, 2008) and (Hussey et al., 2009) as all information that one can read outside of books, journals and daily newspapers. Grey literature includes governmental publications, advices by councils, guidelines etcetera. Investigating this kind of resources is useful since not all efficiency measures are published in regular journals and are findable in databases such as the Scopus and PubMed database.

The focus of the literature review was to seek for methods for efficiency measurement, type of inputs and type of outputs. Furthermore most ideally we would like to know how hospitals performed on efficiency of the production of health for the individual patient rather than measuring the efficiency of health care. In order to make this possible account has to be made for the health status of the patient and the severity of the disease. A case-mix adjusted efficiency measurement would solve this problem.

The care pathway and the different elements were researched by doing a literature research and by interviewing employees related to the organization of the care process around the CRC patient in four hospitals. Different team members (n=42), spread over 5 hospitals who were interviewed in order to understand and explore the care process can be listed:

- GE surgeon (n=5)
- Stoma nurse (n=4)
- Head/coordinating nurse of surgical ward (n=5)

- Radiologist (n=2)
- Head/coordinator of radiology department (n=6)
- Head/coordinator of operating rooms (n=7)
- Scheduling and admission (n=3)
- Gastroenterologists (n=2)
- Head/coordinator of endoscopy department (n=5)
- Outpatient clinic nurse/secretary (n=3)

3.2 Results

3.2.1 Types of efficiency

Efficiency deals with the conversion of inputs into outputs. Different approaches were discussed in Chapter 2.

In literature different types of efficiency were found and can be summarized:

- Allocative efficiency: to select a mix of inputs that produces a given output at minimum costs (or resource use)
- Technical efficiency: to obtain the maximum output, given a certain input
- Scale efficiency: an efficient amount of inputs and outputs are used. This is the case if an increase or decrease to scale exists. This is also explained as “diminishing returns”.

These definitions are well described by (Bruce Hollingsworth & Peacock, 2008) and (Morris et al., 2010). When evaluating efficiency it is important to first determine an exact definition. The definition is also based on the approach of efficiency that is chosen. One can focus on the production of health (outcomes), or the production of healthcare (output).

In a systematic review by Hussey et al (2009) an analysis was done to assess the different types of efficiency measures that are used in health care. They reviewed literature between January 1990 and May 2008 and used the search terms efficiency, inefficiency, productivity, and economic profiling. They found that there is a wide variety of efficiency measures, but that knowledge is lacking how to account for quality factors in efficiency measurements. They also describe that not much experience is done with true efficiency measures in practical use and that it is not clear which methods exist globally to assess efficiency.

Romley et al. (2009) present four types of measurement based on a literature review on efficiency measures in managed care environments. These are measurement of productivity, cost of service, cost of episode and cost of covered life. The World Health Organization (WHO) has a focus on economic efficiency when using efficiency measurement and uses terms as “Health facility economic efficiency analysis” (World Health Organization, n d). Efficiency appears to be related with the use of resources and their cost-effectiveness. Efficiency can therefore be closely linked with economic efficiency.

3.2.2 Levels of measurement

When reviewing literature about efficiency measurements in health care different levels of measurement can be distinguished. From a macro perspective one can assess and compare the efficiency of a health system (focus on national or on regional), health care delivery at both physician (individual or group) and hospital level (location or hospital group). Since this research is focused on the efficiency of the delivery of care for a specific disease in order to compare care providers, the focus will be at hospital level. Most literature regarding efficiency at hospital level were concerned with measuring efficiency total hospital or at departmental level. No literature was found however about a certain care path which is not organized in a focused factory setting.

A care path can be described as a supply chain where multiple departments are dependent on each other's processes and the product is centered. In our case the patient flows through different departments, each with its own efficiency. PubMed defines a care path with a Medical Subject Header as a critical pathway: schedules of medical and nursing procedures, including diagnostic tests, medications, and consultations designed to effect an efficient, coordinated program of treatment. Another name that is used is clinical pathway.

3.2.3 Inputs and outputs

In literature various input and output variables were found. The choice of variables is not arbitrarily and depends on the goal of the efficiency study.

There is a difference between outputs and outcomes in the process of health care delivery. Outcomes deal with the actual gains of health care provision such as "value-added" to health or increase in quality of life. Since this is difficult to measure, surrogate measures can be used such as the cure of a disease, increase in Quality Adjusted Life Years (QALY), but also complication rates, re-admissions or deaths.

Outputs deal with the direct product of the transition of the inputs. This can be seen as the physical output of the care process; a diagnosis, a treatment or an intermediate stage of these.

Jacobs et al. (2011) make the distinction between additional health conferred on the patient and patient satisfaction related to the health effect. They introduce the term "quality-adjusted physical outputs" as an alternative for outcomes.

The level of aggregation of inputs must be specified. With this we mean that for example using costs for care is a highly aggregated variable, since it includes all kinds of resources. This is because almost all input resources can be expressed in monetary value. One large disadvantage is that it not clear after analyzing what the underlying cause is of efficiency differences between DMU's.

Inputs can be split up between capital and labor inputs (Jacobs et al., 2011). Labor inputs comprise work hours or labor costs. Capital inputs are physical resources such as facilities, equipment, information, materials or as a surrogate measure; costs calculated for each of them.

Niskanen et al. (2009) describe a benchmarking process in surgery of resource use and postoperative outcome.

Table 3. Inputs and outputs found in literature for measuring efficiency

Input	Output	Reference
- Specialist/physician FTE (labor), - Nurse FTE (labor), - Other workers FTE (labor), - Bed size (capital)	- Patient days: medical days, surgical days, simple days, complex days, long-term care days - Number of patients: medical patients, surgical patients - Number of outpatient visits	(Magnussen, 1996)
- Inpatient care (case mix adjusted using DRG's) - Outpatient care (case mix adjusted using DRG's)	- Physician FTE (labor), - Other labor FTE, - Medical expenses	(Martinussen & Midttun, 2004)
- Physician FTE	- Number of hospital patient discharges	(Hao & Pegels, 1994)

- Nurse FTE - Bed size	per year, - Number of surgeries per year, - Combined number of emergency and outpatient visits per year	
- Cost of service (labor/capital) - Cost of episode - Cost of covered life - Productivity and utilization		J. A. Romley et al., 2009;
Number of ORs (capital)		Romley et al., 2009; Timbie & Normand, 2008
- Operation room turnover times - Length of stay in ICU - Length of stay in the hospital - Re-admissions to hospital - Costs of care: - personnel costs, - other costs (medication etc.)	- Morbidity - Complications - Mortality: - in-hospital mortality - mortality at months - Long-term mortality, - mortality compared to general population	Niskanen et al. (2009)
- Number of dialysis machines - FTE nurses	- Patients treated per month	Kontodimopoulos & Niakas, 2005

The author of this report visited five different hospitals in order to get understanding of the care process and take notice of differences in the different care paths a patient follows.

For the colorectal cancer care specific choices can be made regarding the use of inputs and outputs. Since care is organized differently in hospitals and tasks are allocated differently one should account for that. Specific choices are for example made to allocate certain tasks to be performed by a nurse practitioner or a colon care nurse instead of the surgeon. This can be caught using wage rates as labor input.

Since the relation between labor and number of patients treated can be explained by cycle time it is interesting to evaluate the difference of cycle times for care processes. We think this is a better efficiency measure compared to lead times since this this measures the actual process and not the “buffer” time of the patient, which is more related with timeliness instead of efficiency.

3.2.4 Calculation methods:

Different calculation methods can be identified and are described below. Some methods are more sophisticated than others and use multiple inputs and outputs.

Ratio analysis

A ratio is fairly simple and straightforward method to measure efficiency. It is easy to understand and to calculate. There are however great disadvantages using this method. It does not account for multiple inputs and multiple outputs. It does not make a trade-off between different resource distributions. If for example the ratio of physicians per bed is calculated, it does not account for differences between hospitals in nurses per bed (which could be much higher in hospitals where less physicians per bed are available). In ratio analysis no adjustment is made for this kind of influencing factors.

Other examples of ratio analysis are (costs)/(treatment), (number of treatments)/(FTE physicians), (outpatient clinic appointments)/(physician work hour) etc. The acceptance of ratio analysis as a decent method for efficiency

analysis depends greatly on the goal. If the only goal is to compare a single input and output, this is a suitable method.

Least-Square Regression analysis

Least square regression analysis is based on formulating the relation between inputs and outputs as a linear function which is:

$$y_i = a + b_1 x_1 + \cdots + b_n x_n + e$$

Where *y* describes the relation between inputs and outputs, *i* stands for a different observation (over time, or between hospitals), *b* is a weight factor for different input/output ratio *x*.

This seems a fairly easy method. There are however great drawbacks and disadvantages using this technique. One of them is that DMUs are compared to the average efficiency (regression line). Figure 7 shows an example of a fictive analysis to illustrate the possible results, adapted from (Ozcan, 2008).

The limitation can be explained in Figure 7. The regression line is constructed using the data of 10 hospitals using the nursing hours/inpatient admission ratio and costs of medical supplies/inpatient admission ratio. H1 (left circle) is most efficient on nursing hours per admission and H4 (right circle) appears most efficient on costs of medical supplies. The regression line shows a linear efficiency line, which is an average. From regression analysis point of view the efficient DMUs should move towards the regression line, and actually become less efficient (Ozcan, 2008). Furthermore no difference is made between the weight of cost expenses and nursing hours.

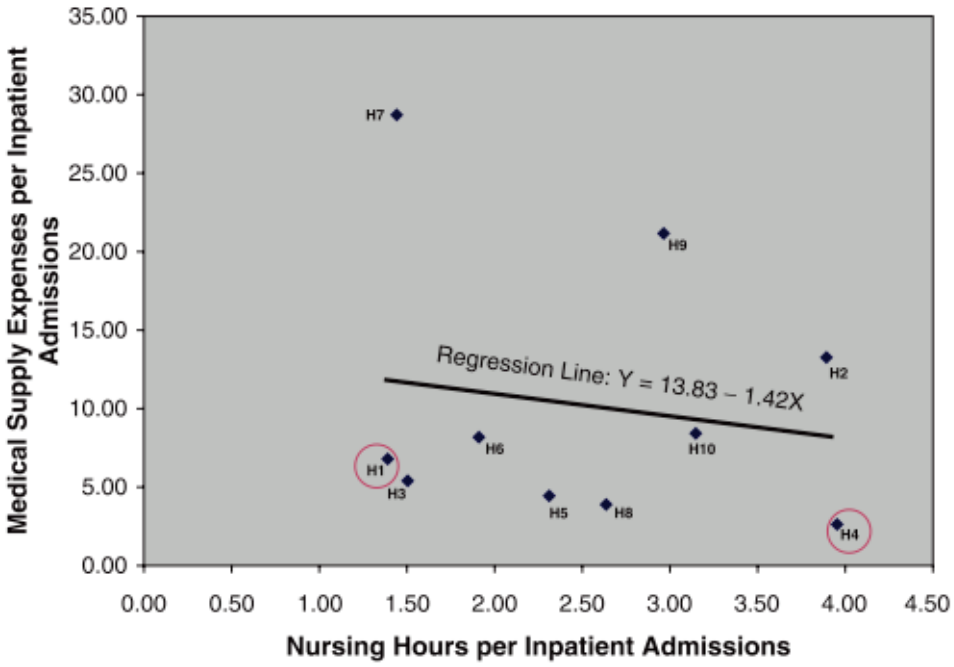


Figure 7: Scatter diagram of hospital performance, taken from (Ozcan, 2008)

Frontier analysis

Using frontier analysis in efficiency measure a trade-off can be made between a set of inputs and outputs.

Frontier analysis can be divided into two mainstreams of efficiency frontier analysis, which are Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA). DEA is a non-parametric technique whereas SFA is a parametric technique.

Stochastic Frontier Analysis (SFA)

SFA is a parametric stochastic method and is therefore able to account for stochastic errors. Weights of the different sets of inputs and outputs have to be pre-defined. The choice of these weights have a major influence on the efficiency outcome and are therefore of great importance. The weighting may be based on consensus, known guidelines or standards, or expert elicitation.

SFA can cope with multiple inputs and a single output. If it is desired to use multiple outputs, these should first be aggregated into a single output (Bruce Hollingsworth & Peacock, 2008).

Data Envelopment Analysis (DEA)

DEA is non-parametric method to define technical and allocative efficiency with the ability to use multiple inputs and outputs. A relative efficiency is calculated. This means that the DMU's are compared to each other and the assumption is made that at least some of them operate at the production frontier (envelope). These DMUs serve as best practice and DMUs, which are not on the frontier, are compared to these hospitals. The value of efficiency is always between 0 (least efficient) and 1 (most efficient). DEA is currently the most used efficiency calculation method in health care (B. Hollingsworth, 2008).

With the use of Figure 8, DEA is explained. A until G (the dots) are DMUs, where A,F, and G are on the frontier. The letter *e* indicates the intersection at the frontier from a linear line from the origin to E. Efficiency is measured as:

$$Efficiency = \frac{Oe}{OE}$$

Since the number of outputs can differ per DMU it is important to consider the type of returns to scale. Two options are used: various return to scale (VRS) or continuous return to scale (CRS).

This allows efficiency calculations when the production function is unknown. It solves a linear function with adjustable weights for the inputs and outputs. The weights are chosen for each variable for each DMU to show the DMU as positive as possible, under the constraint that no other DMU, with the same weights for the variables, is more than 100% efficient.

Numerous examples of the usage of DEA in health care and other sectors are available. Examples are: the efficiency measurement of hemodialysis units in Greece (Kontodimopoulos & Niakas, 2005), evaluation of operating room suite efficiency in the Veterans Health Administration (Basson & Butler, 2006) and the use of DEA to identify best healthcare systems with the use of multiple inputs and outputs in order to improve care processes (Benneyan, 2008).

A disadvantage of DEA is that it is a deterministic approach, and therefore is disturbed by outliers. An outlier influences the frontier greatly and a measurement error therefore influences the relative efficiencies. The results of DEA are not corrected for statistical noise and an efficient DMU is considered to be genuinely efficient. Furthermore DEA is only suitable when comparing a significant amount of DMUs. If too few DMUs are included in the analysis they will be on the efficiency frontier because they all will receive different weights for the input and output vectors. A rule of thumb is that one should at least include a number of DMUs that is grater than the square of the sum of inputs and outputs used in the calculation. This means that for two inputs and two outputs (four variables) at least 16 different DMUs should be included. A trick to increase the number of DMUs is to split a year efficiency evaluation in half years. Each DMU is then included twice; for the first and the second half year.

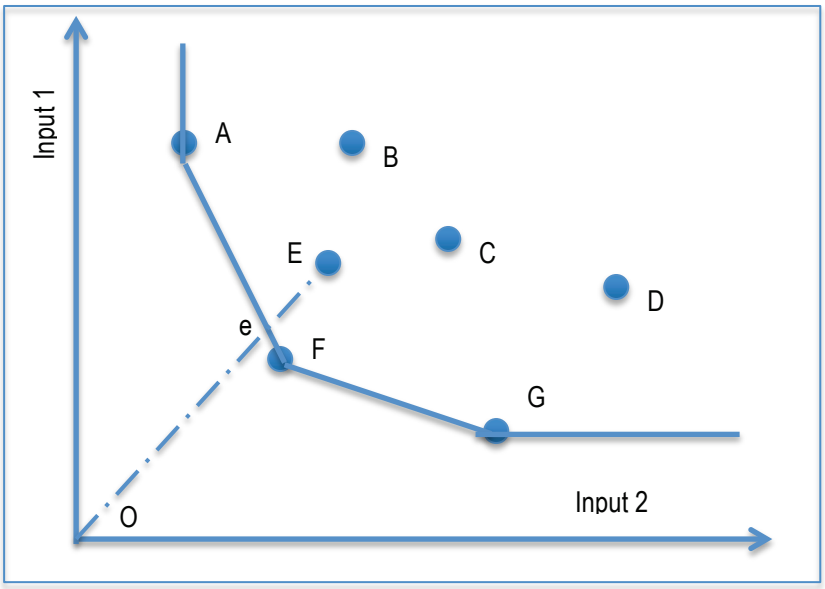


Figure 8: *Example of DMUs in an efficiency measurement.*

The assumption that at least some DMU are efficient because they are on the frontier is not always desired since decision makers are also interested in the performance of the "efficient" DMUs. Is it possible for them to improve, and if, what should be improved. Literature describes super-efficiency as a possible solution to overcome this problem. Super-efficiency is a modified version of DEA to rank efficient units, since standard DEA is not able to discriminate between efficient DMUs. Calculating super-efficiency is done by excluding the DMU under evaluation and solving the linear equation again for all other DMUs. The excluded DMU will then gat a more than 100% efficient score (Andersen & N. C. Petersen, 1993). Using this method it becomes possible to discriminate between DMUs on the original efficiency frontier. This is especially useful when a small number of DMUs is included in the study (Tone, 2002).

Using restricted weights would show a more realistic efficiency measurement since the total mix of inputs and outputs is important. If weights are unrestricted the calculation allows in order to become efficient to set weights of variables on zero.

Total factor productivity (TFP)

Total factory productivity can be used with multiple inputs and outputs and overcomes the weakness of the single ratio analysis. Index numbers are used to calculate the difference between a base period and the current period

(Jacobs et al., 2011). This method however is not widely used except the Malmquist index (Ozcan, 2008). This index will be explained in a separate topic.

Malmquist index

A key consideration for the usage of the Malmquist index is the availability of longitudinal data regarding inputs and outputs. Also they should be measured consistently over time (Jacobs et al., 2011). Due to changes in health care organization such as different pay methods, fusions, specialization and care path construction and adjustments it is often difficult to get valid and comparable measures over time. In this study we are not primarily interested in changes of a DMU over time, but rather in the comparison between various DMUs.

3.2.5 Multi-stage analysis: supply chain efficiency

Joe Zhu (2009) describes the difficulties of measuring supply chain efficiency. Many difficulties arise when measuring complete supply chains since multiple departments and stakeholders are involved in the production process. In the context of this report however an analogy can be made between a supply chain and a care path. In other efficiency measures the transforming process is seen as a black box where certain inputs will result in outputs and outcomes that can be measured. In evaluating a supply chain intermediate inputs and outputs are derived.

Another approach for the measurement of efficiency of a care path is to measure efficiency of the individual departments involved in the process. However a true supply chain efficiency measure such as the colorectal care path is more than just the performance of the individual supply chain members (Zhu, 2009).

3.2.6 Application to the colorectal pathway

For the analysis and quantification of efficiency in the colorectal cancer the calculation methods are studied to come to a customized efficiency measurement. First it should be noted that a demarcation should be made to focus on only one care pathway. CRC consists of three pathways, which are the colon, short rectum and long rectum pathway. For each pathway a different efficiency calculation should be performed.

To make the analysis less complex more demarcations can be made. During observations and interviews it became clear that not every department has an evenly important role in the care for the patient.

Outpatient clinic surgery: At the outpatient clinic for surgery there is a large variety in labor mix. A nurse-practitioner (NP) for stoma care, NP for oncological care, physician-assistant (PA), and surgeon are involved in the outpatient clinic care. Wage differences exist

The organization and coordination of care for colorectal patients is mostly done by surgeons or specialized nurses.

Surgical ward: The surgical ward is the department most patients spent most time (excluding Intensive Care Unit for critically ill patients) and where care is provided for several days. The length-of-stay will account for most cost variation. The length-of-stay depends on the severity of disease, quality of care, quality of surgery, guidelines regarding post-operative care, the patient's reaction on care, and the patient's health status preoperatively (co-morbidities).

Surgery department: The department covering all operating rooms is one of the most expensive departments within a hospital. The differences between hospitals on efficiency of this department are based mostly on utilization. Turnover time should be minimized. Since different specialists make use of the resources, efficiency measurement should be specified to the colorectal patients.

Radiology: The care for CRC patients was least focused on the radiology department. This is a highly shared resource for the total hospital and diagnostics for CRC patients are only a slight percentage of all care provided. Also the processes between hospitals seem standardized and the process of providing the surgeon with dissemination diagnostics is standardized. We assume that therefore the radiology department can be discarded.

Endoscopy department: The endoscopy department is involved in the diagnosis of colorectal cancer and is one of the start points of the care path. The general practitioner, surgeon, internist or gastroenterologist can refer patients suspected for CRC to undergo a colonoscopy.

For rectal patients the radiotherapy department is an important part of the care path. This care is often provided by tertiary centers. Because this is out of the scope of the intramural surgical care for the CRC patient, this is not included in our research.

Proposed efficiency measurement method

We propose DEA as an appropriate method to assess efficiency of the colorectal pathway. This choice is based on the possibility to include multiple inputs and outputs, trade-offs can be made between these variables and it is a non-parametric approach. A non-parametric method is suitable for the colorectal care path because weighting criteria are difficult to establish. This difficulty is common since each MDU makes its own trade-offs between the mix of inputs.

A relevant measure is the use of outcome efficiency, which measures the relation between inputs and outcomes. These patient-related-outcomes are used as outputs. Since efficiency of care can be associated with Since environmental context is an important factor in outcome measurements, these should be case mix adjusted. The Dutch Surgical Colorectal Audit (DSCA) uses a method to measure per hospital the case mix adjusted complications and mortalities. As an outcome for the surgical process we want to measure the number of case mix adjusted patients without complications. This is the product of the care path. Most ideal would be to measure the actual health gain, but that is due to complexity and long term follow up not feasible.

As inputs we can measure the total number of FTEs of surgeons that are dedicated for colorectal surgery. Furthermore the total costs of the pathway can be calculated by using costs per activity and hence count the type of activities a patient underwent during the diagnostic and treatment process.

Inputs: A combination of labor inputs and capital inputs will reflect the trade-offs made in the different care paths. Besides after analysis it becomes clearer what causes the differences between hospitals.

Labor: the amount of labor will be expressed using work hour adjustment. Weighing is done using the average Dutch wage. A point of discussion however would be that trade-offs are being made between nurses and physicians, which is not always desirable.

Costs per activity will be calculated by defining the process in different steps.

Outputs: patient related outcomes are included in the outputs since efficiency is related with quality of care. These outcomes however should be case mix adjusted to correct for the environmental context (the factors a hospital has no influence on).

Table 4	Ratio analysis	Least-square regression analysis	Stochastic Frontier Analysis	Data Envelopment Analysis	Total Factor Productivity
Multiple inputs	-	+	+	+	+
Multiple outputs	-	-	-	+	+
Mix of monetary and physical variables	-	-	+	+	+
Unknown trade-offs between variables	n/a	-	-	+	-
Influence of outliers	+	+	-	-	+
Used in health care settings	+	-	-	+	-

A second approach

Since the data we want to use for an ideal and economical efficiency analysis, a second best approach is proposed and tested for the colon carcinoma patients. With the use of available data for 15 hospitals, a DEA analysis is performed. An input-oriented, constant returns to scale method is used.

Inputs that were used:

- Total lead-time (from first visit hospital to surgery) in workdays for all patients summed up, using the mean lead-time × the number of patients
- Total number of hospital visits prior to surgery for all patients summed up, using the mean number of visits × the number of patients

The products of a care pathway are treated patients. Another product is the summed length-of-stay of all patients. Since it is necessary to formulate all inputs and outputs in the same direction, the inverse of the length-of-stay is taken as an output measure. The median of the length-of-stay is used

Outputs that were used:

- Number of patients treated
- Total length-of-stay (from surgery to discharge) for all patients summed up, using the 1/(median length-of-stay) × the number of patients. We decided to use the median since after inspection of the data it appeared that the mean was greatly affected by outliers. These outliers are caused by exceptional complicated patients and disturb therefore the measurement because small number of patients were used in the analysis

Table 5: inputs and outputs used in DEA model

DMU	Patients treated	Inverse of length of stay	Total visits	Total lead-time
{Type}	*Output*	*Output*	*Input*	*Input*
H1	71	10.14	284.0	2122.9
H2	36	5.14	133.2	1443.6
H3	43	5.38	172.0	1165.3
H4	21	2.63	77.7	382.2

H5	18	2.57	73.8	444.6
H6	30	3.00	120.0	888.0
H7	27	3.00	110.7	1101.6
H8	42	1.53	180.6	1600.2
H9	24	4.80	144.0	703.2
H10	80	8.00	448.0	2392.0
H13	46	5.11	294.4	1720.4
H14	32	6.40	160.0	1040.0
H16	48	7.39	321.6	2054.4
H17	44	6.29	264.0	1592.8

For the calculation software was used (a plugin for Microsoft Excel, developed by Joe Zhu) and an online DEA analysis application (Data Envelopment Analysis Online Software, www.deaos.com , developed by Behin-Cara). Both applications gave the same results of the analysis.

Table 5 shows the data used as inputs and outputs in the analysis. The original data on hospital level can be found in Table 14.

After the DEA-calculation, we can conclude that based on the chosen inputs and outputs, three DMUs appear efficient (H2, H4 and H14). Table 6 shows the result of the analysis and the calculated weights for the variables. Since no constraints on weights were defined, it was possible for DMUs to have zero weight on items.

After the calculation of the relative efficiency of the DMUs, super-efficiency was calculated in order to see differences between the efficient DMUs. Table 7 provides the super efficiencies.

Table 6: Results of efficiency measurement and calculated weights of inputs and outputs

	Efficiency	Patients treated	Inverse of length of stay	Total visits	Total time
H1	97.07%	0.004476619	0.064388096	0.003135653	5.15683E-05
H2	100.00%	0.009096728	0.130840039	0.006371815	0.00010479
H3	92.50%	0.021511628	0	0.005813954	0
H4	100.00%	0.016998763	0.244496573	0.011906805	0.000195817
H5	96.74%	0.017601027	0.253159058	0.012328662	0.000202755
H6	92.50%	0.030833333	0	0.008333333	0
H7	90.24%	0.033423668	0	0.009033424	0
H8	86.05%	0.020487265	0	0.005537099	0
H9	99.20%	0	0.206659832	0	0.001422071
H10	66.07%	0.008258929	0	0.002232143	0
H13	57.81%	0.012567935	0	0.003396739	0
H14	100.00%	0.008061105	0.115944474	0.005646411	9.28598E-05
H16	61.98%	0.004017181	0.057779915	0.00281384	4.62759E-05
H17	66.15%	0.004919629	0.070759995	0.00344596	5.66716E-05

Table 7: Results and ranking of super efficiency

	Super efficiency	Rank
H1	97.07%	5
H2	108.09%	3
H3	92.50%	7
H4	135.71%	1
H5	96.74%	6
H6	92.50%	8
H7	90.24%	9
H8	86.05%	10
H9	99.20%	4
H10	66.07%	12
H13	57.81%	14
H14	113.65%	2
H16	61.98%	13
H17	66.15%	11

Discussion

There are several methods to measure efficiency of a care path. The most ideal method and interesting from a cost containment perspective would be to include economical variables or surrogates for those. This could be labor hours or available capacity at OR or outpatient clinic. When using monetary variables one should account for differences in currency exchange rates and value variations over time, differences in wages and costs of resources when comparing care paths in different countries and over time. In a national setting on a short term these monetary changes can be neglected.

Another approach from a patient and physician point of view of efficiency is to make use of number of hospital visits and timeliness. Because this data was available a test was performed to see if efficiency measurements using lead-times, number of hospital visits, patients treated and length of stay would work. The method returned H4 as most efficient. This was also our hypothesis when just inspecting the raw data.

To test consistency and validity of the efficiency measurement, we suggest evaluating the efficiency scores over time. Efficiency is unlikely to change greatly in a short time (without large structural changes in the organization of patient care). Therefore data from for example one half of a year and another half of a year can be compared using correlation analysis.

In the DEA calculation we used the medians of the input and output variables. No correction was done for the variance in the hospital or standard deviation. Also the confidence interval was not calculated. Using confidence intervals, one could do multiple DEA calculations to test the sensitivity of the data for changes. A lower limit and an upper limit can be used to evaluate if changes in efficiency occur.

Chapter 4 Development of a leanness framework

This chapter is dedicated to the second and third research question:

2. How can "leanness" be described and how can it be operationalized for colorectal surgical care?

3. How can the process characteristics framework, initially developed by Van Vliet et al (2011), be adapted to the colorectal cancer care pathway in order to construct a quantifiable framework to determine " leanness" of a colorectal caner care pathway?

4.1 Methods

Leanness framework

For the quantification of leanness a framework had to be constructed based on the six operational lean characteristics as were proposed by (Ellen J Van Vliet et al., 2011). The operational categories, which need to be researched, were: operational focus, autonomous work cell, physical layout, multi-skilled team, pull planning and elimination of waste. The constructed model should emphasize on the multiple stages of the value stream (interdepartmental) instead of focusing on individual stages or single departments.

This study is an explorative study in order to explore the possibilities for constructing a new measuring instrument for the assessment of leanness.

We did a literature study to identify lean metrics to quantify leanness based on the previously mentioned six operational characteristics. These elements have been coupled to possible indicators to measure objective and quantitative the different subgroups of the framework. Often metrics or principles that are now named Lean or Six Sigma already were applied before the term itself was used. Therefore, the research should be broader than just Lean or Six Sigma and should also focus on general performance indicators. In this part of the research we focus on non-financial indicators. An earlier master thesis research by Anne Niezink (2011) proved that it was difficult to obtain reliable data concerning real costs of care for different hospitals.

The search terms we used were: *lean metrics, leanness, quantification lean, and lean framework* in the search engine Scopus. Results were sorted on relevance. Furthermore research was conducted on the different items of the framework proposed by Van Vliet (Ellen J Van Vliet et al., 2011). Search terms here used were: *operational focus, layout, multi skilled team, work cell* and *pull planning.* The search terms were also combined with *lean* to gather specific lean principles for the different items of the framework.

A key assumption that has been made is to only look at the CRC care path for elective surgery. Furthermore the research will focus on the intramural pathway, which can be roughly defined as:

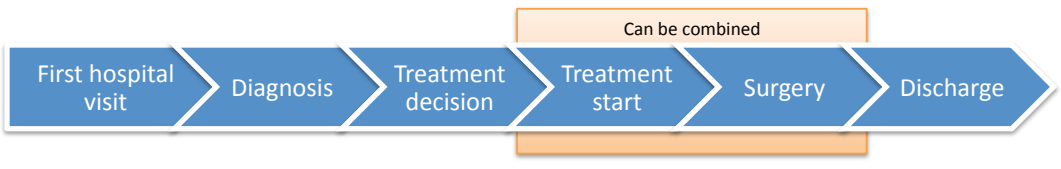


Figure 9. Simple flow chart of care process

The start of the treatment does not necessarily mean the start of the surgery (from a patient point of view) since for rectum carcinoma patients preoperative radiotherapy is often advised.

4.2 Results

Often not only the term lean is used when the literature described lean. Lean Six Sigma is a combination of Lean Thinking and Six Sigma as a systematic innovation effort to enhance healthcare and remain or become cost efficient, deliver high quality care and get a high patient satisfaction (Koning et al., 2006). Besides, the Theory-of-Constraints is used in literature about pathways and its role in improving healthcare (Mould, Bowers, & Ghattas, 2010).

In an article by Saurin, Marodin, & Ribeiro (2011), a framework was proposed to assess the use of lean production practices in manufacturing cells. Attributes of lean production principles were divided into subdomains: a) human resources, b) production planning and control, c) process technology. Using these subdomains both human and technical factors are included. The three subdomains are based on a technical subsystem, a personnel subsystem and a work design subsystem. A manufacturing cell is an administrative unit with a dedicated infrastructure with independent performance targets, workers and supervisors. It should be monitored and managed separately from other resources (Saurin et al., 2011). Although healthcare is different from a production system parallels can be drawn. A manufacturing cell could be compared with a department as radiology, the outpatient clinic or the operating center. Each of the different departments is a semi-autonomous subsystem of a hospital.

In Lean Thinking one of the primary analytical tools is the value stream map (Koning et al., 2006). A value stream map can be used to identify activities in the current state (both value adding and non-value adding) and hence waste can be identified. Lead and cycle times often also become visible. If a step in the process does not add value or will result in a redundancy for a next process downstream, the process step should be eliminated if possible. The usage of a multidisciplinary care pathway is an example of a value stream map. Ng et al (2010) applied process mapping to increase the efficiency of an emergency care department (ECD) in Canada. He made the comparison of an ECD with a production system as ECD as timely, accurate and empathetic medical care (Ng, Vail, Thomas, & N. Schmidt, 2010). Not only the processes were part of the evaluation and were improved, also the physical layout of the department was changed. This varied from placing stock carts with 90% of most used stock within close reach of a patient, reduce stocking to a certain maximum and minimum control levels and placing visual markings on the floor for standard equipment such as an ECG machine in order to give them a fixed place.

As already stated in the introduction, one could focus on different organizational levels when assessing leanness. One could focus at the base: the implementation of Lean Principles in the work cell design. Another measure would be the leanness of the care pathway. The differences can be depicted in Figure 5. In this figure the different organizational levels are related to Lean. At top level we can discuss the Lean enterprise, which is in this case the hospital. At a deeper level there is a difference between the pathway that is used for a certain disease and the hospital departments themselves. At an even more detailed level, the design of the process for disease management, in this case the colorectal cancer care path can be placed. The other part is the implementation of lean principles on a department.

In literature a relation can be found between a care pathway and supply chain management. The definition of supply chain management can be derived from Chan et al. (2003) who gives the definition: *"Supply chain management is the integration of key business processes from end user through original suppliers that provide products, services and information that add value for customer and other stakeholder"*. In this definition the key business processes can be seen as for example the diagnostics that are done at radiology, which is the original supplier. The product could be the CT-scan, the service and the description of the scan by a radiologist and the information is valuable for both the patient and the surgeon.

When determining leanness the focus could be on the implementation of lean practices (which should be visible in the organization) or the performance, measured in outcomes.

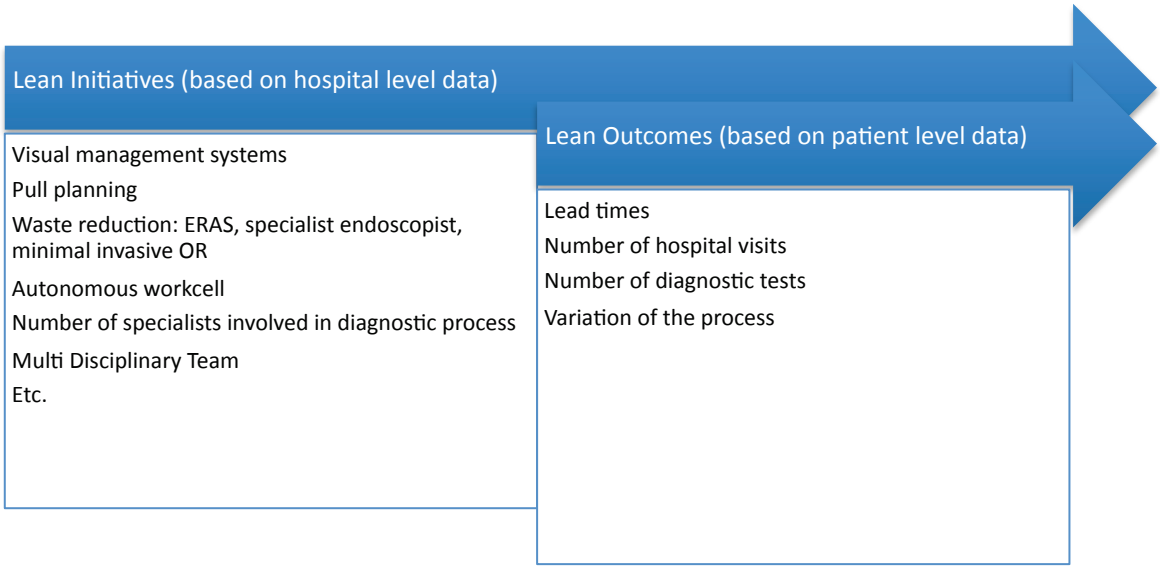


Figure 10. *Lean initiatives (process and organizational characteristics) and lean outcomes*

Examples of benefits from Lean Thinking were found in literature and could be measured. For this search the pure financial factors were excluded in this part of the report because of time constraints. These are examples and the list is not meant to be exhaustive.

Table 8: Lean attributes

Attributes	**Type of indicator**	**Reference**	**Possible measure**	**Part of framework**
Shorter cycle	Outcome; streamlining of process	(Bhasin, 2008), (Slack et al., 2007)	Time between patients	No
Shorter lead times	Outcome; streamlining of process	(Bhasin, 2008), (Slack et al., 2007)	Lead times	Yes
Faster response time	Outcome; just in time	(Bhasin, 2008)	Access time hospital	No
Greater production flexibility	Outcome; customer variation response	(Bhasin, 2008)	Clear distinction between different types of CRC	Yes
Higher (care) quality	Outcome;	(Bhasin, 2008)	Shorter length-of-stay, lower case mix corrected mortality/morbidity/complications	Partly

Better customer service	Outcome;	(Bhasin, 2008)	Customer satisfaction, Consumer Quality Index	No
Higher throughput	Outcome; just in time	(Bhasin, 2008)	Lead times	Outcome measure
Smooth information flow	Organizational structure;	(Vinodh & Chintha, 2011)	Electronic Health Record, Multi Disciplinary Team meeting,	Yes
Status of quality	Process; visual management	(Vinodh & Chintha, 2011)	Visual management system	Yes
Status of productivity	Process; visual management	(Vinodh & Chintha, 2011)	Visual management system	Yes
Principles for waste elimination	Process; proper care	(Vinodh & Chintha, 2011)	Enhanced Recovery After Surgery Program; Specialist endoscopist	Yes
Manufacturing planning	Process; pull system	(Vinodh & Chintha, 2011)	Central planning of activities;	Yes
Process transparency	Process; visual management system, process alignment	(Parry & Turner, 2006)	Use of pathways, use of flowcharts	Yes
Number of stages in the process	Process; waste reduction	(Slack et al., 2007)	Number of departments involved (diagnostics, treatment)	No
Patient centeredness	Structure, value	(Slack et al., 2007)		No
5S application	Structure, complexity reduction	(Slack et al., 2007)	Tidiness, sorting materials, visual management systems	Partly
Multi-skilled teams	Structure, multi-skilled team	(Kollberg, Dahlgaard, & Brehmer, 2007)	Number of people in department belonging to a multi-skilled team	Yes
Scheduling	Structure, pull planning, complexity reduction	(Kollberg et al., 2007)	Number of non-urgent patients that are being boked on low-demand periods	Yes
Process control	Process, value stream	(Kollberg et al., 2007)	Amount of processes mapped, amount of process measurements	Yes
Continuous improvement	Structure, continuous improvement	(Kollberg et al., 2007)	Number of improvement suggestions per employee per year, Number of people involved in improvement teams	Yes

The different approaches that are used to measure the leanness based on the actual outcomes of care are:

Lead-time

Lead-time is the time between two events, for example the time between a colonoscopy and the definite result of the pathologist. Different lead times in the colorectal process can be measured. Using lead times the time of the process can be quantitatively assessed and compared. One of the items in lean thinking is to reduce throughput time (Slack et al., 2007). This is of course closely related to lead times. However, not all delay and longer lead times are waste. On occasions there is therapeutic or diagnostic value to delay. The delay or lengthened lead times we focus on is on system-induced delay and not the delay that clinicians or guidelines wish to prescribe. Nevertheless a clear distinction should be made between system-induced delay (which is also influenced by choices of the clinician) and delay that really adds value to the process (McClean et al., 2008). Also clinicians were asked about lead-times and they believe that patients want to be treated as fast as possible, but sometimes they also need some time to handle the situation. The diagnostic process and oncological care can be overwhelming when the process steps follow each other up too quickly.

The diagnostic phase can be defined as the time between the first diagnostic test (such as a colonoscopy or CT-scan) and the last visit to the outpatient clinic prior to surgery. Another possibility would be to take the date of the MDT as the date for the end of diagnostic process since at that moment the final diagnosis and treatment strategy is decided. In practice however not every patient is discussed in a MDT and for the total patient group it is therefore easier to take the date of the last visit to the outpatient clinic of surgery.

The therapeutic process is considered here as the day of surgery until the day of discharge since this research is focused on the surgical care for the colorectal patient. It would be better however to include both chemotherapy and radiotherapy in the process analysis for the total care path of the CRC patient since this reflects more the patient point of view and stresses the importance of patient-centered care. The lead-time between the day of surgery and the day of discharge depends highly on the use of a fast track protocol (see section about elimination of waste) and the medical condition of the patient. Therefore this lead-time is less valuable in assessing leanness and therefore not included in the framework.

Another method to measure the total process of diagnostics would be the time between the first and the last test. It is however still unclear when the real final diagnosis and treatment plan has been made.

The therapeutic process can be defined as the time between the first start of the therapy and the discharge of the hospital. In the case of CRC there is a large difference between the different locations and ingrowth of the tumor.

Number of visits to hospital

The number of visits to the hospital is a measure for waste. The less visits, the Leaner the process is considered. Also a combination of different process steps on one day is a measure of lean since it is time saving for the patient and creates more flow.

Process standardization

- To look whether a process is standardized in a hospital one can look retrospectively at the variation of the process. This can be compared to the mean or the median of the lead-time. It is assumed that in a hospital where the care process is standardized, aligned and according to strict protocols the lead-time will be more or less the same for the elective patients.
- The regression between two events could be calculated to quantify the relation between date for the endoscopy and the surgery. Another regression that is useful is the relation between date of surgery and the date of discharge.
- The standard deviation (SD) or the variance reflects the process standardization since the more variance and the higher the standard deviation the less the standard the care process is since there is no standard lead-time in the care pathway.

Besides looking at actual outcomes it is interesting to see which lean instruments/tools or principles are visible at the department. A list of possible tools, which could be seen on the departments, are presented in Table 8.

4.2.1 Levels of measurement

When measuring variables, the attributes can be composed of different levels of measurement such as: *nominal*, *ordinal*, *interval* and *ratio* (Babbie, 2004).

Nominal measures are characteristics of exhaustiveness and mutual exclusiveness like the presence of a radiotherapy unit within the hospital. The only thing that can be said when two hospitals are compared if they

have the variable in common or not. *Ordina*l measures can be logically ranked and represent relatively more or less of the variable. However the distance between two states does not necessarily be the same. What can be concluded is that one hospital has more, less or the same of the variable when compared to another hospital.
Interval measures are like ordinal measures only now the actual distance separating different states does have a meaning. *Ratio* measures have all the characteristics of nominal, ordinal and interval measures but have in addition a true zero point like number of hospital visits. In the construction of the framework as much as possible

4.2.2 Methodologies to set up composite measures

Specific techniques exist to combine indicators into a single measure. Examples are indexes and scales. Both indexes and scales are ordinal measures. An index is a composite measure that summarizes different variables and can be ranked. A scale is a more sophisticated index since in a scale the different valuables that attribute to the final score can have a different weighing (Babbie, 2004).

The different variables used as surrogate variable to assess the implementation of lean initiatives are described below. They are categorized per factor of the six operational lean characteristics. No weight adjustments have been made since the weights are not investigated. This is a weak point of the scorecard and could influence the usability. When using equal weighting can also introduce double counting if two metrics are highly correlated (Profit et al., 2010). We based the point distribution on empirical data gained through observations during on-site visits at five hospitals.

Between brackets the “leanest“ score is indicated. The type of characteristic is closely linked to the triad planning and control, the system and the performance. Figure 3 visualizes this. A hospital has most control over the planning and control characteristics, next is the system which is a mix of characteristics which could be relatively easily changed (using an electronic health record) by hospital management or given facts (such as location, number of beds etc.)

Performance is here seen as ‘lean’ outcomes since this is true measure for leanness. Lean characteristics are evidence that an organization is trying to be lean, however it says nothing about the true leanness itself. The ‘lean’ initiatives are rated in the scorecard (Table 9).

Using composite scores makes the scoring less complex. It does, however, also hide certain information since it is not possible to differentiate between two hospitals or identify differences, when one hospitals scores high in a category on a certain item, and another hospital scores high in the same category on another item. There are different aggregation methods. Profit et al. (2010) describe the three most used ones; additive aggregation (full compensation), multiplicative aggregation (partial compensation) and non-compensatory methods such as multi-criterion analysis (no compensation). Additive aggregation is adding up the scores in a category. This is the simplest method, but allows hospital to compensate for low metrics with another metric. We choose this method since it is not clear yet how the metrics within a category influence each other and how hospitals score on them. No total aggregate score is feasible since weighting of categories is not established.

Table 9: Scorecard organizational ' lean' characteristics			
Between brackets the "leanest" score is indicated. The MP is the maximum amount of points that can be scored per category			
	Rating	Definition	Type of characteristic
1. Operational focus	MP= 6		
a.) Focuses on reducing lead time + hospital visits + costs at same time	0 or 1 (1)		Planning and control
b.) Hospital focuses on operational aspects	0 or 1 (1)		Planning and control
c.) Commitment to quality [RPA]	0 – 4 (4)		System
2. Autonomous work cell	MP= 10		
a.) Multidisciplinary outpatient clinic for colorectal patients	0 or 1 (1)		System
b.) Fixed sessions per week?	0 or 1 (1)	0=yes, 1=no	System
c.) All diagnostics present at hospital	0 or 1 (1)	0=no, 1=yes	Planning and control
d.) Radiotherapy present at hospital	0 or 1 (1)	0=no, 1=yes	System
e.) Specialized nursing ward	0 or 1 (1)	0=no, 1=yes	System
f.) Slots planned in advance			
a. Outpatient clinic Gastro-intestinal	0 or 1 (1)	0=no, 1=yes	System
b. Outpatient clinic Surgery	0 or 1 (1)	0=no, 1=yes	System
c. Diagnostics: X-thorax	0 or 1 (1)	0=no, 1=yes	System
d. Diagnostic: CT-scan	0 or 1 (1)	0=no, 1=yes	System
e. Diagnostics: MRI-scan	0 or 1 (1)		System
3. Physical lay-out	MP= 12		
a.) Safety environment, cleanliness and order [RPA]	0 – 4 (4)		System
b.) Visual management system [RPA]	0 – 4 (4)		System
c.) Use of space, movement of materials, and product line flow [RPA]	0 – 4 (4)		System
4. Multi-skilled team	MP= 4		
a.) Use of a multi-disciplinary team meeting	0 or 1 (1)	0=no, 1=yes	Planning and control
b.) Use of a dedicated surgery team	0 or 1 (1)	0=no, 1=yes	Planning and control
c.) Formation of a surgery team	0 or 1 (1)	0=no, 1=yes	System
d.) Formation of a nursing team	0 or 1 (1)	0=no, 1=yes	System
5. Pull planning	MP:= 16		
a.) Using one-stop shop for diagnosis and staging	0 or 2 (2)		System
b.) Using a clinical path for colorectal malignancies	0 or 1 (1)		System
c.) Using or planning to use a flow chart	0 or 1 (1)		System
d.) Management of complexity and urgencies [RPA]	0 – 4 (4)		Planning and control
e.) Supply chain integration [RPA]	0 – 4 (4)		Planning and control
f.) Scheduling system of outpatient clinic and OR [RPA]	0 – 4 (4)		Planning and control
6. Elimination of non-value adding activities (waste)	MP = 8		
a.) Using a fast-track protocol based on Enhanced Recovery After Surgery (ERAS)	0 – 3	0=no protocols, 1=protocols available, 2=idem + checklist is used, 3=idem + checklist is checked and feedback is given	System
b.) Using a dedicated endoscopist	0 or 1		System
c.) Use of electronic health record		0=no, 1=yes	

a. Outpatient phase b. Inpatient phase d.) Single patient file e.) Open access colonoscopy	0 or 1 0 or 1 0 or 1 0 or 1	0=no, 1=yes 0=no, 1=yes 0=no, 1=yes 0=no, 1=yes	System System System Planning and control

In Table 10 the different Lean outcomes are summarized.

Table 10: Lean outcomes		
Lead times a. First hospital visit – surgery b. Surgery – discharge c. Pathology from endoscopy (PA) – MDT meeting d. MDT meeting - surgery	Ratio Ratio Ratio Ratio	Mean, median, 66% percentile, 90% percentile
Number of patient visits prior to surgery	Ratio	Mean, median, 66% percentile, 90% percentile

Operational focus:

Focuses on reducing lead time + hospital visits + costs at same time

In a lean incorporated hospital or pathway the focus is on medical performance (quality), reduction of lead times (flow) and reduction of costs (economic efficiency) at the same time. A survey could be used to gain knowledge about performance of a surgical colorectal pathway within a hospital. However, surveys are subjective and it is often difficult to get the proper lean indicators from a questionnaire (Wan & Frank Chen, 2008). Therefore from interviews with hospital staff this item is scored by the interviewer.

Hospital focuses on operational aspects (or on medical aspects)

This question is asked to GE-surgeons in various hospitals using a list of factors that could influence the organization of the care process. They are asked to rate from the most important to the least important. The different factors that are used are: patient satisfaction, employee satisfaction, utilization of capacity, cost reduction, efficiency, quality of medical care and salary of medical specialist. The three most important factors are hence listed and a choice is made between hospital is focusing on medical content, operational aspects or both.

Number of hospital visits prior to surgery

In the original framework by Van Vliet et al. (2011) the number of hospital visits was one of the performance indicators. Besides, the GE-surgeons that were interviewed, also stressed the importance of keeping the number of hospital visits low and have different activities combined. It is assumed that if two activities take place on the same day, the patient went to the hospital only once. One remark should be made; most surgeons prefer timeliness above combination of visits. If activities are separated and it becomes therefore possible to have an earlier diagnosis, then the separate visits are preferred. The visits that will be included are the visits necessary for diagnostic tests, visits to the outpatient clinic of gastroenterology to see the gastroenterologist (or in case of non presence of a GE-specialist the internist) and the visits to the surgical outpatient clinic. The appointments with nurse practitioners or other caregivers such as physiotherapist, dietician, radiotherapist or the oncology department are not counted here to reduce complexity of measurement.

Commitment to quality

Goodson et al. (2002) developed a Rapid Plant Assessment (RPA). This is a measuring tool to quickly score a manufacturing plant on how on first sight a process is organized and different aspects are scores and hence an index-score is calculated. In the different categories of the framework also elements of the RPA are described. In an adapted version of the RPA the commitment to quality is assessed for the hospital in total on a 5-point Likert scale.

Commitment to quality can be defined as striving for continuous improvement of quality and productivity. It is assumed that attention to quality is easy to spot. If employees are proud of their program they will give it a name, post banners and make the program visible. Besides results of the program could be published on publication boards for employees or intra-net. Besides it must be easy for an employee to register (medical) faults and there should be openness about mistakes and critical thinking should be encouraged. It should be easy to give feedback on a process and give suggestions for improvement. This is in line with Lean principles.

Autonomous work cell:

An autonomous work cell can be described as a dedicated department delivering only care for a specific disease, earlier described as a focused factory. In the colorectal surgery this could be seen as an outpatient clinic reserved only for colorectal surgical patients. The number of workstations in this work cell and the workstations arranged in the processing sequence to facilitate flow are included as well. Since colorectal surgery is less specialized as the cataract surgery, which was analyzed by Van Vliet et al. (2011) using the category “autonomous work cell”, there are some modifications made to the framework.

Fixed sessions per week

The number of fixed sessions per week for colorectal surgery is measured in the framework to measure how autonomous the work cell is. The more sessions fixed per week for CRC surgery, the more dedicated the work cell is for CRC care and therefore is more Lean.

All diagnostics present at hospital

The physical presence of all necessary diagnostics within the hospital is leaner than having some diagnostics in a different hospital, since this increases the number of handovers and processes are likely to be less aligned and appointments are more difficult to combine. Furthermore, seen from patient perspective it is more patient friendly to let the patient have as less different departments involved as possible.

Radiotherapy present at hospital

We assume it is more difficult to align the process sequence if the radiotherapy department is not physically present at the hospital and the surgeon needs to make appointments with a tertiary institution for the radiation therapy. Radiotherapy is in practice only indicated for rectal carcinoma. The planning of the surgery depends heavily on the radiotherapy and therefore alignment is important for both operational aspects as well as medical quality.

Specialized nursing ward

Using a specialized nursing ward where care is provided to a small patient mix and only gastro-intestinal patients are treated. This could be a stand-alone ward or a section of the ward reserved for the colorectal patients.

Slots planned in advance

Using the Theory-of-Constraints the critical pathway should be addressed when improving flow. The care process depends on resources such as availability in the schedule of the outpatient clinics, radiology department, operating room, nursing ward and in some hospitals a standard Intensive Care Unit (ICU) admission is part of the

pathway. When slots are planned in advance for the colorectal patient, which can be based on historical data and expected number of patients, care can be aligned and complexity is reduced since all different steps are in a logical sequence and the patient flows through the health care system.

Lean physical layout:

In a lean physical layout processes are aligned and close to each other. There are little handovers and transfers of information. When assessing Lean physical layout one could focus on the visible implementation of Lean principles like 5S, visual management system, protocols, efficient way of organizing departments and facilitating flow.

In an adapted version three different categories can be scored on a 5-point Likert scale, which are:

- Safe environment, cleanliness and order: In a clean environment and where workplaces are neat and orderly different materials are easy to find, easy to count or their stock can be estimated. In these environments the air quality is good, the workplace is well lit and the levels of noise are low.

- Visual management system: It is assumed that in well functioning departments visual signage and instructions are visible and guiding employees. Such signage can assist staff to increase productivity, carry out the right work at the right time at the right place. Good visual management also includes displaying information like an overview of the team members and vacation schedules. Color coding or, sound or light signals, protocols, bed planning, current state of the operation, and quality or productivity overviews are examples of visual management.
  By making information visible and transparent for the employees (and the patient), they will become more motivated to improve the processes. Information boards, schedules for the day and displaying waiting times are examples of transparent information in healthcare (Kollberg et al., 2007).

- Use of space, movement of materials and product line flow: In the best organizations space is efficiently used, materials are moved as less as possible along the shortest route. The storage of materials and instruments is at the place where they are used.

Each of the categories is scored for five different departments, which were identified as highly involved in the care for the CRC patient:

- Outpatient clinic surgery
- Endoscopy / outpatient clinic gastroenterology
- Radiology
- Operating center
- Nursing ward

Multi-skilled team:

In a multi-skilled team the different team members can perform multiple tasks but limited by their specific competences and regulations. According to Lean Thinking the medical system should rethink their departmental structure and organize care and its expertise into multi-skilled teams. The intention is that the patient receives steady attention and treatment. In a smaller team, but with broader skills, most patient problems can be solved within the work cell. The classic system focuses on narrowing skills.

Multi Disciplinary Team meeting

During a multi disciplinary team meeting a patient is discussed and care can be aligned such as radiotherapy, chemotherapy or stoma care. Because of the complexness to gather all kinds of specialist together the MDT meeting is on weekly basis. For rectal carcinoma each patient has to be discussed at a MDT preoperatively and postoperatively (Association of Comprehensive Cancer Centers - The Netherlands, 2011). This is due to the

relatively complex care path of rectum carcinoma. For colon carcinoma in 2009 this was not yet compulsory, but currently also these patients should be discussed both pre- and postoperatively. Thinking in Lean principles a MDT can have a strong advantage and a strong disadvantage. The advantage is that care is provided at high quality since not only the surgeon is involved in the diagnostic process and setting up a treatment plan. The disadvantage is that not every patient is complex enough to discuss in a MDT since no real added value is given to the knowledge the surgeon has. Also the treatment plan that is proposed will not be changed. Waiting until the MDT will, however, delay the process and therefore lead times will be increased.

Use of a dedicated surgery team

Using a dedicated surgery team is linked with the autonomous work cell and all team members involved know exactly how care should be provided. It is assumed that this will increase quality of care and probably also faster operating time. On the other hand, the same dilemma in Lean Thinking arises as compared to the MDT. Once a team member of the dedicated surgery team becomes unavailable, the surgery cannot be performed and therefore the flexibility is decreased.

Pull planning:

In pull planning the patient flows through the process. The care path could be seen as a supply chain. A supply chain could be viewed as a single entity, which is managed centrally, in which all the involved team members are functionally integrated and their work is synchronized (Chan & Qi, 2003). They share a mutual goal, which is to serve the customer, in this case the patient.

With pull-planning Van Vliet et al. (2011) mean that there are as less customer order decoupling points as possible and the patient flows through the whole process without many interruptions. An order decoupling point is the moment in the process when certain actions need to be planned (Hopp & Spearman, 2007). This could be achieved by directly planning all necessary appointments at the first decent suspect of a malignancy. The patient therefore does not have to wait until the resources become available again for the patient, but the resources already are prepared.

Scheduling activities in advance is actually not pull planning, since the definition of pull planning in manufacturing business would be to do not produce anything without demand from a work cell further in the process line (Hopp & Spearman, 2007).

Using one-stop shop for diagnosis and staging

In a Lean care path the additional diagnostics can take place at a preoperative assessment day. This is a one-stop shop diagnosis and staging. In this case the patient only has to visit the hospital once for all diagnostics. This will reduce the lead-time for the diagnosis and will let the patient flow through the system. It is also a form of patient centeredness where the patient is placed in the foreground with time and comfort as key elements of the system. This would attribute to the leanness (Womack & Jones, 2003). This category gets 2 points because of the importance compared to the other items in this category.

Using a clinical path for colorectal malignancies

When a clinical path is used the care is standardized for patients and processes can be aligned. Therefore flow is created. Doctors to treat patients on an individual basis but with a care pathway the care for identifiable patient groups can be structured. It is assumed that using a standard pathway for patients is more ‘lean’ compared to not using a pathway or flowchart to get insight into patient streams. The care pathway can act as a value stream in ‘ lean’ terms and make it visible for the hospital or physician which value adding activities have to be done and which non-value adding activities are present.

Using or planning to use a flow chart

It is assumed that hospitals that have a flowchart of their process have done some kind of value stream mapping and have therefore implemented one of the most important factors of Lean manufacturing; identifying value and waste.

Management of complexity and urgencies

One of the items of the RPA is the category "management of complexity and urgency". This item is rated on a 5-point Likert scale for the five different departments (see page 36). In this category it is judged how well a department can cope with variability of patients (such as complexity or time of arrival) and with urgencies. For this scoring observations should be done and besides an employee with enough knowledge about the whole department should be interviewed in order to gain hidden information, which is not easily visible. Certain indicators such as the manual recording of data and a large number of keyboards (Goodson, 2002) can be used as a surrogate measurement. In the best organizations it is not necessary that the involved employees each have their own file and have to record the status of the patient in the care process. Inventories should be kept to a minimum but never too little. An electronic check when delivering drugs to patients at the ward for example is a safety check for medication errors and therefore serves the reduction of complexity.

Supply chain integration

This is another question from the RPA and is scored overall for the hospital. In a well integrated supply chain there is a limited number of suppliers and the delivery of materials is standardized through the hospital. High quality and cost reduction should be a focus. Also the suppliers can do the leveling of inventories. The lead times, costs and quality indicators should be published.

Scheduling system of outpatient clinic and OR

A proper scheduling system for the outpatient clinic and the OR are important since both departments have a high influence in the care for the CRC patient (Hompes & Cunningham, 2011). Balancing the capacity with the demand is a technique to create flow. It is assumed that if scheduling is done in a smart way the lead times are reduced and the patients flow more smoothly through the care system.

Elimination of non-value adding activities (waste):

There are several things a hospital can do to eliminate waste. One of this is the implementation of a fast-track protocol. Another type of elimination of waste is the appointment of a coordinator for the care of the CRC patient. In this way it one person has the overview of all care for the patient and can improve alignment and sharing of information. This is sometimes referred to as a case-manager, but it could also be the surgeon or a special nurse.

Fast-track protocol

In the care pathway for the colorectal patient the (Lassen et al., 2009) usage of a fast-track protocol becomes more and more standard for elective patients. A fast-track protocol has as goal to enhance the recovery of the patient and therefore reducing morbidity, mortality, reducing length of stay and enhancing patient experience.

There is a large amount of scientific evidence the relatively new fast-track protocols really enhance the recovery of the patient. The well-known protocol ERAS (Enhanced Recovery After Surgery) is especially for colorectal surgery and was developed in 2005, based on a consensus review (Lassen et al., 2009).

In literature contrasting outcomes of the ERAS program can be found. However, they do agree about the reduction of length of stay and that it is beneficiary in comparison with conventional recovery care (Spanjersberg, Reuring, Keus, & van Laarhoven, 2011).

The elements of the fast-track protocols is based on mainly four pillars (Donohoe et al., 2011):

- Pre-operative preparation
- Anesthetic factors
- Intraoperative and surgical factors
- Post-operative management

A more detailed and extended list is presented in Appendix A.

Using a dedicated endoscopist

In a study by Lorenzo-Zúñiga et al. (2009) it was found that high volume endoscopist make less mistakes, complications and the quality of the performed endoscopy was better (Lorenzo-Zúñiga et al., 2009). There is a rising interest in the use of dedicated endoscopist. Besides these dedicated endoscopist does not have to be a doctor, but also could be a nurse(-practitioner) with an additional training. The quality and safety of the endoscopy is compared in a British study and it has been found that it does not matter if doctors or nurses performed the endoscopy. Furthermore the patient satisfaction was higher for patients who got their endoscopy by a nurse-endoscopist (Maslekar, Hughes, Gardiner, Monson, & Duthie, 2010; Williams et al., 2009). The cost decrease that is expected if nurses will perform the endoscopies is not yet proven and it is likely that there will be no significant difference (Richardson et al., 2009).
Nevertheless it is expected that a dedicated endoscopist will have less interruptions from other tasks that need to be performed and this could be seen as a Lean principle.

Use of electronic health record

The use of an electronic health record will promote a better structure in information and all care providers can have access to up to date information about the patient. In a Lean organized pathway there is a smooth information flow (Vinodh & Chintha, 2011). Health records on paper are only present at one location, not readable for all care providers and multiple providers of care cannot update it.

A distinction has been made between the outpatient phase (outpatient clinic, preoperative diagnostics) and the inpatient phase (during surgery and stay in hospital). This was based on the observations that were done in 18 Dutch hospitals.

Single patient file

Having a single patient file will reduce complexity and will enhance the smoothness of information flow. Each department involved in the process sequence has than the same source of information and all updates are at the same place. In a Lean organization no time should be spend for updating multiple files.

Open access colonoscopy

Open access colonoscopy allows referral from GP to a colonoscopy straight away without prior gastrointestinal consultation at an outpatient clinic. This allows the procedure to more accessible. Studies have been carried out to prove that this way of organizing care is as safe as a pre-assessment by the gastroenterologist. An interview concerning possible complications is carried before the endoscopy is performed, but does not necessarily have to be during a consultation (Rainis, Keren, Goldstein, Stermer, & Lavy, 2007).

In a study by Klemann et al. it was investigated whether open access colonoscopy would be wisely used by GP's to send in patients more frequently to detect malignancies earlier. Besides it will reduce the number of patient visits to the hospital since the patient does not have to come prior to the endoscopy for a consultation by the gastroenterologist (Klemann et al., 2011). It can also enhance the lead times since now only one appointment has to be scheduled instead of two.

4.2.3 Environmental context

To identify differences between hospital types and their leanness the following characteristics were collected:

Table 11: Environmental context

Item	Options
Type of venture surgeons	• Paid employment • Staff venture • Individual venture
Hospital Type	• Categorical • Academic • Large non-academic • General
Involvement of surgery department in education and training	• No • Yes, for medical interns • Yes, for surgical residents • Yes, specialization surgical oncology • Yes, specialization gastrointestinal surgery
Number of beds	Ratio (rounded to 50 beds to keep data anonymously)
Member of the association of tertiary medical teaching hospitals (STZ hospital)	• Yes • No

4.2.4 Analysis of data

Table 9 shows the framework to score for lean characteristics present in the departments involved in the CRC care. The points of the framework will be summed up per area to get an aggregate score per category.

To account for outliers the lead times will be calculated in percentiles, a 66% and a 90% percentile. The 66%-percentile represents approximately 2/3 of the patients. The 90%-percentile only filters out a few extreme outliers but can be less useable since the numbers of patients that can be analyzed are quite low per hospital. Furthermore the mean and median will be calculated. The difference between the mean and median is a measure for the skewness. The median is less effected by outliers and will therefore be more reliable to measure lead-times compared to the mean.

For the analysis of the lead-times workdays were used, except for the length-of-stay since it does not matter whether a patient is admitted during workdays or not. Workdays are all days excluding weekends (Saturday and Sunday) and holidays (New year's day, Easter Monday, Ascension day, Whit Monday).

A bivariate non-parametric Kendall's tau test will be performed in order to detect correlations between the aggregated scores of the framework and lead-times and number of hospital visits. A two-tailed method is since it is not sure what the predicted nature is of the relationship. The significance will be calculated and a threshold level will be set at P=0.05. Kendall tau test is preferred above a bivariate Pearson Chi-square test because the Chi-square test is based on linear relationship between the data itself instead of ranking of the data, which suits more with ordinal data. Also the amount of data, at most 18 hospitals with a complete framework, makes it unfavorable for the Chi-square test since in low amounts of data the distribution is not Chi-squared. (Field, 2009).

Chapter 5 Hospital comparison

This chapter is dedicated to answer the fourth research question:

4. What are the results when comparing Dutch hospitals on their leanness using the developed framework and which relations can be found between the framework and lead-times and number of hospital visits?

5.1 Methods

5.1.1 Selection of study population

For the hospital selection and to get comparable benchmarking partners the DSCA is used. The invited hospitals should at least have correctly registered 50 patients in the first year of the registration, 2009. A total of 17 hospitals were visited who replied positively after the invitation.

The study focuses on the intramural pathway and does not include primary care and/or tertiary care like radiotherapy centers.

The care paths for patient types that will be observed are patients with a primary colorectal malignancy who received surgical care on an elective basis. Patients who were admitted as emergency patients or patients that followed a total customized urgent path were not included. Furthermore patients operated using Transanal Endoscopic Microsurgery (TEM) were also excluded since this type of surgery is only performed in a limited amount of hospitals.

5.1.2 Study design

The study design is a mixed-method national multi-center retrospective comparable benchmark. Both quantitative and qualitative data will be used.

5.1.3 Data collection per hospital

For the collection of the data several methods were used:

Interviews:

Interviews with gastroenterologist surgeons (GE-surgeons) are used to gain insight in the hospital specific care process of CRC. This is done using a semi-structured interview. In a semi-structured interview there is room for more explanation and additional questions can be asked to verify certain answers or get clarification on processes (Babbie, 2004). This interview was conducted using a standard set of questions, but cause of its flexibility, new questions are allowed for to be able to adapt to specific situations. The interview was based on 67 predefined questions and the duration was between 1 and 1,5 hour.

The questions asked in the interview were a combination of open and closed questions. Special attention has to be paid to bias by the interviewer and the interviewee for certain questions regarding quality and delicate questions. These questions should be asked as an open question without any hints in the question itself.

The subject of the questions involve general characteristics of the hospital and surgical department, planning and scheduling of care, multidisciplinary consultation, nursing ward, fast track program (early recovery program),

The results of the questionnaire are standardized with the possibility for registration of comments and answers on the additional ad-hoc questions.

Hence five different departments in each hospital were visited to conduct a semi-structured interview with a worker from the department with good knowledge and understanding of the care for the CRC patients. This is in line with the Lean Principles of investigating a process (or problems) in the place where they happen; looking at the process (observation) and talking to people involved (interview). This could be indicated in Japanese as *Gemba,* which can be translated from Japanese as the place where the action is happening (Saurin et al., 2011).

The visited departments were:

- Gastroenterologist outpatient clinic / endoscopy department
- Surgery outpatient clinic
- Radiology
- Operating room complex
- Surgical ward

Radiotherapy will not be analyzed since not all hospitals have their own radiotherapy department.

Observations

Observations were done at the hospital. Elements of the Rapid Plant Assessment (RPA) (Goodson, 2002) were used as a base for the observations. In the RPA different elements of a manufacturing process are scored to get a quick impression of a plant. Not all elements apply for healthcare and therefore it was necessary to select the relevant items of the RPA.

Besides interviews, some aspects of the care process will be observed. These observations are combined with the interview visit and should be done on the different departments involved in the CRC patient care; out-patient clinic, surgical department, nursing ward, radiology, radiotherapy and day treatment chemotherapy. For these observations it is necessary to gain access to the necessary departments and careful planning and cooperation with the hospitals is therefore inevitable.

The observations were done using a standard questionnaire, which needs to be answered by the researcher. If a question cannot be simply observed, it is possible to interview the involved employee at the observed department.

The topics of the observations will be patient satisfaction, safety, visual management system, planning system OR and out-patient clinic, use of facility, structure and process alignment, teamwork and motivation, condition and management of medical instruments, and management of complexity, variation and urgency.

Medical record review (retrospective)

For the analysis of the lead times, hospital visits and the assessment of process alignment quantitative data was retrieved from the hospital information system (HIS) and the electronic health record (EHR). Also data that is filled out by the hospitals for the DSCA patient registry is used. The DSCA dataset is used as a starting point and additional data is retrieved from the HIS and EHR. The data of the DSCA cannot be retrained centrally since then only anonymous data would be available due to privacy regulations. A part of the retrospective research is counting the number of patient visits and the time of the actual visits to the hospital for consultation, diagnostics or treatment.

Before assessing the leanness of a hospital or its incorporation of lean principles it is important to understand the organizational context in which the hospital is places. Therefore organizational characteristics (environmental context) are collected during the interviews and observations as well.

Researchers

The hospitals were visited by different researchers; A.G.H. Niezink(AN), D.J. Pluimers (DP) and the author of this report (MM). Niezink and Pluimers also constructed the questionnaire for the semi-structured interview with the GE-surgeons, which was slightly adapted by the author to fit the current research by adding questions. No questions of Niezink and Pluimers were adapted to keep the questions the same across the research.

5.1.4 Data analysis

Data was analyzed and pre-processed using Microsoft Excel 2011 for Mac [Redmond, Washington, USA] and IBM PASW Statistics 18 (SPSS) [Chicago, Illinois, USA].

5.2 Results

In this part of the report the results of the framework described in Chapter 4 are presented for selection of Dutch hospitals. The hospitals that were visited participated anonymously and are therefore not listed by their name of location. The bed capacity is binned in widths of 50 beds to keep hospitals anonymous. Their environmental contextual characteristics however are summarized in Table 12. The detailed differences of hospitals in process characteristics of care provided for the colorectal patients, is presented in Appendix E.

In total 18 hospitals were visited. The author visited five of these hospitals. Because of differences in data collection and data availability not all data from the 18 hospitals can be used for all types of calculations.

Table 12: environmental context participating hospitals

Hospital	Hospital type	Involved in education and training	Bed capacity[2] (Binned)	Venture type of surgeons	Member of tertiary medical teaching hospitals (STZ)
H1	Large non-academic	Yes, for residents surgery	351 – 400	Staff venture	Yes
H2	Academic	Yes, for GE-surgeons	1301 – 1350	Paid employment	No
H3	General	Yes, for interns medical students	301 – 350	Individual venture	No
H4	General	Yes, for interns medical students	301 – 350	Individual venture	No
H5	General	Yes, for residents surgery	251 – 300	Individual venture	No
H6	Academic	Yes, for GE-surgeons	851 – 900	Paid employment	No
H7	Categorical	Yes, for oncology surgeons	151 – 200	Paid employment	No
H8	General	Yes, for residents surgery	501 – 550	Individual venture	No
H9	Large non-academic	Yes, for GE-surgeons	651 – 700	Individual venture	No
H10	General	Yes, for residents surgery	601 – 650	Individual venture	No
H11	Large non-academic	Yes, for oncology surgeons	1051 – 1100	Individual venture	No
H12	General	No	301 – 350	Individual venture	No
H13	General	No	351 – 400	Individual venture	No
H14	General	Yes, for interns medical students	301 – 350	Individual venture	Yes
H15	General	No	301 – 350	Staff venture	No
H16	Large non-academic	No	451 – 500	Individual venture	No
H17	Large non-academic	Yes, for residents surgery	401 – 450	Staff venture	No
H18	Large non-academic	Yes, for GE surgeons	651 – 700	Individual venture	Yes

5.2.1 Results of the scorecard

Using the framework of Table 9, we calculated a score for each of the six categories, based on the results of the semi-structured interview and observations that were done. Table 13 shows the results. The values are given and the cells are colored (red= lowest, dark green=highest) to make differences easier visible. The maximum score is given in the bottom row. We expect hospitals with a maximum score to have in that category all proposed lean initiatives implemented. When it was not possible to answer all questions of a category in the framework, no

[2] Bed capacity was retrained from *Deuning CM (RIVM). Locaties algemene en academische ziekenhuizen 2010. In: Volksgezondheid Toekomst Verkenning, Nationale Atlas Volksgezondheid. Bilthoven: RIVM, <http://www.zorgatlas.nl> Zorgatlas\Zorg\Ziekenhuiszorg, 6 december 2010. Bed capactities are based on capacity in 2008 but are unlikely to change much in one year. It appeared that there was no publicly available single database to look up the capacities of 2009.*

score was given to this category. We did this to keep hospitals comparable. When we were not sure how much points were in a category because of missing data, we indicated this with n/a. Where possible, information was retrieved to complete the framework as much as reasonable achievable. For eight out of 18 hospitals it was possible to fill all six categories of the framework. In the categories "physical layout" and "elimination of waste" there were hospitals close to the maximum amount of points that could be scored. Hospital 8 is an unusual case since too little data was available to get a comprehensive overview of the hospital and fill in the scorecard. The data at patient level was however used to get more insight in the differences between lead-times, number of hospital visits and the different trajectory the patients followed. None of the hospitals scored maximum points on more than one category. Only hospital 6, 10 and 18 scored on a category the maximum amount of points; H6 and H10 on multi-skilled team and H18 on operational focus.

The item regarding the use of a dedicated endoscopist (framework: Elimination of waste, item b) was discarded since in no hospitals a dedicated endoscopist was routinely used for the CRC patients.

TABLE 13: scoring of the framework

Hospital	Operational focus	Autonomous work cell	Physical lay-out	Multi-skilled team	Pull planning	Elimination of waste
H1	4	4	9	2	11	5
H2	n/a	4	7	2	n/a	4
H3	n/a	5	5	2	n/a	7
H4	n/a	4	7	3	n/a	5
H5	n/a	2	7	3	n/a	1
H6	2	n/a	7	4	5	n/a
H7	3	6	9	3	7	2
H8	n/a	n/a	n/a	n/a	n/a	n/a
H9	n/a	5	6	3	n/a	n/a
H10	n/a	4	6	4	n/a	2
H11	n/a	5	6	3	n/a	n/a
H12	4	3	6	3	10	5
H13	n/a	6	7	3	n/a	2
H14	4	1	7	2	10	3
H15	4	3	6	3	8	3
H16	2	2	7	4	9	4
H17	3	1	8	2	8	5
H18	6	5	7	3	11	6
MAXIMUM	6	10	12	4	16	8

The total group of patients was split up between one of the three main path ways which are colon carcinoma, rectum carcinoma with a short radiation time (5 * 5 Gy, in a period of one contiguous workweek) and rectum carcinoma with a long radiation time (45-50 Gy), which is spread over a longer time and surgery should be delayed to let the tissue recover. This causes a delay of approximately 14 weeks (Association of Comprehensive Cancer Centers - The Netherlands, 2011). A small group of patients with rectum carcinoma was not radiated preoperatively. Since this group of patients per hospital is quite small and did not differ much from the short colorectal carcinomas, they were included in the rectum short group.

The distribution of patient-types in our analysis can be found in Appendix B.

It was not always possible from the data we collected to make a distinction between the different patient types. In hospital number H9, for example, no clear distinction could be made based on the collected data between rectum carcinoma (short) and rectum carcinoma (long). Therefore only the patients who could be identified were included.

Figure 11 shows the difference in lead times between the different patient categories. The error bars indicate the two-tailed standard deviation. The standard deviation is quite large and reflects the variety in process. We expected that there would be less variety since most hospitals visited used a clinical path. A well-thought clinical path could give structure and overview to a process, and therefore care can be standardized. A reason for the variation could be that pathway construction for the CRC care is a recent development and it takes time to integrate it fully in the medical practice. Also the adherence to the pathways is not measured.

Furthermore lead-times per patient type and number of hospital visits were calculated; a 90%-percentile, a 66%-percentile, a median, a mean and SD were determined. After an analysis of the data, it appeared that it was not possible to always calculate a proper 90%-percentile due to the low number of patients in a certain category, especially for the short and long rectum trajectory. Therefore we decided to not include the 90%-percentile. Because not from all hospitals proper data about lead-times was retrieved, H11, H12, H16 and H18 were excluded.

Because the order of events was not similar in all hospitals and even within hospitals the order of activities can differ per patient, it was difficult to calculate the time the different types of diagnostics. Therefore the more general lead-times, which always are in the same order, were taken for comparison.

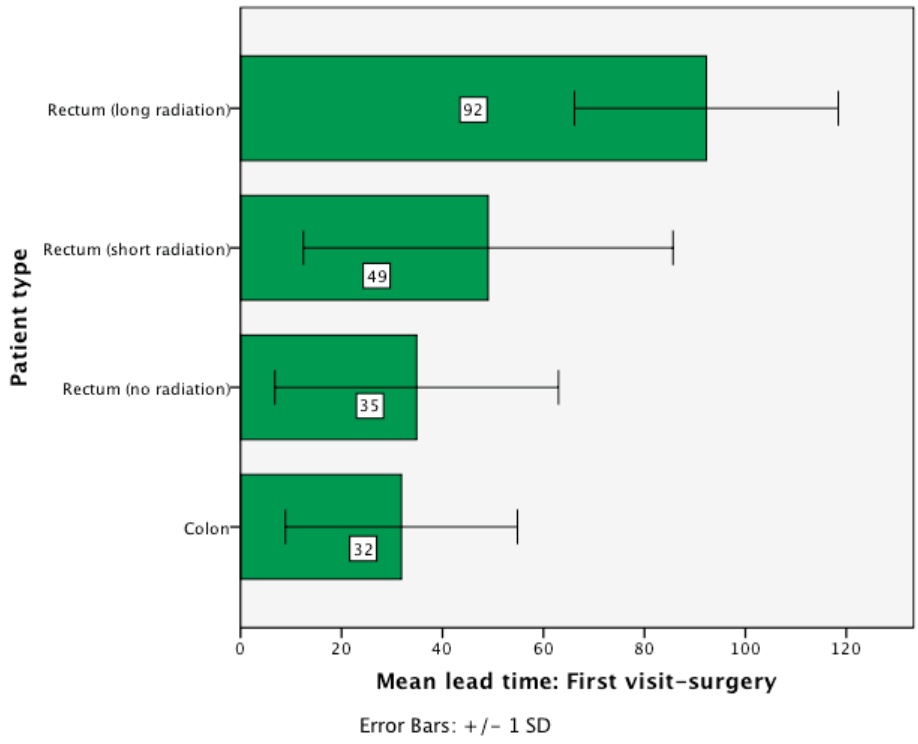


Figure 11: Mean lead-time (from first visit hospital until surgery) of different patient types

Table 14. Results of lead-times and hospital visits per patient trajectory

	LT workdays First visit - Surgery			LT days Length of stay			LT workdays Multidisciplinary meeting - Surgery			Number of hospital visits prior to surgery		
Hospital	**Colon**	**Rectum short**	**Rectum Long**	**Colon**	**Rectum short**	**Rectum Long**	**Colon**	**Rectum short**	**Rectum Long**	**Colon**	**Rectum short**	**Rectum Long**
H1												
66%	32.5	43.6	91.7	8.0	12.9	10.9	22.9	30.6	85.7	4.0	5.0	6.0
Median	29.0	35.0	84.5	7.0	11.0	9.0	20.0	25.0	79.5	4.0	5.0	6.0
Mean	29.9	41.3	79.4	8.6	14.2	15.3	20.5	31.1	72.8	4.0	4.8	5.5
SD	9.4	14.7	24.2	6.4	11.6	24.2	9.3	16.2	25.8	0.6	0.7	0.8
N	71	17	8	72	17	8	72	17	8	72	17	8
H2												
66%	44.8	86.7	106.8	10.9	16.7	13.7	35.0	84.4	87.5	4.0	5.0	4.0
Median	39.0	57.0	98.0	7.00	12.0	12.0	30.5	35.0	80.0	4.0	5.0	4.0
Mean	40.1	87.5	94.4	9.8	14.7	12.0	39.2	75.5	69.7	3.7	4.4	4.0
SD	14.1	65.3	33.6	6.0	9.2	5.3	41.1	69.5	69.7	1.0	1.3	1.2
N	36	13	23	33	13	22	22	13	23	36	13	23
H3												
66%	27.0	37.7	183.6	17.0	8.0	13.9	14.0	19.0	93.0	4.0	5.0	5.0
Median	25.0	33.0	150.0	8.00	7.0	11.0	12.0	17.0	93.0	4.0	5.0	4.5
Mean	27.1	32.2	150.0	6.00	7.4	11.0	12.4	18.6	93.0	4.0	5.0	4.5
SD	10.1	7.3	49.5	6.62	7.3	49.5	6.1	6.5	-	0.5	0.0	0.7
N	43	13	2	43	13	2	23	13	1	45	14	2
H4												
66%	20.0	23.0	87.8	17.8	-	28.6	17.3	20.2	82.0	4.0	4.0	5.0
Median	16.0	21.0	82.5	8.0	7.0	18.0	15.0	17.0	82.0	4.0	4.0	4.5
Mean	18.2	20.7	82.5	16.0	10.6	18.0	14.3	17.0	82.0	3.7	3.9	4.5
SD	10.1	5.4	7.8	6.2	10.8	15.6	4.1	5.0	-	0.6	0.4	0.7
N	21	7	2	21	7	2	4	3	1	21	7	2
H5												
66%	27.2	33.0	95.1	15.6	37.9	10.0	15.3	24.8	87.0	4.0	4.0	5.0
Median	20.0	33.0	92.0	7.0	14.0	6.0	11.0	19.0	81.0	4.0	4.0	5.0
Mean	24.7	30.2	87.6	5.0	28.5	12.7	11.3	21.8	66.1	4.1	4.0	4.7
SD	13.1	5.9	27.9	5.2	36.2	16.1	4.7	5.6	32.1	0.7	0.7	1.3
N	18	5	15	17	4	15	7	5	13	18	5	15
H6												
66%	32.8	37.0	107.6	23.0	11.0	24.5	22.0	21.1	84.9	5.0	6.0	5.3
Median	27.5	35.0	105.5	10.0	9.0	11.5	19.0	18.0	46.5	4.0	6.0	4.5
Mean	29.6	41.4	104.0	7.0	14.0	19.5	22.4	18.7	46.0	4.0	5.6	4.5
SD	21.9	18.1	5.7	8.9	15.9	19.9	20.3	3.8	45.7	1.2	0.5	1.3
N	30	9	4	31	9	4	17	6	4	31	9	4
H7												
66%	33.5	45.3	106.9	25.2	13.6	16.7	33.3	36.5	84.7	4.5	5.0	4.0
Median	31.0	34.5	94.0	9.0	10.5	12.0	23.5	31.0	77.0	4.0	4.5	4.0
Mean	40.8	56.3	91.0	8.0	16.1	24.6	36.8	39.9	81.1	4.1	4.8	3.7
SD	42.3	50.9	34.9	16.9	15.0	34.9	39.6	34.5	9.6	1.1	0.9	1.3
N	27	18	11	27	18	11	12	13	7	27	18	11
H8												
66%	33.8	37.0	94.6	33.8	13.8	28.9	22.1	28.8	85.6	4.0	6.0	6.0
Median	27.5	35.0	80.0	27.5	10.0	15.0	19.0	25.0	72.5	4.0	6.0	6.0
Mean	38.1	40.5	82.5	38.1	15.1	24.3	24.5	30.0	72.3	4.3	5.5	5.8

SD	31.8	18.9	17.5	13.2	13.1	23.4	21.6	19.5	14.0	0.6	0.6	0.5
N	42	17	4	41	17	4	40	17	4	42	17	4
H9												
66%	28.5	90.8	119.4	8.5	41.3	9.9	12.9	-	-	6.5	11.8	10.3
Median	23.5	39.0	104.0	5.0	24.0	104.0	10.5	-	-	6.0	8.0	9.0
Mean	29.3	63.3	106.7	7.3	24.0	106.7	10.5	-	-	6.0	10.0	8.7
SD	22.5	49.2	20.1	4.3	25.5	3.0	3.5	-	-	2.2	3.5	2.6
N	24	3	3	24	2	3	2	-	-	24	3	3
H10												
66%	25.0	30.8	96.4	13.0	15.1	14.6	-	-	-	6.0	5.0	10.0
Median	22.0	27.0	85.0	10.0	9.0	8.5	-	-	-	5.0	5.0	9.5
Mean	29.9	32.6	84.3	13.3	13.5	12.8	-	-	-	5.6	5.0	9.9
SD	15.3	20.8	25.2	11.2	9.2	9.0				1.8	1.7	2.6
N	80	32	12	78	31	12				80	32	12
H13												
66%	38.0	47.2	92.1	11.0	11.0	13.	-	-	-	7.0	7.0	10.0
Median	26.5	35.0	86.0	9.0	9.5	8.50	-	-	-	6.0	6.5	9.0
Mean	37.4	48.5	90.3	10.2	9.7	13.9	-	-	-	6.4	6.5	9.1
SD	30.8	39.6	10.5	9.0	6.0	13.1				2.1	2.3	1.6
N	46	19	15	51	20	14				51	20	15
H14												
66%	31.8	49.6	92.5	7.1	24.9	6.0	16.0	32.2	70.0	6.0	7.0	9.6
Median	26.0	40.0	87.0	5.0	10.0	5.0	15.0	24.0	66.5	5.0	5.0	9.0
Mean	32.5	55.6	79.0	7.6	14.8	6.0	15.0	28.7	56.0	5.0	6.5	8.1
SD	19.2	44.4	25.4	7.2	11.4	3.0	1.4	13.9	28.4	1.8	2.4	2.6
N	32	11	6	31	11	5	2	6	4	33	11	6
H15												
66%	45.0	43.1	111.3	9.0	12.8	20.9	13.5	26.2	74.0	7.0	7.0	11.0
Median	38.0	36.5	94.0	6.5	9.5	19.0	10.5	13.0	70.5	7.0	6.5	10.0
Mean	42.8	38.7	100.2	9.3	15.7	19.6	22.4	18.6	60.3	6.7	6.6	9.8
SD	34.8	16.5	12.9	7.2	16.8	7.8	44.3	12.4	28.0	2.2	1.0	1.3
N	48	10	5	48	10	5	18	7	4	48	10	5
H17												
66%	38.1	44.8	100.9	8.0	9.9	10.0	21.1	34.5	83.9	6.0	7.0	11.0
Median	31.0	40.0	94.0	7.0	8.5	8.5	16.0	29.0	82.0	6.0	7.0	11.0
Mean	36.2	46.9	98.0	9.1	13.4	9.4	21.8	34.5	83.3	6.0	7.1	10.5
SD	20.2	18.0	12.2	6.9	11.0	3.4	19.8	19.5	1.4	1.4	1.3	1.6
N	44	14	11	43	14	10	37	13	11	44	14	11

When looking at the 66%-percentile of the different parameters the lead-time between first visit and surgery for the colon trajectory is shortest in H4 (20.0 workdays) and longest in H15 (45 workdays). For the short rectum trajectory H4 is again the fastest hospital (20.7 workdays), whereas H2 has the longest lead-time (87.5 workdays). For the long rectum trajectory H4 has the shortest lead-time (87.8) compared to the longest H3 (183.6). The lead-time between first visit and surgery is seen as most important because this really indicates the total care path prior to surgery.

A large variety in lead-times can be observed between hospitals and patient types. The number of hospital visits prior to surgery is more standardized, although there are a few outliers with higher number of hospital visits. For this item the median was evaluated. The number of hospital visits for the colon trajectory varied between 4 (H1 – 8) and 7 days (H15). For rectum short trajectory the range was between 4 visits (H4, H5) and 8 visits (H9). For the long rectum trajectory the range is between 4 (H7, H2) visits and 11 visits (H17). Most variation was found in visits to the surgical outpatient clinic. In some cases patients had to visit the hospital up to 8 times prior to surgery. There were fewer combinations of appointments than expected. The combinations of appointments were based on the data from the hospital information system. The dates of the different appointments were compared and if two different appointments (for example a visit to the outpatient clinic and a CT-scan) were combined, this was counted as a combined appointment. The process steps that were most combined were the X-thorax and

CT-scan. A possible reason could be that in all hospitals it was possible to have a walk-in X-thorax, the time to make the scan is short and requires no special preparation (such as the bowel preparation for CT-scans and MRI-scans) and therefore can easily be combined.

There was a discrepancy between hospitals regarding the point of view on one-stop shop diagnosis. According to one hospital this was not possible since different contrast-agents are used for the CT-scan and the MRI-scan. This would mean that the two scans could not be combined on the same day. Another hospital, however, explained that this would not be a problem and it is all a matter of scheduling. Among the participating hospitals only two hospitals provided one-stop shop diagnostics for at least colon carcinoma.

5.2.2 Correlation analysis

A correlation analysis was performed using the earlier described (see Analysis, chapter 4) Kendall's tau test. The relation between the different categories of the scorecard/framework and the mean and median of lead-times (*first visit-surgery* [weekdays]; *result pathology-MDT meeting* [weekdays]; *MDT meeting-surgery* [weekdays]; *surgery-discharge*), and the number of hospital visits prior to surgery. These were all calculated for the three patient types. The results are presented in Table 15. A P-value threshold of 0.05 was used as level of significance. The number of hospitals shown in the table indicates how many hospitals could be included for the calculation, since for some hospitals no score was calculated for each category.

Table 15. Results of correlation analysis of lean outcomes and framework

Number	Trajectory	Row	Column	N of hospitals	Test result	P-value	Relation
1	Rectum (long)	Lead-time First visit-surgery (median)	Operational focus	6	-0.783	0.049	Negative
2	Colon	Lead-time MDT-surgery (median)	Physical layout	11	0.607	0.016	Positive
3	Rectum (short)	Lead-time MDT-surgery (median)	Physical layout	10	0.595	0.026	Positive
4	Rectum (long)	Lead-time PA-MDT (mean)	Multi-skilled team	10	0.747	0.007	Positive
5	Rectum (long)	Lead-time PA-MDT (median)	Multi-skilled team	10	0.637	0.021	Positive
6	Rectum (long)	Length of stay (mean)	Multi-skilled team	13	0.471	0.044	Positive
7	Rectum (long)	Lead-time First visit-surgery (median)	Pull planning	6	-0.926	0.014	Negative
8	Rectum (long)	Lead-time workdays PA-MDT (mean)	Pull planning	6	-0.828	0.022	Negative

Table 16. Results of correlation analysis for the categories of the scorecard

Number	Row	Column	N of hospitals	Test result R	P-value	Relation
1	Pull planning	Operational focus	9	0.658	0.024	Positive
2	Pull planning	Elimination of waste	9	0.612	0.049	Positive

A total of 8 significant ($p<0.05$) correlations were found. We expected more correlations between the framework to score Lean initiatives (scorecard) and the Lean outcomes. It was expected that if there would be a relation, it would be negative since the higher the score for the framework category, the higher the expected leanness. Therefore a high score in the framework would predict a decrease of lead-time or number of hospital visits. In Lean terms, the lower the lead-times and number of hospital visits, the leaner it is. In terms of efficiency, this does not necessarily mean that the process is organized more efficient. A large over-capacity for example can result in quick service, short lead-times and more opportunities to combine visits, but from efficiency perspective too much resources are used, or too little activities are carried out with a certain amount of resources available.

Interesting to see is the negative correlation between "operational focus" and the median of the lead-time between first visit and surgery for the long rectum pathway (Table 15, #1). This means that scoring high on operational focus would predict a reduction of time for the total throughput for the long rectum pathway. This was not found for the short rectum and colon pathway and was not what we expected.

The correlation between "physical layout" and the median of the lead-time from MDT to surgery (Table 15, #2 and #3) is positive for both the colon and short rectum trajectory. This indicates that there is an opposed relationship than we expected. We did not find a reason why a Lean "physical layout" would increase the lead-times, but it indicates that physical layout is not as important as we expected. During the on-site visits however we observed that mostly "physical lay-out" has an influence on the on-line operational part of the process. A better physical lay-out with clear signs, visual aids, conveniently arranged materials and easy surveyable process steps for employees and patients will probably reduce the length of the activities such as surgery or duration for a scan, but this is not measured in this research. The total time per activity could be a quantitative measure to analyze the differences between hospitals. Also the amount of overwork could be a quantitative measure for the ability of a hospital to keep its processes manageable and predictable.

The correlation between multi-skilled team and the mean and median of the lead-time of PA to MDT (Table 15, #4 and #5) and the mean of length of stay (Table 15, #6), is positive for the long rectum path. This can be explained by the fact that the definition of a multi-skilled team is not that a multidisciplinary team is composed, but rather that each worker has more skills and can work interchangeably. It is assumed that this would cause fewer interruptions in the workflow. In a multi-disciplinary team, tasks are strictly divided and because of scheduling complexities, meetings are only once a week or once in two weeks. Since it is mandatory to discuss rectum carcinomas pre-operatively the patient is put on hold until the meeting has taken place. In the colon pathway a lesser proportion of patients were discussed in a preoperative MDT meeting in 2009.

The last category with significant correlations is pull-planning. In the long rectum path, the median of the lead-time from first visit to surgery and the mean of the lead-time from PA to MDT is negatively correlated with pull-planning. This was like we expected. An increase in the score on pull-planning means a decrease of waiting time for the patient in the long rectum pathway.

There were no significant correlations with the number of hospital visits. This could be since it appears that for the last 4 hospitals in the analysis there is an increase in number of hospital visits prior to surgery and it seems that the calculation is done differently. Therefore they should not be compared independently and errors can occur when calculating correlations. Unfortunately because this data is collected from patient files, which can only be accesses from the hospital itself, it is too time consuming to redo the data collection.

Correlations were also determined between the six categories of the framework. Table 16 shows the significant results. A positive correlation between “pull planning” and “operational focus” was found. This was like expected since we assume that “operational focus” influences all other categories. We therefore expected more categories to have a correlation with “operational focus”, but it seems that pull planning is most important. We also found a correlation between “pull planning” and “elimination of waste”. This is more surprising, since there are no directly recognizable items in the framework that seem related.

5.2.3 A more detailed correlation analysis

A second, more detailed, correlation analysis was carried out (a list of the different items that were tested against the lead-times and number of hospital visits can be found in Appendix C). This time all elements of the framework and the environmental context characteristics of the different hospitals were tested against the mean and median of the lead-times and number of hospital visits. All significant results ($P< 0.05$) are presented in Appendix D.

For some cases, correlations were found although it appears logical since in practice the two items seem unrelated.

There is a negative correlation, which indicates that the presence of slots for CT and MRI will lead to a lower lead-time between the Multidisciplinary Team Meeting (MDT) and surgery. This is not logical since the MDT is done after all diagnostics are ready.

Three negative correlations were found between the availability of a clinical pathway and the mean of the lead-time between first visit and surgery for the short rectum trajectory. For the long rectum trajectory the correlation was found for the mean of this lead-time. A negative correlation is what we expected; if the hospital used a clinical pathway, we assumed care would be provided faster.

Correlations between “does the hospital use a single patient file” and lead-times were found. The time from PA to MDT seems positively affected by having a single patient file. A negative correlation (-0.545, $P=0.033$) was found for the long rectum pathway. This is according to our expectation. Having a single patient file reduces the need to update multiple files. A positive correlation however was found between the lead-time between MDT and surgery. This was unexpected since this would mean that having a single patient file would increase the time between MDT and surgery. During site visits it became clear that the time between MDT and surgery greatly depends on the availability of the operating room for the specialist performing the surgery. The scheduling department does not review the patient file in order to schedule the patient. Most of the times a separate application for surgery need to be filled out by the surgeon (in cooperation with the anesthesiologist).

Having a flow chart available seems to have a strong relation with the lead-time and length of stay for the rectum trajectory. Six significant correlations were found. All correlations were negative. This means that having a flow chart available affects the reduction of lead-time and length of stay. This is what we expected since a flow chart increases the understanding of the care path and makes it easier to get a clear view of the position of the patient in the complete process and the responsibilities of different employees in the care delivery process. The relations were found in the lead-time from first visit to surgery (rectum (short)), the length of stay (rectum), lead-time of PA to MDT and lead-time of MDT to surgery. In the five hospitals that were observed by the author the flow charts

really demonstrated the understanding of the involved staff in the process. Nevertheless the flow charts were not distributed over all personnel. Only the ones directly involved in the care for the colorectal patient and involved in planning and decision-making, were well informed about the existence of the flowchart and also participated in the construction. For example the radiology department and OR personnel did not know about the flow chart and the intended care path for the patient. In the observed hospitals flowcharts with quantitative information were missing.

Two categories with only one significant relation were “focus on medical content or operational aspect” and the availability of a multidisciplinary outpatient clinic. Both were related with the long rectum trajectory. The focus on operational aspects seemed to be negatively related with the median of the lead-time between MDT and surgery. This was like expected, although it appeared that for surgeons it is difficult to find a balance between operational aspects and medical content, and that they do not exclude each other. The presence of a multidisciplinary outpatient clinic was positively correlated with the length of stay. This was unexpected since the multidisciplinary outpatient clinic is not involved in the inpatient care. Since there were only three hospitals with a multidisciplinary outpatient clinic it can also be an artifact and not a real relationship.

Five correlations were found for the one-stop shop diagnosis. For the colon path a relation was found with the mean of the number of hospital visits. For the short rectum path relations were found with the mean of the lead-time of first visit until surgery, the median of the lead-time of PA until MDT, and the mean and median of length of stay. This last correlation is unexpected since the one-stop shop diagnosis does not seem to have a relation with the organization of the length of stay.

Most of the categories of the Rapid Plant Assessment did not show significant correlations. Exceptions are the categories regarding “scheduling system” and “supply chain”. The category “scheduling system” is correlated with the number of hospital visits for the mean and median of the colon trajectory, and the mean of the number of hospital visits for the short rectum trajectory. These were negative relationships, like expected. The better the scheduling system, the less number of hospital visits have to take place since combinations of appointments can be made. Nevertheless, we also expected a correlation with the lead-times.

Slot reservation for CT and MRI diagnostics for colorectal patients occurred in three hospitals. In these hospitals slots were reserved for both diagnostics and therefore the results of the correlation analysis are for both diagnostic planning, the same. There were positive relationships for the median of the lead-time between PA-MDT for the long and short rectum trajectory. This was not what we expected. Our expectation was that slot planning would lead to shortened lead-times. The result was therefore contradictory. A possible reason could be that not enough slots are planned and there is more demand than capacity is freed. No significant correlations between slot planning and number of hospital visits were found.

Remarkable are the last correlations found. The presence of a specialized nurse for colorectal care is positively correlated with the mean lead-time of PA to MDT for the colon and the long rectum path. This would mean that a presence of a colon care nurse would increase the lead-time. No explanation for this can be found.

To summarize, highest negative correlations were found for the availability of flow charts of the process. Highest positive correlation was the presence of a dedicated colon care nurse with the lead-time. Significant correlations were mostly found only for a specific patient trajectory.

Chapter 6 Discussion and Conclusion

6.1 Discussion

In Chapter 2 theory is provided about health care performance, efficiency, quality, health care provision and process improvements. Chapter 3 focused on efficiency measurement. Different methods are discussed, but it is difficult to choose the best method since no real consensus exist which method is best to use in health care. Measuring efficiency of a certain patient type, across multiple departments was not described in literature. Most challenging are the shared use of resources and how to address these.

An approach is done using DEA and two inputs and two outputs to quantify efficiency. This is not the most ideal method and does also not contain economic variables. The method also does not deal with true efficiency, but rather with timeliness. From a patient and physician perspective, however, it became clear that in practice there is often confusion between timeliness and efficiency.

An important factor that influences the complete process efficiency and timeliness is the planning/scheduling department. This department or departments were not included in this research, although it could reveal interesting results. This was due to the demarcation of the topic.

Large differences are present in the visited hospitals. Scheduling can be subdivided in planning of the operating rooms (scheduling of patients, materials, and staff), outpatient clinic planning (scheduling of patients and staff), radiology planning (scheduling of patient, equipment capacity and staff) and endoscopy planning (scheduling of patient, equipment, recovery, and staff). The planning and alignment of a radiotherapy center is also part of the scheduling complexity. When we visited the hospitals it became clear that there were differences in process designs of scheduling.

In the third chapter a framework was constructed to quantify initiatives for leanness and how to measure lean outcomes. The framework resulted in a scoring list to create indexes in six different categories. In the third chapter this framework was tested using a set of hospital data that was collected during this research and earlier research.

There are different criteria one can assess measurement quality, such as precision and accuracy, reliability, validity and validation process. The framework is not really precise since mostly ordinal input is given and an aggregated score for each category is constructed. Some characteristics are obtained using interviews. This is subjective and qualitative and not always good to analyze. The interviewees provided a lot of information but because the scope during the research was quite broad not all individual characteristics, initiatives and comments could be used. This made interviewing not precise and difficult to compare because each researcher had his or her own approach.

The interview was validated by visiting different departments and re-asking questions from the interview that was carried out with the GE-surgeon. However this was more in indication if there was doubt about certain questions and not a structured validation protocol was used. Also the final data collected was not validated at the hospital or the concerned employees. No feedback session was held about the collected data and to collect additional information about reasons why certain things are the way they are. Furthermore to be a tool to improve the processes feedback should be given about the processes that were found.

Outcomes: the different dates of activities were gathered from the Hospital Information System or Electronic Health Record. This seems quantitative and objective, however there are cases when a date is set in the patient record to at least have a date. When possible data was used from the DSCA since this appeared to be of better quality than the Hospital Information System since the registry is also used for statistics and the stakeholders (the surgeons) have to authorize their data. Nevertheless the incentive currently for the national registry DSCA and a quality indicator asked by the health inspectorate, is how much fields are entered (completed data), and not the quality of the field. Therefore some data seems to have mistakes, which can be a misinterpretation of an appointment that is scheduled but appeared to be only a note for the surgeon. The IT-system however counted this as an appointment. This can vary from wrong birthdates (and therefore calculating a wrong age) to missing dates of pathology reports authorizations.

Performance and efficiency of care process was measured using lead-times and number of hospital visits. However sometimes a lead-time is deliberately longer because the patient preferred to have a certain appointment later instead on the most optimal day. This is a service provided by the hospital, but will eventually result in a lower performance when measuring lead times. Also the number of hospital visits is increased if two appointments can be scheduled earlier instead on the same day. The choice is often made by the patient, in cooperation with the treating specialist or scheduling department.

When analyzing correlation coefficients it appeared that there often is a not expected relationship (for example a positive relationship instead of a negative relationship) and that it differs for the mean, median and 66%-percentile whether the correlation coefficient is significant ($P<0.05$) or not.

No correction for patient case mix was applied which is important for the length of stay (since patients with a more likelihood for complications are expected to stay longer).

Patient satisfaction: The care process is there to serve the patient and not the other way around. According to Lean Thinking the quality should be measured from the customer perspective and not only from a medical technical point of view. The quality can be measured using health related outcomes, but actually it is the patient satisfaction that matters. Different hospitals are implementing the Customer Quality Index to measure using a standardized method patient satisfaction. Results of patient satisfaction and an analysis what patients value most is lacking in this research and report.

Hospital visits: The onsite hospital visits and observations were performed in 2010 and 2011. Between the first and final hospital visit is almost one year of time.

Different interviewers with different experience levels conducted interviews. Different observers did observations using only a semi-standardized method but no decent training for scoring the different aspects was done. The Rapid Plant Assessment, of which elements were included in this research, is normally conducted by a team of observers, after an extensive training session of three days (Goodson, 2002). A better approach would be to first get more familiarized with the colorectal cancer care before focusing on terms for the quantification of leanness because then a better understanding would lead to a better framework.

There was a difference among the hospitals about open access endoscopy. On one hand, one can say that it will decrease the number of visits to the outpatient clinic of internal medicine or gastroenterologist. However there are also clues that the number of unnecessary endoscopies performed will rise without a gatekeeper mechanism of a physician. An in between approach is the use of a specialized nurse to screen on forehand for the endoscopy for the need, possible complications and making sure proper bowel preparation is performed since this will also decrease rework.:

Focus: the focus of the leanness measurement was merely on medical related processes such as the diagnostic test and the surgery itself. The administrative part of the departments work was not within the scope of this research. Also the planning and scheduling of resources was not researched in detail. It is assumed by the author that this is an interesting area and there are large differences between hospitals. During the visits it became clear that the largest differences are between centralized and decentralized scheduling of patients, smart scheduling of operating rooms using historical data per surgeon and type of surgery. Furthermore some hospitals adjust the scheduled operating time for possible complications, based on prediction by the surgeon. The moment of surgery planning can be seen as a customer order decoupling point. The moment of planning decides how early other processes such as pre-assessment at anesthesiology can take place and other parties in the delivery of care can align their processes since operating room availability is often the bottleneck in the care process after all diagnostics have been performed.

Performance could be evaluated by analyzing lead times, cost charts and patient related case mix corrected outcomes, but that is something different compared to quantifying operational focus. A suggestion could be to use sophisticated questionnaires such as the Analytic Hierarchy Process (AHP) (Liberatore & Nydick, 2008) or Conjoint-Analysis (van Til, Stiggelbout, & Ijzerman, 2009) to assess the operational focus of the hospital. By asking specific questions and let hospital management, surgeons and other employees choose between different options one could find out what really is important in that hospital. A problem arises here; who should fill in the questionnaire so practically, who is deciding what the focus of the hospital is on. Different results are expected from surgeons, nurses, managers or patients.

For the elements of the RPA average scores were used for five departments. However is would also be interesting to see whether RPA items per department are related to lead-times and number of hospital visits.

In health care a lot of information is collected during the care process. Billing information, planning and scheduling and medical information are nowadays more and more digital and electronically recorded and stores. This valuable information should be used in order to get insight care pathways and improving care quality for the patient while making it more efficient and productive for the hospital. An example is the data mining strategy that was proposed by McClean et al. (2008) to use simulation software and data mining to identify similarities between different patient types and the care they received. In this way an automated method for value stream or care path detection was established (McClean et al., 2008).

More research has been done on the field of using already existing data for improvement purposes. An example is the advice that is given by PriceWaterhouseCoopers to make efficient use of data and therefore a secondary use of data. This secondary use refers to that the initial collection of the data was for another process (PriceWaterhouseCoopers, 2009).

6.2 Conclusion

In this part of the report the conclusion of the research will be drawn using the research questions used for this project. The initial research questions stated in Chapter 1 will be recapitulated:

1. How can efficiency in the colorectal cancer surgical care pathway be measured and compared across hospitals using inputs, outputs and patient related outcomes?

We proposed a method to use case mix corrected outcomes (for example number of case mix corrected successful surgeries) as outputs and the use of labor and capital as input. Labor can be calculated using FTE of staff available for CRC patients, including surgeons, physician-assistants, and nurse-practitioners. These can be adjusted using average national salaries for each function.

Another approach was using summed lead-times and number of hospital visits as inputs and total number of patients treated and summed length of stay as outputs. Data Envelopment Analysis was used as a non-parametric calculation method. The method appeared to enable the quantification of this type of efficiency.

2. How can "leanness" be described and how can it be operationalized for colorectal surgical care?

There is no clear definition for "leanness" and no standard method to operationalize it for (colorectal) surgical care is available. A clear distinction has been made in this report between the initiatives to become leaner and the outcomes that can be measured. In some researches, leanness was measured by looking at Lean initiatives and intentions to improve the process. Nevertheless, this does not deal with the actual performance and outcomes of the process. A possibility could be the last approach of efficiency measurement described in Chapter 3. This efficiency measure was calculated using outcomes. Using face validity, we can conclude that the results were according to our hypothesis and that the hospital that seemed to have efficient care, also was pointed out in the analysis.

3. How can the "Lean" Framework, initially developed by Van Vliet et al (2011), be adapted to the colorectal cancer care pathway in order to construct a quantifiable framework to determine " leanness" of a colorectal caner care pathway and see relations between lean initiatives and lean outcomes?

The categories were adapted to the CRC care and a scoring system was established for process and system characteristics, which could be score in hospitals. This was done using a literature study and by looking at the process during on site visits in various hospitals. The cataract pathway is less complex compared to the CRC pathway since CRC care is focused primarily on two subgroups; colon carcinoma en rectum carcinoma and there is variation between diagnosis and treatment.

4. What are the results when comparing Dutch hospitals on their leanness using the developed framework and which relations can be found between the framework and lead-times and number of hospital visits?

There are differences visible between hospitals when using the framework. Using the scorecard and correlation analysis, we can conclude that operational focus and pull planning have an effect on the reduction of lead-times for the rectum pathway. Hospitals scoring high on multi-skilled team seem to have longer lead-times for the care process. In a more detailed correlation analysis highest negative correlations were found for the availability of flow charts of the process. Highest positive correlation was the presence of a dedicated colon care nurse with the lead-time. Significant correlations were mostly found only for a specific patient trajectory.

Health care seen as a production system seems harsh, but the similarities between a production system and health care are numerous. The industrialization of healthcare does not necessarily mean that it becomes less personal and that when dealing with costs minimization the quality will drop. Instead the care is delivered at the right time by the right caregiver with higher quality.

Chapter 7 Recommendations

In this last chapter of this report recommendations will be given to improve research and indicate future research areas.

Since the definitions of efficiency, process characteristics, organizational characteristics, Lean, leanness are not clearly defined, first a clear definition should be stated. It is tried in this report, but the definitions can vary per application. Therefore the application of the efficiency measure should first be very clear before assumptions can be made about a calculation method and the selection of inputs and outputs.

Using the data of the DSCA would save much time and the data collection is more reliable than done by three different researchers who were not trained on forehand to collect the data using semi-structured interviews and observations. Also the retrospective collection of additional information on patient level is time consuming and is not practical when comparing large amounts of hospitals, to really identify best practices and use sophisticated techniques such as Data Envelopment Analysis (Benneyan, 2008) with multiple inputs and outputs. Also when measuring efficiency financial data is important. The DSCA data can be used more appropriate if also organizational and environmental characteristics are registered in the database, such as FTE colorectal surgeons, bed capacity at surgical ward, access times etcetera.

Measuring efficiency is easier when calculated for a single department or hospital instead of a disease pathway. Nevertheless the latter is interesting and attempts should be made to understand the complete care process and not only parts (P.T. Vanberkel & E.W. Hans, 2009).

A suggestion could be to use sophisticated questionnaires such as the Analytic Hierarchy Process (AHP) or conjoint-analysis to determine the operational focus of the hospital. Furthermore expert elicitations techniques can be used to get consensus about a decent efficiency measurement for a complete care path.

Delay between therapy and symptoms: to really decrease, provide education about symptoms since delay before patient goes to GP is longer than the total time the patient is in the pathway (Langenbach, J. Schmidt, Neumann, & Zirngibl, 2003). To really improve outcomes and get an overall societal efficiency prevention is one of the best methods to prevent high care costs. Besides the mortality and morbidity will be reduced.

Another suggestion would to focus more specifically only on rectum or colon carcinoma since both pathways differ and make use of different resources. Since it is proven that the outcome of rectum carcinoma will decrease when the therapeutic delay is lengthened, the focus could be to improve the rectum pathway first (Iversen et al., 2009).

References

Andersen, P., & Petersen, N. C. (1993). A Procedure for Ranking Efficient Units in Data Envelopment Analysis. *Management Science*, *39*(10), 1261-1264. doi:10.1287/mnsc.39.10.1261

Aronsson, H., Abrahamsson, M., & Spens, K. (2011). Developing lean and agile health care supply chains. *Supply Chain Management: An International Journal*, *16*(3), 176-183. doi:10.1108/13598541111127164

Association of Comprehensive Cancer Centers - The Netherlands. (2011). Oncoline.

Babbie, E. (2004). *The Practice of Social Research* (10th ed., p. 493). Belmont, USA: Wadsworth/Thomson Learning.

Basson, M. D., & Butler, T. (2006). Evaluation of operating room suite efficiency in the Veterans Health Administration system by using data-envelopment analysis. *American journal of surgery*, *192*(5), 649-56. doi:10.1016/j.amjsurg.2006.07.005

Benneyan, J. C. (2008). Data envelopment analysis models for identifying and benchmarking the best healthcare processes Aysun Sunnetci and Mehmet Erkan Ceyhan. *Engineering*, *4*(3), 305-331.

Berwick, D. M. (2002). A User's Manual For The IOM's "Quality Chasm" Report. *Health Affairs*, *21*(3), 80-90. doi:10.1377/hlthaff.21.3.80

Bhasin, S. (2008). Lean and performance measurement. *Journal of Manufacturing Technology Management*, *19*(5), 670-684. doi:10.1108/17410380810877311

Boat, T. F., Chao, S. M., & O'Neill, P. H. (2008, February). From waste to value in health care. *JAMA : the journal of the American Medical Association*. doi:10.1001/jama.299.5.568

Bredenhoff, E., van Lent, W. a M., & van Harten, W. H. (2010). Exploring types of focused factories in hospital care: a multiple case study. *BMC health services research*, *10*, 154. doi:10.1186/1472-6963-10-154

Burgess, N., & Radnor, Z. (2007). Lean Paradox: Can Lean influence Healthcare? *irspm2010.com*, (2007), 1-13. Retrieved from http://www.irspm2010.com/workshops/papers/M_leanparadox.pdf

Busch, M. (2011). Welke normen zijn er voor aanvaardbare wachttijden in de zorg? *Volksgezondheid Toekomst Verkenning, Nationaal Kompas Volksgezondheid*. Retrieved May 16, 2011, from http://www.nationaalkompas.nl/zorg/sectoroverstijgend/welke-normen-zijn-er-voor-aanvaardbare-wachttijden-in-de-zorg/

Casalino, L. P., Devers, K. J., & Brewster, L. R. (2003). Focused Factories? Physician-Owned Specialty Facilities. *Health Affairs*, *22*(6), 56. Health Affairs. doi:10.1377/hlthaff.22.6.56

Cedars Sinai. (2011). Rectal Cancer. Retrieved June 10, 2011, from http://www.cedars-sinai.edu/Patients/Programs-and-Services/Colorectal-Cancer-Center/Services-and-Treatments/Rectal-Cancer.aspx

Chan, F. T. S., & Qi, H. J. (2003). Feasibility of performance measurement system for supply chain: a process-based approach and measures. *Integrated Manufacturing Systems*, *14*(3), 179-190. doi:10.1108/09576060310463145

DCCG. (2008). About Dutch Colorectal Cancer Group (DCCG). *About DCCG*. Retrieved June 20, 2011, from http://www.dccg.nl/dccg

DelliFraine, J. L., Langabeer, J. R., & Nembhard, I. M. (2010). Assessing the evidence of Six Sigma and Lean in the health care industry. *Quality management in health care*, *19*(3), 211-25. doi:10.1097/QMH.0b013e3181eb140e

Donabedian, A. (1988). The quality of care: How can it be assessed? *Jama*, *260*(12), 1743. Am Med Assoc. Retrieved from http://jama.ama-assn.org/cgi/content/abstract/260/12/1743

Donabedian, A. (2005). Evaluating the Quality of Medical Care. reprint of original 1966. *The Milbank quarterly*, *83*(4), 691-729. doi:10.1111/j.1468-0009.2005.00397.x

Donohoe, C. L., Nguyen, M., Cook, J., Murray, S. G., Chen, N., Zaki, F., Mehigan, B. J., et al. (2011). Fast-track protocols in colorectal surgery. *The surgeon : journal of the Royal Colleges of Surgeons of Edinburgh and Ireland*, *9*(2), 95-103. Elsevier Ltd. doi:10.1016/j.surge.2010.07.013

Field, A. (2009). *Discovering Statistics Using SPSS* (3rd ed.). London, GB: SAGE Publications Ltd.

Gezondheidsraad. (2009). *Bevolkingsonderzoek naar darmkanker*. Den Haag: Gezondheidsraad. doi:10.5177/ntvt2010.05.10107

Goodson, R. E. (2002). Read a Plant – Fast A Conversation with Robert Redford. *Harvard Business Review*, (May), 11.

Greenberg, L., & Campion, D. (2006). Efficiency in Health Care : What Does it Mean? How is it Measured? How Can it be Used for Value-Based Purchasing? *AcademyHealth, AHRQ*, (290-04-0001).

Hao, S., & Pegels, C. C. (1994). Evaluating relative efficiencies of Veterans Affairs Medical Centers using data envelopment, ratio, and multiple regression analysis. *Journal of medical systems*, *18*(2), 55-67. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7964213

Hollingsworth, B. (2008). The measurement of efficiency and productivity of health care delivery. *Health economics*, *17*(10), 1107–1128. Wiley Online Library. doi:10.1002/hec

Hollingsworth, Bruce, & Peacock, S. J. (2008). *Efficiency Measurement in Health and Health Care* (1st ed.). New York, USA: Routledge international studies in health economics.

Hompes, R., & Cunningham, C. (2011). Colorectal cancer: management. *Medicine*, *39*(5), 254-258. Elsevier Ltd. doi:10.1016/j.mpmed.2011.02.002

Hopp, W. J., & Spearman, M. L. (2007). *Factory Physics* (3rd ed.). London, GB: McGraw-Hill Education - Europe.

Hussey, P. S., de Vries, H., Romley, J., Wang, M. C., Chen, S. S., Shekelle, P. G., & McGlynn, E. a. (2009). A systematic review of health care efficiency measures. *Health services research*, *44*(3), 784-805. doi:10.1111/j.1475-6773.2008.00942.x

Hyer, N. L., Wemmerlöv, U., & Morris Jr., J. a. (2009). Performance analysis of a focused hospital unit: The case of an integrated trauma center. *Journal of Operations Management*, *27*(3), 203-219. doi:10.1016/j.jom.2008.08.003

Iversen, L. H., Antonsen, S., Laurberg, S, & Lautrup, M. D. (2009). Therapeutic delay reduces survival of rectal cancer but not of colonic cancer. *The British journal of surgery*, *96*(10), 1183-9. doi:10.1002/bjs.6700

Jacobs, R., Smith, P. C., & Street, A. (2011). *Measuring Efficiency in Health Care* (3rd ed.). Cambridge, UK: Cambridge University Press.

de Jager, J. C. (2011). Kamervragen en antwoorden Voorlopige Rekening 2010. *Ministry of Finance | The Netherlands*, (BZ/2011/299M).

Kenagy, J. W., Berwick, D. M., & Shore, M. F. (1999). Service Quality in Health Care. *JAMA: the journal of the American Medical Association*, *281*(7), 661. Am Med Assoc. Retrieved from http://jama.ama-assn.org/content/281/7/661.short

Klemann, V. M. W. T., Wolters, F. L., & Konsten, J. L. M. (2011). Benefits of a well-structured diagnostic process in colon cancer. *Digestive surgery*, *28*(1), 15-21. doi:10.1159/000321894

van de Klundert, J., Gorissen, P., & Zeemering, S. (2010). Measuring clinical pathway adherence. *Journal of biomedical informatics*, *43*(6), 861-72. Elsevier Inc. doi:10.1016/j.jbi.2010.08.002

Kollberg, B., Dahlgaard, J. J., & Brehmer, P.-O. (2007). Measuring lean initiatives in health care services: issues and findings. *International Journal of Productivity and Performance Management*, *56*(1), 7-24. doi:10.1108/17410400710717064

Koning, H. D., Verver, J. P. S., Heuvel, J. V. D., Bisgaard, S., & Does, R. J. M. M. (2006). Lean Six Sigma in Healthcare. *Journal for Healthcare Quality*, *28*(2), 4-11.

Kontodimopoulos, N., & Niakas, D. (2005). Efficiency measurement of hemodialysis units in Greece with data envelopment analysis. *Health policy (Amsterdam, Netherlands)*, *71*(2), 195-204. doi:10.1016/j.healthpol.2004.08.004

Korsgaard, M., Pedersen, L., Sørensen, H. T., & Laurberg, Søren. (2006). Delay of treatment is associated with advanced stage of rectal cancer but not of colon cancer. *Cancer detection and prevention*, *30*(4), 341-6. doi:10.1016/j.cdp.2006.07.001

Kumar, S. (2010). Specialty hospitals emulating focused factories: A case study. *International Journal of Health Care Quality Assurance*, *23*(1), 94-109. doi:10.1108/09526861011010703

Langenbach, M. R., Schmidt, J., Neumann, J., & Zirngibl, H. (2003). Delay in treatment of colorectal cancer: multifactorial problem. *World journal of surgery*, *27*(3), 304-8. doi:10.1007/s00268-002-6678-9

Lassen, K., Soop, M., Nygren, J., Cox, P. B. W., Hendry, P. O., Spies, C., von Meyenfeldt, M. F., et al. (2009). Consensus review of optimal perioperative care in colorectal surgery: Enhanced Recovery After Surgery (ERAS) Group recommendations. *Archives of surgery (Chicago, Ill.: 1960)*, *144*(10), 961-9. doi:10.1001/archsurg.2009.170

Lemmens, L., van Zelm, R., Vanhaecht, Kris, & Kerkkamp, H. (2008). Systematic review: indicators to evaluate effectiveness of clinical pathways for gastrointestinal surgery. *Journal of evaluation in clinical practice*, *14*(5), 880-7. doi:10.1111/j.1365-2753.2008.01079.x

Lemmens, V. E. P. P. (2007). *Clinical Epidemiology of Colorectal Cancer in the Netherlands: studies of variation and trends with the Eindhoven Cancer Registry*. Erasmus University Rotterdam.

Liberatore, M., & Nydick, R. (2008). The analytic hierarchy process in medical and health care decision making: A literature review. *European Journal of Operational Research*, *189*(1), 194-207. doi:10.1016/j.ejor.2007.05.001

Liker, J. K., & Morgan, J. M. (2006). The Toyota Way in Services : The Case of Lean Product Development. *System*, 5-21.

Lorenzo-Zúñiga, V., de Vega, V. M., Doménech, E., Mañosa, M., Planas, R., & Boix, J. (2009). Endoscopist Experience As a Risk Factor for Colonoscopic Complications. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland*, 273-277. doi:10.1111/j.1463-1318.2009.02146.x

Magnussen, J. (1996). Efficiency measurement and the operationalization of hospital production. *Health services research*, *31*(1), 21-37. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1070101&tool=pmcentrez&rendertype=abstract

Martinussen, P. E., & Midttun, L. (2004). Day surgery and hospital efficiency: empirical analysis of Norwegian hospitals, 1999-2001. *Health policy (Amsterdam, Netherlands)*, *68*(2), 183-96. doi:10.1016/j.healthpol.2003.09.003

Maslekar, S., Hughes, M., Gardiner, a, Monson, J. R. T., & Duthie, G. S. (2010). Patient satisfaction with lower gastrointestinal endoscopy: doctors, nurse and nonmedical endoscopists. *Colorectal disease : the official journal of the Association of Coloproctology of Great Britain and Ireland*, *12*(10), 1033-8. doi:10.1111/j.1463-1318.2009.01989.x

McClean, S., Young, T., Bustard, D., Millard, P., & Barton, M. (2008). Discovery of value streams for Lean Healthcare. *2008 4th International IEEE Conference Intelligent Systems*, 3-2-3-8. Ieee. doi:10.1109/IS.2008.4670412

Miller, D. (2005). Going lean in health care. *Instititute for Healthcare Improvement*, (February). Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Going+Lean+in+Health+Care#0

Morris, S., Devlin, N., & Parkin, D. (2010). *Economic Analysis in Health Care*. *John Wiley & Sons, Ltd* (p. 400). London: John Wiley & Sons, Ltd.

Mould, G., Bowers, J., & Ghattas, M. (2010). The evolution of the pathway and its role in improving patient care. *Quality & safety in health care*, 1-7. doi:10.1136/qshc.2009.032961

Ng, D., Vail, G., Thomas, S., & Schmidt, N. (2010). Applying the Lean principles of the Toyota Production System to reduce wait times in the emergency department. *CJEM: Canadian journal of emergency medical care= JCMU: journal canadien de soins médicaux d'urgence*, *12*(1), 50. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20078919/

Ozcan, Y. A. (2008). Health Care Benchmarking and Performance Evaluation. *Operations Research*, *120*. Boston, MA: Springer US. doi:10.1007/978-0-387-75448-2

Parry, G. C., & Turner, C. E. (2006). Application of lean visual process management tools. *Production Planning & Control*, *17*(1), 77-86. doi:10.1080/09537280500414991

Porter, M. E. (2010). What is value in health care. *New England Journal of Medicine*, *363*(26), 2477–2481. Massachusetts Medical Society. Retrieved from http://www.nejm.org/doi/pdf/10.1056/NEJMp1011024

PriceWaterhouseCoopers. (2009). Transforming healthcare through secondary use of health data. *Health Industries*.

PriceWaterhouseCoopers. (2011). Ziekenhuisresultaten verbeteren onvoldoende om kortingen op te vangen. *Press release*. Retrieved June 17, 2011, from http://www.pwc.com/nl/nl/persbericht/ziekenhuisresultaten-verbeteren-onvoldoende-om-kortingen-op-te-vangen.jhtml

Profit, J., Typpo, K. V., Hysong, S. J., Woodard, L. D., Kallen, M. a, & Petersen, L. a. (2010). Improving benchmarking by using an explicit framework for the development of composite indicators: an example using pediatric quality of care. *Implementation science : IS*, *5*, 13. doi:10.1186/1748-5908-5-13

Rainis, T., Keren, D., Goldstein, O., Stermer, E., & Lavy, A. (2007). Diagnostic yield and safety of colonoscopy in Israeli patients in an open access referral system. *Journal of clinical gastroenterology*, *41*(4), 394-9. doi:10.1097/01.mcg.0000225573.27643.3d

Ransom, E. R., Joshi, M. S., Nash, D. B., & Ransom, S. B. (2008). *The Healthcare Quality Book*. (E. R. Ransom, M. S. Joshi, D. B. Nash, & S. B. Ransom, Eds.) (2nd ed., p. 495). Chicago | Washington, United States of America: Health Administration Press, Aupha Press.

Ray, C. D., Zuo, X., Michael, J. H., & Wiedenbeck, J. K. (2006). The lean index: Operational“ lean” metrics for the wood products industry. *Wood and fiber science*, *38*(2), 238–255. Soc Wood Sc Tech. Retrieved from http://swst.metapress.com/index/856151837615714p.pdf

Richardson, G., Bloor, K., Williams, J., Russell, I., Durai, D., Cheung, W. Y., Farrin, a, et al. (2009). Cost effectiveness of nurse delivered endoscopy: findings from randomised multi-institution nurse endoscopy trial (MINuET). *Bmj*, *338*(feb10 1), b270-b270. doi:10.1136/bmj.b270

Romley, J. A, Hussey, P. S., de Vries, H., Wang, M. C., Shekelle, P. G., & McGlynn, E. a. (2009). Efficiency and its measurement: what practitioners need to know. *The American journal of managed care*, *15*(11), 842-5. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19895189

Saari, S. (2006). Theory and Measurement in Business. *Main*, 1-10.

Saurin, T. A., Marodin, G. A., & Ribeiro, J. L. D. (2011). A framework for assessing the use of lean production practices in manufacturing cells. *International Journal of Production Research*, *49*(11), 3211-3230. doi:10.1080/00207543.2010.482567

Schippers, E. I. (2011). Letter to the Dutch House of Representatives: Besluit invoering bevolkingsonderzoek naar darmkanker. *Ministry of Health, Welfare and Sport | The Netherlands*, *6th of Jun*(PG/OGZ 3065362).

Scroll, P., & For, D. (2008). Collecting Grey Literature Collecting Grey Literature : An Annotated Bibliography , with Examples from the Sciences and Technology. *Technology*, (June 2011), 37-41.

Seyedhosseini, S. M., Taleghani, A. E., Bakhsha, A., & Partovi, S. (2011). Extracting leanness criteria by employing the concept of Balanced Scorecard. *Expert Systems with Applications*, *38*(8), 10454-10461. Elsevier Ltd. doi:10.1016/j.eswa.2011.02.095

Slack, N., Chambers, S., & Johnston, R. (2007). *Operations Management* (5th ed.). Essex: Prentice Hall - Pearson Education Limited.

Spanjersberg, W. R., Reuring, J., Keus, F., & van Laarhoven, C. J. H. M. (2011). Fast track surgery versus conventional recovery strategies for colorectal surgery (Review). *The Cochrane Library*, (2).

van Til, J. A., Stiggelbout, A. M., & IJzerman, M. J. (2009). The effect of information on preferences stated in a choice-based conjoint analysis. *Patient education and counseling*, *74*(2), 264-71. doi:10.1016/j.pec.2008.08.025

Timbie, J. W., & Normand, S.-lise T. (2008). A comparison of methods for combining quality and efficiency performance measures : Profiling the value of hospital care following acute myocardial infarction. *Current*, (August 2006), 1351-1370. doi:10.1002/sim

Tone, K. (2002). Continuous Optimization A slacks-based measure of super-efficiency in data envelopment analysis. *European Journal Of Operational Research*, *143*, 32-41.

Vanberkel, P.T., & Hans, E.W. (2009). Holistic healthcare modeling: a viewpoint on managing the complete patient care chain. *Operational Research Applied to Health Services in Action* (pp. 349-352). Wroclaw: Oficyna Wydawnicza Politechniki Wrocławskiej. Retrieved from http://www.utwente.nl/mb/ompl/staff/Vanberkel/orahsviewpoint.pdf

Vanberkel, Peter T., Boucherie, R. J., Hans, Erwin W., Hurink, J. L., & Litvak, N. (2010). Efficiency evaluation for pooling resources in health care. *OR Spectrum*. doi:10.1007/s00291-010-0228-x

Vanhaecht, K., & Sermeus, W. (2003). The Leuven Clinical Pathway Compass. *Journal of Care Pathways*, *7*, 2–7. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:The+Leuven+Clinical+Pathway+Compass#0

Veillard, J., Champagne, F., Klazinga, N., Kazandjian, V., Arah, O. a, & Guisset, a-L. (2005). A performance assessment framework for hospitals: the WHO regional office for Europe PATH project. *International journal for quality in health care : journal of the International Society for Quality in Health Care / ISQua*, *17*(6), 487-96. doi:10.1093/intqhc/mzi072

van de Velde, C. J. H., van Krieken, J. H. J. M., de Mulder, P. H. M., & Vermorken, J. B. (2005). *Oncologie* (7th ed.). Houten: Bohn Stafleu van Loghum.

Vinodh, S., & Chintha, S. K. (2011). Leanness assessment using multi-grade fuzzy approach. *International Journal of Production Research*, *49*(2), 431-445. doi:10.1080/00207540903471494

Vissers, J., & Beech, R. (2005). *Health Operations Management: patient flow logistics in health care* (1st ed.). New York: Routledge.

Van Vliet, Ellen J, Bredenhoff, E., Sermeus, Walter, Kop, L. M., Sol, J. C. a, & Van Harten, W. H. (2011). Exploring the relation between process design and efficiency in high-volume cataract pathways from a lean thinking perspective. *International journal for quality in health care : journal of the International Society for Quality in Health Care / ISQua*, *23*(1), 83-93. doi:10.1093/intqhc/mzq071

van Vliet, Ellen Joan, Sermeus, Walter, van Gaalen, C. M., Sol, J. C. a, & Vissers, J. M. H. (2010). Efficacy and efficiency of a lean cataract pathway: a comparative study. *Quality & safety in health care*, (figure 1). doi:10.1136/qshc.2008.028738

Wan, H.-da, & Frank Chen, F. (2008). A leanness measure of manufacturing systems for quantifying impacts of lean initiatives. *International Journal of Production Research*, *46*(23), 6567-6584. doi:10.1080/00207540802230058

Westert, G. P., van den Berg, M.J., de Jong, J.D., Verkleij, H. (2010). *Dutch Health Care Performance Report 2010. Health Care*. Bilthoven, The Netherlands.

Williams, J., Russell, I., Durai, D., Cheung, W. Y., Farrin, a, Bloor, K., Coulton, S., et al. (2009). Effectiveness of nurse delivered endoscopy: findings from randomised multi-institution nurse endoscopy trial (MINuET). *Bmj*, *338*(feb10 1), b231-b231. doi:10.1136/bmj.b231

Womack, J. P., & Jones, D. T. (1990). *The Machine that Changed the World* (1st ed.). New York: Macmillan Publishing Company.

Womack, J. P., & Jones, D. T. (2003). *Lean Thinking: Banish Waste and Create Wealth in Your Corporation* (p. 384). London, GB: Simon & Schuster Ltd.

World Health Organization. (n.d.). Health facility economic efficiency analysis. *Health Financing and Social Protection*. Retrieved July 10, 2011, from http://www.afro.who.int/en/clusters-a-programmes/hss/health-financing-a-social-protection/programme-components/health-facility-economic-efficiency-analysis.html

Zhu, J. (2009). *Quantitative Models for Performance Evaluation and Benchmarking* (1st ed.). Worcester, USA: Springer.

Appendices

Appendix A: Elements of a fast-track protocol

Appendix B: The distribution of patient types in the database collected at the hospitals

Appendix C: Total list of items for correlation analysis with outcomes

Appendix D: Correlation analysis of process characteristics with lead-times and number of hospital visits

Appendix E: Comparison of process characteristics in Dutch hospitals (tables in Dutch)

APPENDIX A.

ELEMENTS OF A FAST-TRACK PROTOCOL

Fasttrack protocol elements				
Item	**Pre-operative preparation**	**Anesthetic factor**	**Intraoperative and surgical factors**	**Post operatieve management**
	Pre-admission information and counseling	Thromboembolism prophylaxis	Laparoscopic (minimal invasive) surgery	Postoperative analgesia
	No preoperative bowel preparation	Antimicrobial prophylaxis	Choice of surgical incisions	Postoperative nutritional care
	Preoperative fasting and carbohydrate loading	Standard anesthetic protocol	Avoid nasogastric intubation	Early mobilisation
	Pre-anesthetic medication	Prevent and treat postoperative nausea and vomiting	Prevent intra-operative hypothermia	Prevent post-operative ileus
		Peri-operative fluid management	Avoid intra-peritoneal drains	Limit urinary drainage
				Audit

APPENDIX B.

THE DISTRIBUTION OF PATIENT TYPES IN THE DATABASE COLLECTED AT THE HOSPITALS

Frequencies of patient trajectories		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Colon	622	58.7	64.8	64.8
	Rectum (no radiation)	35	3.3	3.6	68.4
	Rectum (short radiation)	176	16.6	18.3	86.8
	Rectum (long radiation)	127	12.0	13.2	100.0
	Total	960	90.6	100.0	
Missing		100	9.4		
Total		1060	100.0		

APPENDIX C.

TOTAL LIST OF ITEMS OF PROCESS CHARACTERISTICS FOR CORRELATION ANALYSIS WITH OUTCOMES

1	Focus on medical content or operational aspects
2	Number of beds
3	Use of a multidisciplinary outpatient clinic
4	Number of day sessions per week for oncology
5	Number of day sessions per week planned for colorectal surgery
6	Fixed sessions per week for colorectal surgery
7	Slots planned for outpatient clinic gastrointestinal
8	Slots planned for outpatient clinic
9	Slots planned for X-thorax
10	Slots planned for CT-scan
11	Slots planned for MRI-scan
12	Number of staff members involved in MDT
13	Is there a specialized nurse for colorectal patients
14	Is there an established nursing team
15	Rapid plant assessment: safety, environment, cleanliness and order
16	Rapid plant assessment: visual management system
17	Rapid plant assessment: use of space, movement of materials and product line flow
18	Rapid plant assessment: commitment to quality
19	Rapid plant assessment: management of complexity and urgencies
20	Rapid plant assessment: supply chain integration
21	Rapid plant assessment: scheduling system
22	Is a one-stop shop for diagnosis used
23	Does the hospital work with a clinical pathway
24	Are there flow charts available for colon patients
25	Are there flowcharts available for rectum patients
26	Electronic health record for outpatient phase used
27	Electronic health record for inpatient phase used
28	Does the hospital work with a single patient file

APPENDIX D.

CORRELATION ANALYSIS

Detailed correlation analysis of categories, significant results (P < 0.05)

Number	Trajectory	Row	Column	N of hospitals	Test result R	P-value	Relation
1	Rectum (short)	Clinical pathway available?	Lead-time workdays First visit – surgery (mean)	13	-0.490	0.040	Negative
2	Rectum (long)	Clinical pathway available?	Lead-time workdays First visit – surgery (median)	13	-0.499	0.039	Negative
3	Rectum (long)	Clinical pathway available?	Lead-time workdays PA – MDT (mean)	10	-0.591	0.033	Negative
4	Rectum (long)	Does the hospital use a single patient file?	Lead-time workdays PA – MDT (median)	10	-0.545	0.049	Negative
5	Rectum (long)	Does the hospital use a single patient file?	Lead-time workdays MDT – surgery (mean)	10	0.602	0.029	Positive
6	Rectum (short)	Flow chart available?	Lead-time workdays First visit – surgery (mean)	13	-0.620	0.011	Negative
7	Rectum (short)	Flow chart available?	Length of stay (median)	13	-0.506	0.042	Negative
8	Rectum (long)	Flow chart available?	Length of stay (mean)	13	-0.579	0.018	Negative
9	Rectum (long)	Flow chart available?	Lead-time workdays PA – MDT (mean)	10	-0.596	0.037	Negative
10	Rectum (short)	Flow chart available?	Lead-time workdays MDT – surgery (median)	10	-0.603	0.036	Negative
11	Rectum (short)	Flow chart available?	Lead-time workdays MDT – surgery (mean)	10	-0.596	0.037	Negative
12	Rectum (long)	Focus on medical content or operational aspect	Lead-time workdays MDT – surgery (median)	10	-0.542	0.049	Negative
13	Rectum (long)	Multidisciplinary clinic available?	Length of stay (mean)	14	0.514	0.028	Positive
14	Rectum (short)	One-stop shop diagnosis?	Lead-time workdays First visit – surgery (mean)	13	-0.483	0.048	Negative
15	Rectum (short)	One-stop shop diagnosis?	Length of stay (median)	13	-0.542	0.029	Negative
16	Rectum (short)	One-stop shop diagnosis?	Length of stay (mean)	13	-0.483	0.048	Negative
17	Rectum (short)	One-stop shop diagnosis?	Lead-time workdays PA – MDT (median)	10	0.596	0.037	Positive
18	Colon	One-stop shop diagnosis?	Number of hospital visits	13	-0.486	0.048	Negative

			(mean)				
19	Rectum (long)	RPA Managing complexity	Lead-time workdays PA – MDT (mean)	10	-0.591	0.033	Negative
20	Rectum (short)	RPA Scheduling system	Number of hospital visits (mean)	13	-0.575	0.012	Negative
21	Rectum (long)	RPA Supply chain	Lead-time workdays MDT – surgery (median)	10	-0.585	0.042	Negative
22	Colon	RPA Scheduling system	Number of hospital visits (median)	13	-0.562	0.024	Negative
23	Colon	RPA Scheduling system	Number of hospital visits (mean)	13	-0.564	0.014	Negative
24	Rectum (short)	RPA Scheduling system	Number of hospital visits (mean)	13	-0.577	0.016	Negative
25	Colon	RPA supply chain	Lead-time workdays First visit – surgery (median)	13	0.492	0.045	Positive
26	Rectum (short)	Slots planned for CT	Length of stay (median)	14	-0.485	0.042	Negative
27	Rectum (short)	Slots planned for CT	Length of stay (mean)	14	-0.602	0.010	Negative
28	Rectum (short)	Slots planned for CT?	Lead-time workdays PA – MDT (median)	11	0.572	0.034	Positive
29	Rectum (long)	Slots planned for CT?	Lead-time workdays MDT – surgery (median)	11	0.545	0.045	Positive
30	Rectum (short)	Slots planned for MRI	Length of stay (median)	14	-0.485	0.042	Negative
31	Rectum (short)	Slots planned for MRI	Length of stay (mean)	14	-0.602	0.010	Negative
32	Rectum (short)	Slots planned for MRI?	Lead-time workdays PA – MDT (median)	11	0.572	0.034	Positive
33	Rectum (long)	Slots planned for MRI?	Lead-time workdays MDT – surgery (median)	11	0.545	0.045	Positive
34	Colon	Specialized nurses for colorectal care?	Lead-time workdays PA – MDT (mean)	11	0.640	0.018	Positive
35	Rectum (long)	Specialized nurses for colorectal care?	Lead-time workdays PA – MDT (mean)	10	0.626	0.028	Positive

APPENDIX E

COMPARISON OF PROCESS CHARACTERISTICS IN DUTCH HOSPITALS (TABLES IN DUTCH)

De verschillende kenmerken van de ziekenhuizen die participeren in het onderzoek zijn samengevat in Tabel 1. Vanwege vertraging bij de aanvraag van de gegevens uit de DSCA (Dutch Colorectal Surgical Audit) konden deze gegevens en de analyse hiervan nog niet opgenomen worden in dit rapport.

Tabel 1: Kenmerken deelnemende ziekenhuizen

Zkh	Ziekenhuis type	Betrokkenheid in onderwijs en training chirurgie	Totale bed capaciteit[3] (per 50)	Organisatie vakgroep heelkunde	Onderdeel van Samenwerkende Topklinische Ziekenhuizen (STZ)
H1	Groot niet-academisch	Ja, voor arts-assistenten	351 – 400	Staf maatschap	Ja
H2	Academisch	Ja, voor chivo GE-chirurgie	1301 – 1350	Loondienst	Nee
H3	Algemeen	Ja, voor co-assistenten	301 – 350	Individuele maatschap	Nee
H4	Algemeen	Ja, voor co-assistenten	301 – 350	Individuele maatschap	Nee
H5	Algemeen	Ja, voor arts-assistenten	251 – 300	Individuele maatschap	Nee
H6	Academisch	Ja, voor chivo GE-chirurgie	851 – 900	Loondienst	Nee
H7	Categorisch	Ja, voor chico onco-chirurgie	151 – 200	Loondienst	Nee
H8	Algemeen	Ja, voor arts-assistenten	501 – 550	Individuele maatschap	Nee
H9	Groot niet-academisch	Ja, voor chivo GE-chirurgie	651 – 700	Individuele maatschap	Nee
H10	Algemeen	Ja, voor arts-assistenten	601 – 650	Individuele maatschap	Nee
H11	Groot niet-academisch	Ja, voor chivo onco-chirurgie	1051 – 1100	Individuele maatschap	Nee
H12	Algemeen	Nee	301 – 350	Individuele maatschap	Nee
H13	Algemeen	Nee	351 – 400	Individuele maatschap	Nee
H14	Algemeen	Ja, voor co-assistenten	301 – 350	Individuele maatschap	Ja
H15	Algemeen	Nee	301 – 350	Staf maatschap	Nee
H16	Groot niet-academisch	Nee	451 – 500	Individuele maatschap	Nee
H17	Groot niet-academisch	Ja, voor arts-assistenten	401 – 450	Staf maatschap	Nee
H18	Groot niet-academisch	Ja, voor chivo GE-chirurgie	651 – 700	Individuele maatschap	Ja

Voor de berekening van de doorlooptijden en het aantal bezoeken per patiënt is gebruik gemaakt van het eigen ziekenhuis informatie systeem van het ziekenhuis. De data is eerste gefilterd zodat alleen electieve patiënten, die via het gebruikelijke pad het ziekenhuis binnenkomen, zijn meegenomen in de berekening.

De data is gebaseerd op het semi-gestructureerd interview met de chirurg en/of eventueel een gespecialiseerd verpleegkundige. De gegevens die verzameld zijn hebben betrekking op het kalenderjaar 2009 en het is dus mogelijk dat er in de tussentijd veranderingen zijn geweest. Deze rapportage zal achtereenvolgens ingaan op de kenmerken van de deelnemende ziekenhuizen (tabel 1), doorlooptijden en aantal patiëntbezoeken (tabel 2), teamsamenstellingen en team kenmerken (tabel 3), planning en plaats reserveringen (tabel 4), zorgpad en MDO (tabel 5) en fast-track (tabel 6).

[3] Bed capaciteit ontleend van *Deuning CM (RIVM). Locaties algemene en academische ziekenhuizen 2010. In: Volksgezondheid Toekomst Verkenning, Nationale Atlas Volksgezondheid. Bilthoven: RIVM, <http://www.zorgatlas.nl> Zorgatlas\Zorg\Ziekenhuiszorg, 6 december 2010. Gebaseerd op situatie 2008*

Tabel 2. Doorlooptijden en aantal bezoeken aan het ziekenhuis

	Doorlooptijd (werkdagen) Eerste bezoek tot OK			Doorlooptijd (dagen) Ligdagen			Doorlooptijd (werkdagen) Pre-operatief MDO tot OK			Aantal bezoeken patient aan ziekenhuis voor OK		
Zkh	**Colon**	**Rectum kort**	**Rectum Lang**	**Colon**	**Rectum kort**	**Rectum Lang**	**Colon**	**Rectum kort**	**Rectum Lang**	**Colon**	**Rectum kort**	**Rectum Lang**
H1												
66%	32.5	43.6	91.7	8.0	12.9	10.9	22.9	30.6	85.7	4.0	5.0	6.0
Mediaan	29.0	35.0	84.5	7.0	11.0	9.0	20.0	25.0	79.5	4.0	5.0	6.0
Gem.	29.9	41.3	79.4	8.6	14.2	15.3	20.5	31.1	72.8	4.0	4.8	5.5
SD	9.4	14.7	24.2	6.4	11.6	24.2	9.3	16.2	25.8	0.6	0.7	0.8
N	71	17	8	72	17	8	72	17	8	72	17	8
H2												
66%	44.8	86.7	106.8	10.9	16.7	13.7	35.0	84.4	87.5	4.0	5.0	4.0
Mediaan	39.0	57.0	98.0	7.00	12.0	12.0	30.5	35.0	80.0	4.0	5.0	4.0
Gem.	40.1	87.5	94.4	9.8	14.7	12.0	39.2	75.5	69.7	3.7	4.4	4.0
SD	14.1	65.3	33.6	6.0	9.2	5.3	41.1	69.5	69.7	1.0	1.3	1.2
N	36	13	23	33	13	22	22	13	23	36	13	23
H3												
66%	27.0	37.7	183.6	17.0	8.0	13.9	14.0	19.0	93.0	4.0	5.0	5.0
Mediaan	25.0	33.0	150.0	8.00	7.0	11.0	12.0	17.0	93.0	4.0	5.0	4.5
Gem.	27.1	32.2	150.0	6.00	7.4	11.0	12.4	18.6	93.0	4.0	5.0	4.5
SD	10.1	7.3	49.5	6.62	7.3	49.5	6.1	6.5	-	0.5	0.0	0.7
N	43	13	2	43	13	2	23	13	1	45	14	2
H4												
66%	20.0	23.0	87.8	17.8	-	28.6	17.3	20.2	82.0	4.0	4.0	5.0
Mediaan	16.0	21.0	82.5	8.0	7.0	18.0	15.0	17.0	82.0	4.0	4.0	4.5
Gem.	18.2	20.7	82.5	16.0	10.6	18.0	14.3	17.0	82.0	3.7	3.9	4.5
SD	10.1	5.4	7.8	6.2	10.8	15.6	4.1	5.0	-	0.6	0.4	0.7
N	21	7	2	21	7	2	4	3	1	21	7	2
H5												
66%	27.2	33.0	95.1	15.6	37.9	10.0	15.3	24.8	87.0	4.0	4.0	5.0
Mediaan	20.0	33.0	92.0	7.0	14.0	6.0	11.0	19.0	81.0	4.0	4.0	5.0
Gem.	24.7	30.2	87.6	5.0	28.5	12.7	11.3	21.8	66.1	4.1	4.0	4.7
SD	13.1	5.9	27.9	5.2	36.2	16.1	4.7	5.6	32.1	0.7	0.7	1.3
N	18	5	15	17	4	15	7	5	13	18	5	15
H6												
66%	32.8	37.0	107.6	23.0	11.0	24.5	22.0	21.1	84.9	5.0	6.0	5.3
Mediaan	27.5	35.0	105.5	10.0	9.0	11.5	19.0	18.0	46.5	4.0	6.0	4.5
Gem.	29.6	41.4	104.0	7.0	14.0	19.5	22.4	18.7	46.0	4.0	5.6	4.5
SD	21.9	18.1	5.7	8.9	15.9	19.9	20.3	3.8	45.7	1.2	0.5	1.3
N	30	9	4	31	9	4	17	6	4	31	9	4
H7												
66%	33.5	45.3	106.9	25.2	13.6	16.7	33.3	36.5	84.7	4.5	5.0	4.0
Mediaan	31.0	34.5	94.0	9.0	10.5	12.0	23.5	31.0	77.0	4.0	4.5	4.0
Gem.	40.8	56.3	91.0	8.0	16.1	24.6	36.8	39.9	81.1	4.1	4.8	3.7
SD	42.3	50.9	34.9	16.9	15.0	34.9	39.6	34.5	9.6	1.1	0.9	1.3
N	27	18	11	27	18	11	12	13	7	27	18	11
H8												
66%	33.8	37.0	94.6	33.8	13.8	28.9	22.1	28.8	85.6	4.0	6.0	6.0
Mediaan	27.5	35.0	80.0	27.5	10.0	15.0	19.0	25.0	72.5	4.0	6.0	6.0
Gem.	38.1	40.5	82.5	38.1	15.1	24.3	24.5	30.0	72.3	4.3	5.5	5.8
SD	31.8	18.9	17.5	13.2	13.1	23.4	21.6	19.5	14.0	0.6	0.6	0.5
N	42	17	4	41	17	4	40	17	4	42	17	4
H9												

66%	28.5	90.8	119.4	8.5	41.3	9.9	12.9	-	-	6.5	11.8	10.3
Mediaan	23.5	39.0	104.0	5.0	24.0	104.0	10.5	-	-	6.0	8.0	9.0
Gem.	29.3	63.3	106.7	7.3	24.0	106.7	10.5	-	-	6.0	10.0	8.7
SD	22.5	49.2	20.1	4.3	25.5	3.0	3.5	-	-	2.2	3.5	2.6
N	24	3	3	24	2	3	2	-	-	24	3	3
H10												
66%	25.0	30.8	96.4	13.0	15.1	14.6	-	-	-	6.0	5.0	10.0
Mediaan	22.0	27.0	85.0	10.0	9.0	8.5	-	-	-	5.0	5.0	9.5
Gem.	29.9	32.6	84.3	13.3	13.5	12.8	-	-	-	5.6	5.0	9.9
SD	15.3	20.8	25.2	11.2	9.2	9.0				1.8	1.7	2.6
N	80	32	12	78	31	12				80	32	12
H13												
66%	38.0	47.2	92.1	11.0	11.0	13.	-	-	-	7.0	7.0	10.0
Mediaan	26.5	35.0	86.0	9.0	9.5	8.50	-	-	-	6.0	6.5	9.0
Gem.	37.4	48.5	90.3	10.2	9.7	13.9	-	-	-	6.4	6.5	9.1
SD	30.8	39.6	10.5	9.0	6.0	13.1				2.1	2.3	1.6
N	46	19	15	51	20	14				51	20	15
H14												
66%	31.8	49.6	92.5	7.1	24.9	6.0	16.0	32.2	70.0	6.0	7.0	9.6
Mediaan	26.0	40.0	87.0	5.0	10.0	5.0	15.0	24.0	66.5	5.0	5.0	9.0
Gem.	32.5	55.6	79.0	7.6	14.8	6.0	15.0	28.7	56.0	5.0	6.5	8.1
SD	19.2	44.4	25.4	7.2	11.4	3.0	1.4	13.9	28.4	1.8	2.4	2.6
N	32	11	6	31	11	5	2	6	4	33	11	6
H15												
66%	45.0	43.1	111.3	9.0	12.8	20.9	13.5	26.2	74.0	7.0	7.0	11.0
Mediaan	38.0	36.5	94.0	6.5	9.5	19.0	10.5	13.0	70.5	7.0	6.5	10.0
Gem.	42.8	38.7	100.2	9.3	15.7	19.6	22.4	18.6	60.3	6.7	6.6	9.8
SD	34.8	16.5	12.9	7.2	16.8	7.8	44.3	12.4	28.0	2.2	1.0	1.3
N	48	10	5	48	10	5	18	7	4	48	10	5
H17												
66%	38.1	44.8	100.9	8.0	9.9	10.0	21.1	34.5	83.9	6.0	7.0	11.0
Mediaan	31.0	40.0	94.0	7.0	8.5	8.5	16.0	29.0	82.0	6.0	7.0	11.0
Gem.	36.2	46.9	98.0	9.1	13.4	9.4	21.8	34.5	83.3	6.0	7.1	10.5
SD	20.2	18.0	12.2	6.9	11.0	3.4	19.8	19.5	1.4	1.4	1.3	1.6
N	44	14	11	43	14	10	37	13	11	44	14	11

Tabel 3: Teamsamenstelling en teamkenmerken

Zkh	Aantal functies betrokken bij diagnostische fase	Type medewerkers betrokken bij diagnostische fase[4]	Aantal MDO's voor coloncarcinoom	Aantal MDO's voor rectumcarcinom (lang/kort)	Aantal functies betrokken bij het MDO	Type medewerkers betrokken bij MDO[2]	Vast operatie team voor colorectale patiënten?	Gespecialiseerde operatieassistenten colorectaal?	Gespecialiseerde OK-assistenten laparoscopie?	Gespecialiseerde verpleegkundigen voor colorectaal?	Gespecialiseerde verpleegafdeling/team?
H1	8	A, B, D, E, F, G, O, P	2	2/2	7	A, B, C, D, E, F, I	Nee	Nee	Nee	Ja	Nee
H2	4	A, B, D, E	1	1/2	9	A, B, C, D, E, F, I, J, N	Ja	Nee	Nee	Ja	Ja
H3	4	A, B, D, E	1	1/1	3	A, B, D	Nee	Nee	Nee	Ja	Nee
H4	5	A, B, C, D, E	0	1/1	8	A, B, C, D, E, F, R, L	Nee	Ja	Ja	Ja	Nee
H5	5	A, B, D, E	-	-	3	B, D, E	Nee	Nee	Ja	Ja	Ja
H6	4	A, B, D, Q	1	1/1	7	A, B, C, D, E, F, N	Nee	Ja	Ja	?	Ja
H7	3	A, B, E	1	1/1	3	A, B, D	Nee	?	Ja	Ja	Ja
H8	3	A, D, E	2	1/1	3	A, B, K	?	?	?	Ja	Ja
H9	2	A, D	1	2/2	7	A, B, C, D, E, F, H, R	Ja	Ja	Ja	Ja	Ja
H10	9	A, B, C, D, F, J, Q , S, T	0	1/1	6	A, B, C, D, E	Nee	Ja	Ja	Ja	Ja
H11	3	A, B, E	2	2/2	6	A, B, C, D, E, M	Nee	Nee	Ja	Ja	Ja
H12	9	A, B, C, D, E, F, G, M, T	2	2/2	8	A, B, C, D, E	Nee	Nee	Ja	Ja	Ja
H13	4	A, B, C, D	2	2/2	6	A, B, C, D, E, F	Ja	Ja	Ja	Ja	Ja
H14	7	A, B, C, D, E, F, Q	2	2/2	6	A, B, C, D, E, F	Nee	Nee	Nee	Ja	Nee
H15	4	A, B, D, E	1	2/2	8	A, B, C, D, E, F, I, R	Gedeeltelijk	Nee	Nee	Ja	Ja
H16	5	A, B, D, E, Q	1	2/2	8	A, B, C, D, E, F, H, R	Nee	Nee	Ja	Ja	Ja
H17	3	A, D, E	3	4/4	8	A, B, C, D, E, F, H, I	Nee	Nee	Ja	Nee	Nee
H18	6	A, D, E, J, N, O	2	2/2	9	A, B, C, D, E, F, G, M, N	Gedeeltelijk	Ja	Nee	Ja	Ja

[4] A=gastro-enteroloog/MDL-arts, B=chirurg, C=medisch oncoloog, D=radioloog, E=patholoog, F=radiotherapeut, G=anesthesioloog, H=nucleair geneeskundige, I=gynaecoloog, J=uroloog, K=internist, L=huisarts M=nurse practitioner, N=physician-assistant, O=case manager, P=wond verpleegkundige, Q=stoma verpleegkundige, R= oncologie verpleegkundige, S=diëtist, T=fysiotherapeut

Tabel 4: Planning en plaats reserveringen

Ziekenhuis	Vaste tijden per week voor colorectale patiënten	Plekken gereserveerd op/voor						One-stop diagnostiek indien mogelijk	Moment van plannen afspraak OK
		polikliniek MDL/interne	polikliniek chirurgie	X-thorax	CT	MRI	endo-echo		
H1	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Dag uitslag PA
H2	Ja	Nee	Nee	Nee	Nee	Nee	?	Nee	?
H3	Nee	Nee	Nee	Nee	Ja	Ja	?	Ja	Op de dag van endoscopie
H4	Nee	Nee	Nee	Nee	Ja	Ja	Nee	Ja	Op de dag van endoscopie
H5	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Zo snel mogelijk bij colon, na MDO bij rectum
H6	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Na stadiëring
H7	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Na stadiëring
H8	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Eerste bezoek polikliniek na MDO
H9	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Dag na het MDO
H10	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Op de dag van endoscopie
H11	Ja	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Anders
H12	Nee	Ja	Nee	Nee	Nee	Nee	Nee	?	Op de dag van endoscopie
H13	Nee	?	Ja	Ja	Ja	Ja	Nee	Nee	Tijdens MDO
H14	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Dag uitslag PA
H15	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Anders
H16	Ja	Nee	Ja	Nee	Nee	Nee	Nee	Nee	Tijdens MDO
H17	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Anders
H18	Ja	Nee	Nee	Nee	Ja	Ja	Nee	Nee	Anders

Tabel 5: Zorgpad en MDO

Ziekenhuis	Aanwezigheid multidisciplinaire polikliniek	Klinisch pad ontwikkeld	Flowchart aanwezig voor colon pad	Flowchart aanwezig voor rectum pad
H1	Nee	Ja	Ja	Ja
H2	Nee	Alleen rectum	Nee	Ja
H3	Nee	Ja	Ja	Ja
H4	Nee	Ja	Ja	Ja
H5	Nee	Ja	Ja	Ja
H6	Nee	Nee	Ja	Nee
H7	Ja	Nee	Nee	Nee
H8	Nee	Ja	Ja	Ja
H9	Ja	Nee	Nee	Nee
H10	Nee	Ja	Ja	Ja
H11	Ja	Ja	Ja	Ja

H12	Nee	Ja	Ja	Ja
H13	Nee	Ja	Ja	Ja
H14	Nee	Ja	Ja	Ja
H15	Nee	Ja	Ja	Ja
H16	Nee	Nee	Nee	Nee
H17	Nee	Ja	Ja	Ja
H18	Nee	Ja	Ja	Ja

Tabel 6: Fast-track

Ziekenhuis	Fast-track behandeling	Manier van implementatie fast-track
H1	Protocol gebaseerd op ERAS	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H2	ERAS-protocol	Protocollen zijn aanwezig, gebruik wordt bijgehouden en feedback wordt gegeven
H3	Protocol gebaseerd op ERAS	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H4	ERAS-protocol	Protocollen zijn aanwezig en worden gebruikt door deze bij te voegen in de status
H5	ERAS-protocol	Protocollen zijn beschikbaar
H6	Protocol gebaseerd op ERAS	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H7	Geen	Geen protocollen aanwezig
H8	ERAS-protocol	Protocollen zijn aanwezig, gebruik wordt bijgehouden en feedback wordt gegeven
H9	ERAS-protocol	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H10	Protocol gebaseerd op ERAS	Protocollen zijn beschikbaar
H11	Protocol gebaseerd op ERAS	Protocollen zijn aanwezig en worden gebruikt door deze bij te voegen in de status
H12	ERAS-protocol	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H13	Protocol gebaseerd op ERAS	Protocollen zijn beschikbaar
H14	ERAS-protocol	Protocollen zijn beschikbaar
H15	ERAS-protocol	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H16	ERAS-protocol	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database
H17	ERAS-protocol	Protocollen zijn beschikbaar
H18	ERAS-protocol	Protocollen zijn aanwezig en worden bijgehouden (checklist) in de status/database