Master's degree thesis

LOG950 Logistics

Measuring Hospital Efficiency at a Process Level with Data Envelopment Analysis - an Exploratory Case Study

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Writing a master thesis is the last task in the journey of receiving a master degree diploma within the study program *Master of Science in Logistics* at Molde University College. The process of writing the master thesis has been exciting and interesting, though challenging. However, with good help from various people the master thesis has been completed. Naturally, there are several people to give appreciation and thanks to.

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Abstract

Background Hospitals are constantly growing and so do their expenditures. Most countries, including Norway, are facing increasing health care expenditures, particularly concerning their hospitals. As a result of the challenging situation hospitals are in, hospital performance has become extremely important. To measure efficiency has become one of the essential performance measurements, and data envelopment analysis, DEA, has become one of the most used tools for measuring and evaluating efficiency of hospitals or within them.

Purpose The purpose of this master thesis is to explore how DEA can be used to explore efficiency at a process level in hospitals.

Methodology This master thesis is an exploratory case study. An input-oriented DEA model with variable returns to scale, VRS, is used to measure efficiency of main diagnoses. In addition, a regression analysis, RA, (ordinary least squares, OLS) is used to measure how and in which degree external explanatory variables affect the efficiency of the main diagnoses.

Data A data set from St. Olavs Hospital including all of the surgical procedures done in the years 2006 to 2009 is used. The data set included data registered for 84 002 surgical procedures. From this 2 312 surgical procedures are studied. 17 different main diagnoses are studied, of which 10 are in the Department of Surgery and 7 are in the Department of Orthopedic.

Results It is found that the mean efficiency score in all of the years 2006 to 2009 for the two departments is high; between 90.2 % and 93.7 %. Further, the mean efficiency scores for each of the two departments separately are high as well. The mean efficiency scores for the 10 main diagnoses in the Department of Surgery are between 88.6 % and 94 %, whilst the mean efficiency scores for the 7 DMUs in the Department of Orthopedic are between 87.7 % and 93.4 %. Also, no statistical differences were found between the two departments. Last, none of the external explanatory variables tested explain the inefficiency in the main diagnoses.

Conclusion It is not possible to draw any certain conclusions of the DEA and RA results. Future research is necessary. St. Olavs Hospital should compare the main diagnoses with the same main diagnoses at other hospitals. In addition, other or additional input and output variables (DRG-points, labour costs etc.) should be included in DEA. In general, future research should study even further how DEA can be used to explore efficiency at a process level in hospitals.

Key words Hospital efficiency, process level, data envelopment analysis, DEA, regression analysis, RA, ordinary least squares, OLS.

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List of Abbreviations

ABF – Activity-based funding

CRS – Constant returns to scale

DEA – Data envelopment analysis

DMU – Decision making unit

DRG – Diagnosis related groups

FTE – Full-time equivalent

OLS – Ordinary least squares

PM – Process management

RA – Regression analysis

RTS – Returns to scale

SE – Scale efficiency

VRS – Variable returns to scale

Chapter 1 Introduction

In this chapter the background, problem area, and the research questions for this master thesis will be presented. The purpose of this master thesis will be presented through the background in section 1.1, whilst the problem area and research questions will be presented in section 1.2 and 1.3 respectively. The structure for the remainder of this master thesis will be presented in the last section, 1.4.

1.1 Background

Hospitals, as any other organization, need to know and measure how they are performing, so they could improve and offer the best possible service (Ajlouni, Zyoud, Jaber, Shaheen, Al-Natour and Anshasi 2013); DEA has become one of the most used tools for measuring efficiency of hospitals. It is found that DEA may help in the process of improving a hospital's efficiency and reduce the resource usage. (Harrison, Coppola, and Wakefield 2004) (Ketabi 2011) In addition, DEA presents a way for managers of hospitals to compare themselves to other hospitals, and acts as a guide for improvement. (Al-Shayea 2011)

Hospitals are, and have always been, a necessity for the society. They are constantly growing and so do their expenditures. Most countries are facing increasing health care expenditures, particularly concerning their hospitals. The increase in health care expenditures is explained by various effects as for instance the challenges concerning "demographic change, epidemiologic transition, community expectations, sophisticated technology, and inadequate information". (Hajialiafzali, Moss, and Mahmood 2007) (Chuang, Chang, and Lin 2011)

In Taiwan, hospitals face various challenges, amongst others "rapid changes in the medical environment and new hospital accreditation requirements". (Chuang, Chang, and Lin 2011) Further, the high hospital expenditures have led to crisis in Greece, which is caused by high demand for better treatment and high hospital service cost. Their hospital expenditures amounted for 60 % of the total health care expenditures in 1997. (Giokas 2002) In Austria the percentage was 50 % in 2002. Though, Austrian hospitals are known for having over-capacities and high admission rates. (Hofmarcher, Paterson, and Riedel 2002) When it comes to Vietnam, their growing and ageing population has led to financial difficulties. There are not enough resources to "finance the rising demand for increased and better quality services". (Pham 2011) The hospitals in Sub-Saharan Africa had hospital expenditures that amounted for as much as 45 % to 69 % of total health care expenditures in 2002. (Kirigia, Emrouznejad, and Sambo 2002) USA also struggles with high hospital expenditures; in 1991 the hospital expenditures were as large as 44 % of the total health care expenditures. This was the fifth year in a row with increasing hospital expenditures. (Wang, Ozcan, Wan and Harrison 1999) This trend has continued; the main reason being increasing demand for quality health care caused by population growth and continued medical advances. (Weng, Wu, Blackhurst and Mackulak 2009) (OECD health data 2013)

Norway is no exception. The threat against the society's economic capacity, due to increasing health care expenditures over the years, is a major issue in Norway. In 2007 nearly every fifth Norwegian krone went to health care (Pettersen, Magnussen, Nyland, and Bjørnenak 2008), and the total health care expenditures were as high as 201 mrd kroner (Statistisk sentralbyrå 2013). Hospital expenditures amounted for 28 % of these, though, this percentage does not include nursing homes and home care expenditures as the other countries include. If these expenditures were to be included, hospital expenditures in Norway would be as high as 54 %. (Universitetet i Oslo 2013) As of year 2011 the total health care expenditures reached nearly 250 mrd kroner in Norway. The development of the total health care expenditures in Norway from 2002 to 2011 is shown in figure 1.1 below. (Statistisk sentralbyrå 2013)

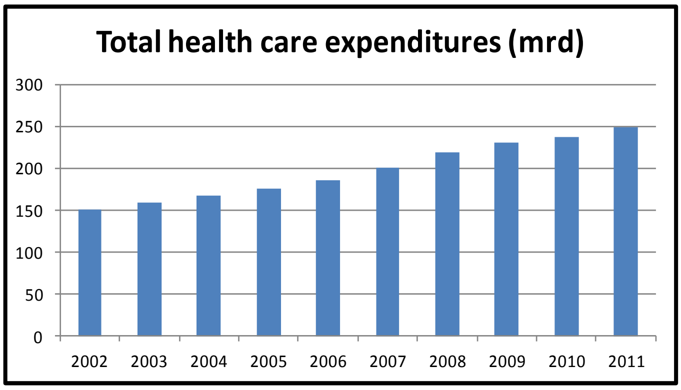

Figure 1.1 Total health care expenditures 2002-2011 – Norway

As a result of the increasing expenditures in health care, the countries mentioned and several others have experienced financial difficulties, and therefore many have struggled with deficits throughout the years. (CBC news 2013) (Connecticut 2013)

In Norway this is also the case. Norwegian hospitals have struggled financially through the years, and especially in the period from mid 1980s throughout the 1990s the hospitals struggled with deficits. (Magma 2013) Figure 1.2 on the next page shows the financial situation in Norway over the years 2002 to 2010. (Helse- og omsorgsdepartementet 2013a)

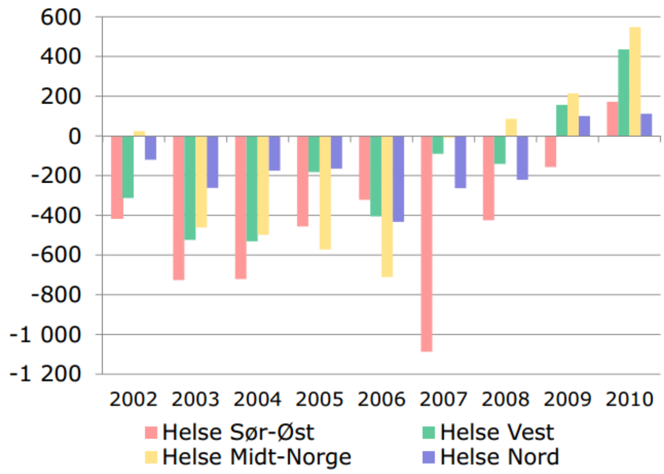

Figure 1.2 Financial situation 2002-2010 – Norway

Figure 1.2 above shows that Norway from 2002 through 2009 mostly struggled with deficits. In total the deficits grew to 9.8 mrd kroner. (Helse- og omsorgsdepartementet 2013b) After this the financial situation improved, and in 2010 the total profit was 1.3 mrd kroner in Norway. (Helse- og omsorgsdepartementet 2013a) The latest year with published data 2011, shows that the results had decreased to 0.8 mrd kroner. (Helsedirektoratet 2013) Even though the results are decreasing, public hospitals in Norway are non-profit organizations, and so to keep the 0 is more than good enough. Though, the financial situation change rapidly, and with approaching challenges, as the ageing of the population and increasing waiting lists, deficits can quickly strike Norwegian hospitals again.

Studies have found that the increase in health expenditures may in addition to the various challenges mentioned, "be due to the inefficient use of resources" (Hajialiafzali, Moss and Mahmood 2007) If hospitals are inefficiently organized they will reduce the health services provided to the population. In addition, they will leave less funds left for other health services, and so the well-being of the population may be damaged. (Hajialiafzali, Moss, and Mahmood 2007) Thus, managers of hospitals have started focusing on their allocation of resources, and effective management of their different processes. There is an on-going debate of the efficiency of health services. (Ketabi 2011) It is important that hospitals evaluate their operational efficiency – have full overview over the different processes and resources needed in hospitals. Higher quality of hospital services can be achieved through a more efficiently use of resources. (Chuang, Chang, and Lin 2011) For instance, if a hospital manages to save time and costs, the hospital could perhaps offer more health care services than it already does. Further, for hospitals to improve management, mobilizing resources, and rationalizing resource allocation, measuring efficiency has become an essential tool. (Hajialiafzali, Moss, and Mahmood 2007)

As a result of the challenging situation hospitals are in, hospital performance has become extremely important. To measure efficiency has become one of the essential performance measurements, and it is found according to Lynch and Ozcan (1994) that the tool data envelopment analysis, DEA, is an effective tool for evaluating efficiency of hospitals or within them.

There has been a lack of good efficiency measuring tools for hospitals, though the characteristics of DEA have led to an increasing interest in measuring and studying the efficiency of hospitals. The reason is that it takes a hospital's complexity into account with allowing for multiple inputs and multiple outputs. DEA studies of hospital efficiency dates all the way back to the early 1980s, and since then numerous studies have been completed. (Weng, Wu, Blackhurst and Mackulak 2009) Hospital DEA studies have been done in numerous countries, however with a varying degree of success. (Helmig and Lapsley 2001) Most of the studies have focused on measuring efficiency at the organizational level, for instance of hospitals, health districts, primary health care services, and nursing homes. (Shetty and Pakkala 2010) Few have done efficiency studies at lower levels. There is therefore a lack of efficiency studies conducted of operations. (Lynch and Ozcan 1994) Clearer, DEA has mostly been used at an aggregated level in hospitals, not at a process level.

Finally, Professor Gavin H. Mooney (1986) expresses the importance of economics in health care, in order to reduce inefficiency. He is worried that health care, as for example hospitals, would (Kirigia, Emrouznejad, and Sambo 2002);

> ***"go on spending large sums to save life in one way when similar lives in greater numbers could be saved in another way. The price of inefficiency, inexplicitness and irrationality in health care is paid in death and sickness."***

1.2 Problem Area

The problem area for this master thesis is to explore efficiency at a process level in a hospital using data envelopment analysis, DEA, and regression analysis, RA. This will be done with data from St. Olavs Hospital. The literature focus will therefore be on DEA, and not on other efficiency and productivity econometric methods.

The data received is data registered for all of the surgical procedures done at St. Olavs Hospital from 2006 through 2009. Since there is a lack of efficiency measuring at a process level this study is an exploratory study, in which it will be explored how DEA could be used to measure efficiency at such a level.

The master thesis will be a case study with data from St. Olavs Hospital. The data from St. Olavs Hospital will be used in order to explore how DEA could be used to measure efficiency at a process level. The data set included more than 84 000 surgical procedures, and so it needed to be reduced in order to make it suitable for DEA and the time limit. Therefore the problem area was narrowed down to only exploring efficiency at a process level using data from the two departments; Department of Surgery and Department of Orthopedic.

Hence, our problem area is;

> ***To explore efficiency using DEA at a process level in the Department of Surgery and the Department of Orthopedic at St. Olavs Hospital in the years 2006 through 2009.***

1.3 Research Questions

The research questions for this master thesis were not formulated until after the data set concerning St. Olavs Hospital were received and thoroughly studied.

In this master thesis the main research question is;

> ***How can DEA be used to explore efficiency at a process level in hospitals?***

In order to explore this, several research questions came to life;

- ***I. How is the combined efficiency at the process level for the two departments Department of Surgery and Department of Orthopedic at St. Olavs Hospital in the years 2006 through 2009?***
- ***II. How is the efficiency at the process level for each of the two departments separately in the years 2006 through 2009?***
- ***III. Is there evidence of any differences in the efficiency at the process level between the two departments in the years 2006 through 2009?***
- ***IV. In which degree is the efficiency at the process level for the two departments affected by external explanatory variables in the years 2006 through 2009?***

1.4 Structure of the Master Thesis

The remainder of this master thesis is structured as follows;

Chapter 2 St. Olavs Hospital

In this chapter the hospital St. Olavs Hospital will be presented. First in section 2.1 some general facts about the hospital will be given. Further, how St. Olavs Hospital has performed financially over the past years, and how they see the future will be presented in section 2.2. Last, in section 2.3 a presentation of the organization and the Department of Surgery and the Department of Orthopedic will be presented.

Chapter 3 Literature review

In this chapter process management, PM, and data envelopment analysis, DEA will be presented. First in section 3.1 PM will be presented. Further, in section 3.2 DEA will be presented, whilst studies using DEA in hospitals will be presented in section 3.3. Last, in section 3.4 strengths and limitations regarding DEA will be presented.

Chapter 4 Research methodology

In this chapter the research methodology used in this master thesis will be presented. First, in section 4.1 exploratory case study will be presented. Further, section 4.2 will present the data collection. Section 4.3 will present the process of a surgical procedure, and further the mathematical formula for DEA, will be presented in section 4.4. Last, regression analysis, RA, will be presented in section 4.5.

Chapter 5 Data

In this chapter the data set from St. Olavs Hospital will be thoroughly explained. First, in section 5.1 the selection process of the data set received from St. Olavs Hospital will be presented through two steps; step 1 and step 2. In section 5.2 and 5.3 the selection of the remaining data for use in DEA and RA will be explained, respectively. Last, in section 5.4 the data remaining for use in DEA and RA will be presented and described.

Chapter 6 Analysis

In this chapter the results will be presented and analysed. In the sections 6.1 through 6.4 the results regarding the research questions will be presented and analysed. Each section will be finished off with a summary of the results.

Chapter 7 Discussion

In this chapter there are three discussion parts. First, in section 7.1, Part I, the DEA and RA results concerning the different research questions will be discussed. Second, in section 7.2, Part II, the choices made, and difficulties and limitations with DEA and RA will be discussed. Third, and last, in section 7.3, Part III, the main research question will be discussed, in which it will be emphasized on which variables might be ideal for DEA at a process level.

Finally, a conclusion and further thoughts will be given.

Chapter 2 St. Olavs Hospital

In this chapter the hospital St. Olavs Hospital will be presented. First in section 2.1 some general facts about the hospital will be given. Further, how St. Olavs Hospital has performed financially over the past years, and how they see the future will be presented in section 2.2. Last, in section 2.3 a presentation of the organization and the Department of Surgery and the Department of Orthopedic will be presented.

2.1 St. Olavs Hospital – General Facts

St Olavs Hospital, also called St. Olavs Hospital - Trondheim University Hospital, is one of Norway's largest and most recognized hospitals. The hospital is located several places in the county of Sør-Trøndelag, and the main facilities are located in Trondheim, at Øya, Østmarka, Brøset, and Lian. (St. Olavs Hospital 2013a) A map of the hospital is found in attachment 1.

In Norway, public hospitals are organized through four different regional health authorities, and St. Olavs Hospital is part of the regional health authority "Helse Midt-Norge" (St. Olavs Hospital 2013b) The hospital acts as the local hospital for the 302 000 people situated in the county of Sør-Trøndelag, however it provides services for the people situated in the counties of Møre og Romsdal, Sør-Trøndelag, and Nord-Trøndelag, which count 695 000 inhabitants all together. (St. Olavs Hospital 2013c)

Hospitals in Norway, and in other countries, could be classified in three different types; university teaching hospitals, central hospitals, and local hospitals. (Linna, Häkkinen, Peltola, Magnussen, Anthun, Kittelsen, Roed, Olsen, Medin, and Rehnberg 2010) St. Olavs Hospital is defined as a university teaching hospital, and is integrated with the Norwegian University of Science and Technology (NTNU). (St. Olavs Hospital 2013c)

In addition to being a teaching hospital St. Olavs Hospital offers specialist health care services in somatic and mental health care. (St. Olavs Hospital 2013a) St. Olavs Hospital possesses expertise in several different areas. The hospital has both national, multi-regional, and regional functions or tasks and centres of expertise. Amongst other specialties, the hospital has national functions of fetal medicine, photophoresis treatment, and spinal disorders, and a multi-regional function of neonatal surgery for inherited malformations. The national centres include pain care unit, advanced laparoscopic surgery, headache centre, 3D ultrasound, and MRI-centre. (St. Olavs Hospital 2013d and St. Olavs Hospital 2013e)

St. Olavs Hospital’s main tasks and focus are patient treatment, the teaching of patients and their relatives, and education for health professionals. (St. Olavs Hospital 2013f) The hospital has also an individual responsibility to conduct research. (St. Olavs Hospital 2013 d) St. Olavs Hospital’s vision is (St. Olavs Hospital 2013g);

> “St. Olavs Hospital – a source for health and development”

Through their education and research program, quality improvements, utilization of resources and internal prioritizing in the hospital, the goal is to embrace this vision. (St. Olavs Hospital 2013d)

2.2 St. Olavs Hospital – Financial History and Future Plans

2.2.1 St. Olavs Hospital – Financial History

In Norway, public owned hospitals receive financial support through their regional health authority, which receives their financial support through the Norwegian Government. The financial support is a mixture of basic funding and activity-based funding, ABF. The basic funding is the largest grant (60 %), and is decided by number of inhabitants in a health authority region and its age composition, and is independent of production of health services. The ABF (40 %) is a supplementation with a unit price system; where specific surgical procedures give a specific amount of DRG-points (Diagnosed Related Groups). (Helse- og omsorgsdepartementet 2013c)

Even though public hospitals receive financial support from their regional health authority, hospitals in Norway have financial difficulties. St. Olavs Hospital's financial history shows no difference. Table 2.1 below shows the reported annual results for St. Olavs Hospital from 2003 through 2011. (St. Olav Hospital 2013h)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011
Annual result (in 000 kr)	-301 308	-326 972	-423 652	-649 531	-542 381	-64 728	23 018	462 395	130 768

Table 2.1 Annual results 2003-2011

From table 2.1 it is seen that in the first years 2003 through 2006 there is a downward trend. From having an annual result of about 300 million kroner in deficits, the following years showed even worse results. The downward trend peaks in 2006, where the hospital reports a deficit of nearly 650 million kroner. The downward trend seems to change to the positive from 2006 on; the results for the following years are showing an upward trend. Year 2009 is the first year with profit. The change only in one year is remarkable; the hospital goes from having an annual result of approximately 23 million kroner in profit in 2009, to having annual result as high as approximately 462 million kroner in 2010. However, the upward trend seems to change again. From 2010 to 2011, the annual result dropped to about 130 million kroner, though still profit. It is clear that St. Olavs Hospital has struggled with deficits through the years, and that their profit is dropping. However, the future is unknown.

2.2.2 St. Olavs Hospital – Future Plans

In hospitals changes happen rapidly and often, and so St. Olavs Hospital works for improvements to not lose focus.

Through St. Olavs Hospital's most important strategy "Main program for improvement 2012-2016", the hospital hopes to continue with profits, and turn the situation in the right direction again. The "Main program for improvement 2012-2016" was first adopted in 2010, and further revised in 2011. The goal is to continuously work for improvement at all levels in the hospital, and the hospital strives to always think and ask "can this be done better?" (St. Olavs Hospital 2013d)

In the strategy "Main program for improvement 2012-2016", prioritized areas are those that have the most potential for improvement in quality, logistics, and effective resource utilization. (St. Olavs Hospital 2013i) With better planning and logistics, the goal is to increase the quality, efficiency, and safety for the patients and employees at St. Olavs Hospital. How activity and available personal resources could better adopt to each other is mainly a focus. (St. Olavs Hospital 2013i) This may imply that St. Olavs Hospital has potential for efficiency improvements.

Some of the different measures that will be focused on in the upcoming years are presented below (St. Olavs Hospital 2013i);

- Standardized patient path ways
    - Standardize the patient course for the largest patient groups, through for example fast-track surgery
- Activity and workforce planning
    - Secure larger degree of coordination of central and local projects at St. Olavs Hospital, which have focus on patient and personnel logistics
- The use of the preparation room in the operation departments
    - Secure effective logistics in the operation theatres with help from parallel processing of operation patients
- Cooperation of the activity in the department of emergency
    - Establish a real coordinating tract to develop structure and cooperation, and secure proper treatment and effective patient flow through the department of emergency

2.3 St. Olavs Hospital – Organization

Hospitals in general, including St. Olavs Hospital, are highly complex and huge, and consist of many "mini" organizations.

St. Olavs Hospital is organized through clinics, divisions, departments and sections. Per January 1st 2013, St. Olavs Hospital had a total of 19 clinics and divisions, in addition to various departments and sections. (St. Olavs Hospital 2013g and 2013j) Each of the clinics could be seen as "mini" organizations, since they are divided further into several departments and sections. In addition to this the different clinics, departments, and sections are spread over a large area.
The organization of St. Olavs Hospital is shown in figure 2.1 below. (St. Olavs Hospital 2013g, 2013k, and 2013l)

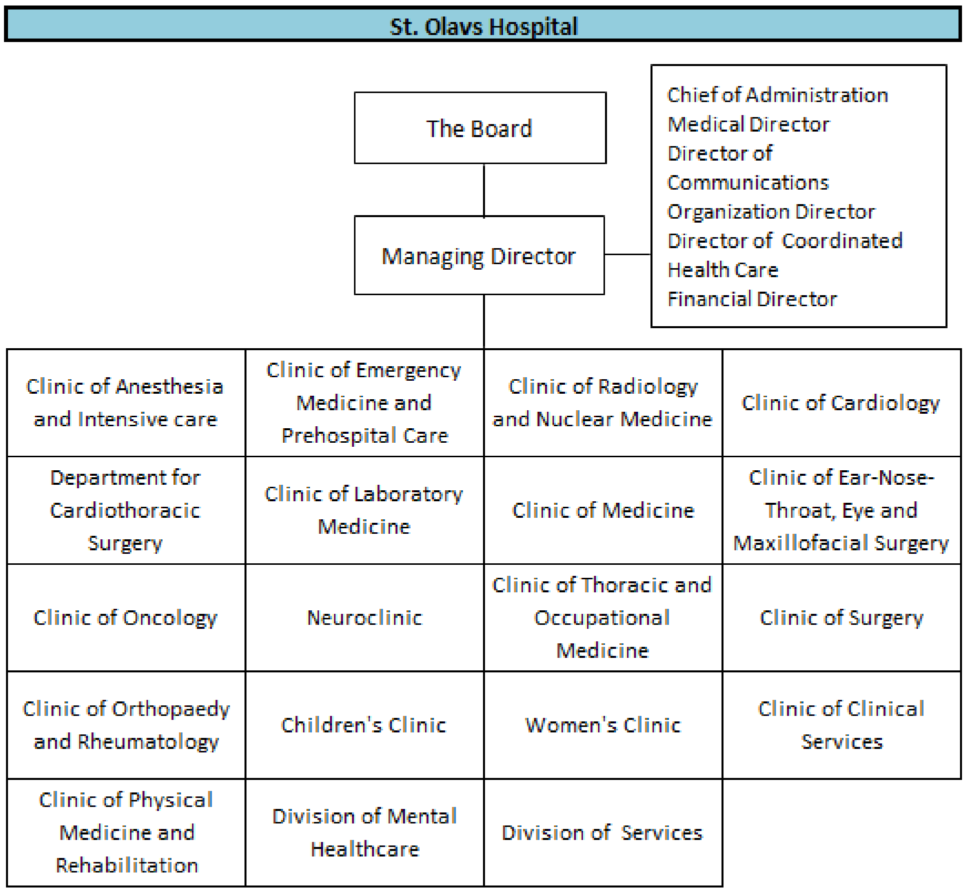

Figure 2.1 Organization chart – St. Olavs Hospital

2.3.1 The Department of Surgery and the Department of Orthopedic

The department of Surgery is part of the Clinic of Surgery, and is one of the largest departments at St. Olavs Hospital. The department offers surgical procedures (treatments or examinations) within the six areas (St. Olavs Hospital 2013m);

- Gastrointestinal surgery
- Urology
- Child surgery
- Vascular surgery
- Breast and endocrine surgery
- Plastic surgery

The department of Orthopedic is part of the Clinic of Orthopaedy and Rheumatology, and is one of the largest departments at St. Olavs Hospital. The department offers surgical procedures (treatments or examinations) for injuries and diseases of (St. Olavs Hospital 2013n);

- Bones
- Joints
- Muscles

The two departments each have their own operation theatres, and their staffs are highly educated and specialized. The employees at the departments consist of nurses with specialization within operation, in addition to technicians and assistants.

Both departments perform planned and emergency surgical procedures. The planned surgical procedures are performed Monday to Friday from 7:30 till 15:30, whilst emergencies are performed 24/7.

Chapter 3 Literature Review

In this chapter process management, PM, and data envelopment analysis, DEA will be presented. First in section 3.1 PM will be presented. Further, in section 3.2 DEA will be presented, whilst studies using DEA in hospitals will be presented in section 3.3. Last, in section 3.4 strengths and limitations regarding DEA will be presented.

3.1 Process Management

Organizations either produce a product or deliver a service. To be able to do so, there is a need of processes and process management, PM.

A process can be defined as;

> ***"any activity or group of activities that takes one or more inputs, transforms and adds value to them, and provides one or more outputs for its customer"*** (Krajewski and Ritzman 2001a)
>
> and
>
> ***"series of operations performed in the making or treatment of a product"*** (TheFreeDictionary 2013a)

PM can be defined as;

> ***"the selection of the inputs, operations, work flows, and methods that transform inputs into output"*** (Krajewski and Ritzman 2001b)

For organizations to be able to survive it is crucial for them to understand which processes are included in the transformation of input to output, and what the processes contain. (Ungan 2006) In order for an organization to stay put in the market it is important to focus on improvement measures. Mapping of processes can help organizations to find areas where improvements are achievable and/or necessary. Improvement potentials as higher efficiency, better work flow, cost reduction, and increase in produced and sold products and/or services could then be achieved. Especially to analyse the flow of processes could be beneficial for organizations, since better methods or procedures can usually be found. (Schroeder 1993)

The re-thinking and re-engineering of one's processes has become widespread in organizations. Several organizations have studied their processes in hope of finding ways to improve. This is also the case in the health care sector, especially in hospitals. (Kumar and Shim 2005) (Misra, Kumar, and Kumar 2008) The management of hospitals struggles with assigning each process with the appropriate support that is needed for patients, and therefore faces problems with keeping the budget. (Kraus, Büchler, and Herfarth. 2005) Thus, hospitals need to find ways to improve. A common method in the process of improving has been to re-engineer processes in hope of achieving higher efficiency. Though, when hospitals re-engineer their processes it is crucial that the quality is not forgotten or becomes poorer. (Kumar and Shim 2005) (Kumar and Ozdamar 2004)

One of the main areas for re-engineering has been to study PM concerning surgical procedures. Reasons are that the number of surgical procedures is steadily increasing (Cinquini, Vitali, Pitzalis, and Campanale 2009), that they require different resources (i.e. operating theatres, technical, medical and other equipment), in addition to that they generate revenue (Kumar and Shim 2005) (Kumar and Ozdamar 2004) (May, Spangler, Strum, and Vargas 2011). It is found that the operation theatres (the surgical procedures) are responsible for 9 to 10 % of a hospital's budget, and that the planned surgical procedures are responsible for approximately 52 % of all hospital admissions. Hence, the management of the operation theatres affects a hospital's patient flow, costs and resource utilization. (Gupta 2007)

Bertolini, Bevilacqua , Ciarapica, and Giacchetta (2011) found in their study of the surgical ward at Parma Hospital, several areas where improvements were needed; in the preparation of the operation theatres, in the numbers of operating sessions, and in the availability of specific surgical equipment. Various other hospitals are also in need of improvement in these areas, in addition to in the surgical procedure. There have been found several different ways through which improvements can be achieved.

A possible way for improvement is found to be through standardization. Ungan (2006) mentions several benefits with standardization regarding that it provides consistent surgical procedures. It thereby increases the perception of quality and makes process control easier. Through standardization it is possible to increase efficiency and reduce uncertainty. Though, it is of importance to know that not all processes are suitable for standardization. (Ungan 2006) Surgical procedures at hospitals are complex, and so they may be difficult to standardize. However, there is variation in the complexity of surgical procedures, and so maybe standardization is possible for some of the surgical procedures. (Kraus, Büchler, and Herfarth 2005)

Further, Verdaasdonk, Stassen, Widhiasmara, and Dankelman (2009) found that standardization could be possible when following checklists during the process of a surgical procedure, and that a checklist can make a surgical procedure more efficient, in addition to improve the surgical safety. The reason being, that it ensures that the steps in a surgical procedure are followed and done correctly, thus one is not relying on the human memory alone. In addition, according to Verdaasdonk, Stassen, Widhiasmara, and Dankelman (2009) a checklist would provide; "a defense strategy to prevent human errors, a memory aid to enhance task performance, standardization of the tasks to facilitate team coordination, a means to create and maintain a safety culture in the operation room, and support quality control by hospital management, government, and inspectors."

Further, improvement potentials in the process of a surgical procedure were found in both the study of Al-Hakim and Gong (2012) and the study of Sokolovic, Biro, Werthemann, Haller, Spahn, and Szucs (2006). Al-Hakim and Gong (2012) found that the time of a surgical procedure could be reduced with approximately 25 %. The reason for the surgical procedure to last longer than needed was due to lack of communication and coordination, failure to follow procedures, and poor information flow. Sokolovic, Biro, Werthemann, Haller, Spahn, and Szucs (2006) found in their study that overlapping induction of anesthesia could increase operating theatre efficiency, and release staff (nurses and physicians) to spend more time with other patients.

When hospitals focus on re-engineering their processes, the measuring of efficiency becomes important. In order to find areas where improvement of processes is needed and possible, in addition to be able to evaluate if the re-engineering has been successful or not, to measure efficiency is useful. (Kumar and Shim 2005) (Kumar and Ozdamar 2004) (Lynch and Ozcan 1994) Measuring efficiency has not always been an issue of priority, though after the introduction of ABF (DRG-points) it received wide attention. (Cinquini, Vitali, Pitzalis, and Campanale 2009)

Further, Poulin (2003) says that;

> ***"There is pressing need to review health care practices to improve hospital operations and bolster their efficiency and effectiveness. Improved operations should provide better cost control, while maintaining the quality of care delivered to the public."***

3.2 Data Envelopment Analysis

Data envelopment analysis, DEA, is a non-stochastic and non-parametric linear programming technique that measures efficiency. In other words, DEA does not require any functional form neither does it take “noise” into account when measuring efficiency. (Fried, Lovell, and Schmidt 1993a) DEA was firstly introduced by Charnes, Cooper, and Rhodes (1978), and was built on the work of Farrell (1957). The first DEA model assumes a constant returns to scale, CRS, production, and allows for multiple inputs and multiple outputs. However, the first DEA model cannot clearly distinguish between scale efficiency, SE, and technical efficiency (efficiency), and so Banker, Charnes, and Cooper (1984) developed a second DEA model which assumes a variable returns to scale, VRS. (Chuang, Chang, and Lin 2011)

3.2.1 The Efficiency Frontier

DEA defines an efficiency frontier based on the best performers in a sample. Further, efficiency scores are measured according to this efficiency frontier. In figure 3.1 below an efficiency frontier is shown.

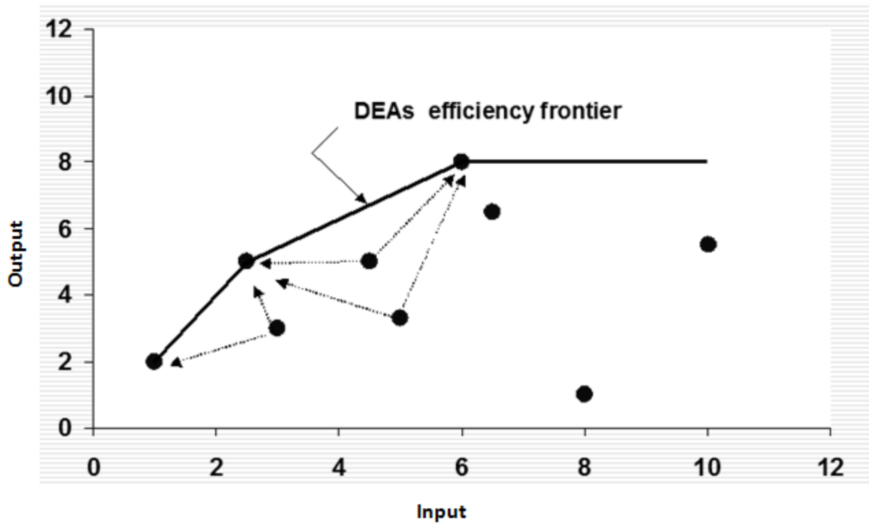

Figure 3.1 Efficiency frontier

DEA produces efficiency scores from 0 to 1 for performers in a sample. The best performers, on which the efficiency frontier is based, have an efficiency score of 1 or 100 % and are classified as efficient performers. (Harrison, Coppola, and Wakefield 2004) As seen in figure 3.1 above, there are 3 black dots on DEAs efficiency frontier. These illustrate the best performers with efficiency scores of 1. A performer not located on the efficiency frontier has been assigned an efficiency score below 1 or

100 %, and is classified as an inefficient performer. As seen in figure 3.1 on the previous page, there are several black dots not located on DEAs efficiency frontier.

The efficiency scores for the performers in a sample are not absolute, since they are solely based on the actual performers in the sample. (Harrison, Coppola, and Wakefield 2004) If other performers were to join the sample or others omitted, the performers' efficiency scores may change. The distance from a best performer to an inefficient performer gives a picture of how much the inefficient performer must improve to become efficient. All inefficient performers should technically be able to be placed on the efficiency frontier. For an inefficient performer to become efficient, the best way may be to learn from the closest best performers. Thus, DEA can help inefficient performers identify possible benchmarks to become efficient performers. (Harrison, Coppola, and Wakefield 2004) This is illustrated with the arrows in figure 3.1 on the previous page.

When conducting DEA there are several characteristics one must decide upon;

- ***Decision making unit***
- ***Input***
- ***Output***
- ***Orientation***
- ***Returns to scale***

3.2.2 Decision Making Unit

The decision making units, DMUs, are the performers in a sample. The DMU is what one wants to measure the efficiency of, and naturally a DMU could be in various forms. DEA assigns each DMU with an efficiency score. A criterion in DEA is that the number of DMUs must be twice as much as the sum of inputs and outputs used. (Chuang, Chang, and Lin 2011)

3.2.3 Input and Output

For DEA to calculate efficiency scores there is a need for input and output. DEA allows for multiple inputs and multiple outputs. It is important that the inputs used in the DEA reflect the output, in other words the inputs put in must be the ones that produce the output. If not, the efficiency scores produced will give a wrong picture of the efficiency. (Chuang, Chang, and Lin 2011)

A way to check that the input and output reflect each other is by calculating correlations between them. In DEA it is important that there is high correlation between the input and output, though the correlation between the different inputs should not be as high. However, in some cases high correlations between different inputs are allowed; since they combined produce the output. (Odeck 2013) Naturally, the inputs and outputs vary depending on what the study is evaluating efficiency of. High correlation is defined as 0.7 or above. (Odeck 2012a)

3.2.4 Orientation

In DEA one can choose between two types of orientation; input orientation or output orientation.

An input-oriented DEA model is used when one wants to conduct input-savings. In other words one wants to produce the same output by using less input. An output-oriented DEA model is used when one wants to maximize the output, though whilst keeping the input constant.

One should select the orientation according to which quantities inputs or outputs the manager has most control over. However, the two orientation types will find the same efficient and inefficient performers, though the efficiency scores for the inefficient performers may differ between the two orientations. (Coelli, Rao, O'Donnell, and Battese 2005a)

3.2.5 Returns to Scale

There are two types of returns to scale, RTS, in DEA; constant returns to scale, CRS, and variable returns to scale, VRS.

CRS is when an increase in input results in a proportionate increase in output (constant scale of operation). VRS is when an increase in input results in more (increasing scale of operation) or less (decreasing scale of operation) than a proportionate increase in output. From this one understands that CRS is the optimal scale. (Odeck 2012b)

It is the type of RTS that decides the form of the efficiency frontier. CRS produces a linear line, whilst VRS produces a line with curves formed by the best performers. This is illustrated in figure 3.2 on the next page.

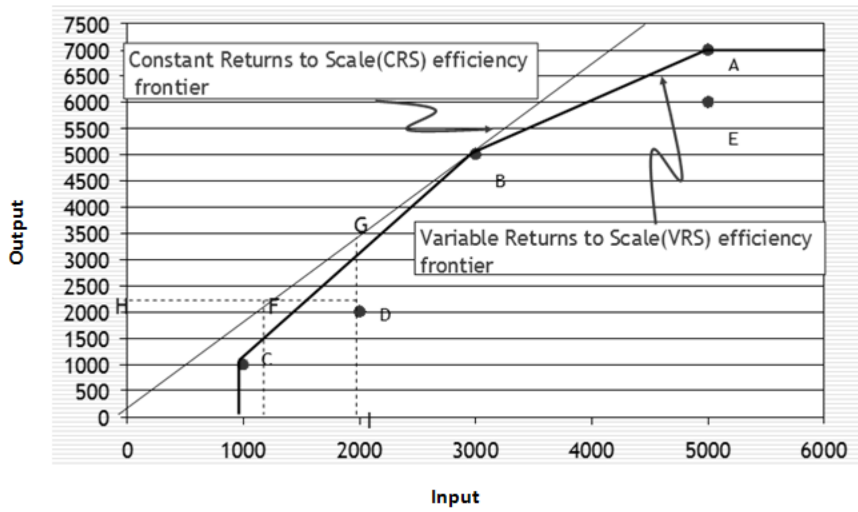

Figure 3.2 CRS and VRS frontiers

VRS tends to classify more efficient performers and higher efficiency scores than CRS. (Sikka, Luke, and Ozcan 2009) As seen in figure 3.2 above VRS finds three efficient performers, whilst CRS only finds one.

With respect to the two orientation types CRS will classify the same performers as efficient and inefficient; this is also the case for VRS. (Fried, Lovell, and Schmidt. 1993b) (Coelli, Rao, O'Donnell, and Battese 2005a) Further, CRS produces the same efficiency scores for both of the two orientations, whilst unequal when VRS. (Coelli, Rao, O'Donnell, and Battese 2005a)

Further, when it comes to CRS and VRS, the gap between them provides a measure of scale efficiency, SE. Better explained through the following formula;

$$SE = \frac{CRS}{VRS}$$

From this one can understand that CRS efficiency results are a product of two factors; one due to scale inefficiency and one due to inefficiency; where scale inefficiency is inefficiency as a result of producing with wrong scale of operation.

Researchers often conduct SEs in order to find which of the two RTS they should use. If the SEs are found to be small, then CRS will be the appropriate choice, and vice versa. (Kirigia, Emrouznejad, and Sambo 2002)

3.3 Data Envelopment Analysis – Studies in Hospitals

DEA has through the years been used in numerous efficiency studies. Researchers all over the world have opened their eyes for the possibilities DEA studies could bring, and DEA has been used in various organizational forms. Efficiency studies using DEA has been conducted in many various sectors (Al-Shayea 2011), as for instance (Chuang, Chang and Lin 2011); the bank sector, the airline sector (and the transport sector in general), and the school sector. Also, when it comes to measuring efficiency in hospitals and health care DEA has been acknowledged for being a successful tool. This, since it allows for multiple inputs and multiple outputs. (Harrison, Coppola, and Wakefield 2004)

DEA has been used to measure efficiency in several ways in hospitals since it was firstly used in the 1980s in the studies of Grosskopf and Valdmanis (1987), Wilson and Jadlow (1982), Nunamaker (1983), Sherman (1984), and Register and Bruning (1987). (Weng, Wu, Blackhurst, and Mackulak 2009) Researchers in many countries have applied DEA when studying hospital efficiency. Some examples are Austria, Finland, the Netherlands, Vietnam, Norway, Spain, Sweden, Kenya, United Kingdom, Saudi-Arabia, and USA. (Shetty and Pakkala 2010) Further, DEA has been used to compare different kinds of DMUs in hospitals, as for instance;

- Efficiency of hospitals from different countries
- Efficiency of hospital clusters within one country
- Efficiency of hospitals within one country
- Efficiency of departments within one hospital or amongst hospitals within one country

Researchers have studied efficiency in hospitals using DEA with different time horizons; all from months to several years.

Further, researchers must make choices regarding the characteristics of DEA. The characteristics one must choose amongst in DEA are; DMU, input, output, orientation, and RTS.

Two tables will give an overview over some of the hospital studies using DEA that have been carried out in various countries. The tables will show the researchers choice of characteristics in DEA and the results from their studies. All of the studies are at an aggregated level, not at a process level. Table 3.1 and table 3.2 will be presented on the next pages. More previous studies are presented in attachment 2.

Hajialiafzali, Moss, and Mahmood (2007)			
Country: Iran	*DMU:* 53. SSO (social security organization) hospitals	*Inputs:* 1. Total no. of FTE medical doctors, 2. Total no. of FTE nurses, 3. Total no. of other personnel in FTE, 4. Avarage no. of staffed beds	*Outputs:* 1. The no. of outpatient visits, 2. The no. of emergency visists, 3. The ratio of no. Of major surgeries to total surgeries, 4. Total no. of medical interventions
Orientation: Input orientation	*Returns to scale:* Variable returns to scale (VRS)	*Results:* 26 of 53 (49 %) hospitals were labeled efficient by DEA. The average efficiency score for the SSO hospitals were 0.9 with a standard deviation of 0.146. Inefficient hospitals had an average efficiency score of 0.9.	
Pham (2011)			
Country: Vietnam	*DMU:* 101. General hospitals	*Inputs:* 1. Number of beds, 2. Personnel (FTE physicians and non-	*Outputs:* 1. Outpatient visits, 2. Inpatient days, 3. Surgical operations performed
Orientation: Input orientation	*Returns to scale:* Constant returns to scale (CRS) and Variable returns to	*Results:* It was found an average efficiency score of 0.66 using CRS, whilst VRS showed an average efficiency score of 0.72. In addition to this it was found that the scale efficiency was 0.92, indicating that the hospitals had an improvement potential of 0.08.	
Helmig and Lapsley (2001)			
Country: Germany	*DMU:* 15. The hospital sectors private, public and welfare	*Inputs:* 1. No. of beds, 2. Labour expenses (etc. amount of expenses for physicians, nursing personnel), 3. Operational expenses (not including payroll, capital, and derpreciation expenses)	*Outputs:* 1. Hospital inpatient discharges, 2. Teaching expenses (the amount of expenses for teaching and educational facilities)
Orientation: Input orientation	*Returns to scale:* Variable returns to scale (VRS)	*Results:* Overall the private sector is reported to be less efficient than the other two sectors public and welfare. Mean efficiency over the five years for the different sectors were; private (86.4 %), public (96.9 %), and welfare (99.2 %)	
Kirigia, Emrouznejad, and Sambo (2002)			
Country: Kenya	*DMU:* 54. Public hospitals	*Inputs:* 1. Medical officers/pharmacists/dentists, 2. Clinic officers, 3. Nurses (including enrolled, registered, and community nurses), 4. Adm. staff, 5. technicians/technologists, 6. Other staff, 7. Subordinate staff, 8. Pharmaceuticals, 9. Nonpharmaceutical supplies, 10. Maintenance of equipment, vehicles, and buildings, 11. Food and rations	*Outputs:* 1. Outpatient Department casualty visits, 2. Special clinic visits, 3. MCH/FP visits, 4. Dental care visits, 5. general medical admissions, 6. Paediatric admissions, 7. Maternity admissions, 8. Amenity ward admissions
Orientation: Input orientation	*Returns to scale:* Constant returns to scale (CRS) and Variable returns to scale (VRS)	*Results:* 40 of 54 public hospitals were efficient, whilst the remaining 14 were inefficient. The inefficient hospitals had an average efficiency score of 84 %. It was also found that the average scale efficiency score in the whole sample was 90 %; implying that there was room to increase total outputs about 10 %.	
Steinmann, Dittrich, Karmann, and Zweifel (2004)			
Country: Germany and Switzerland	*DMU:* 251 Swiss hospitals and 105 German hospitals	*Inputs:* 1. Staff (academic, nursing, administrative), 2. Expenses, 3. Patient days, 4. Number of beds	*Outputs:* 1. Number of cases treated (medical, pediatric, gynecological, surgical, intensive care)
Orientation: Input orientation	*Returns to scale:* Constant returns to scale (CRS)	*Results:* It was found that German hospitals are more efficient on average than the Swizz hospitals.	

Table 3.1 Hospital DEA studies

Hofmarcher, Paterson, and Riedel (2002)			
Country: Austria	*DMU:* 31. Hospital wards	*Inputs:* 1. Labour (real labour expenses for medical staff and administrative staff), 2. Available beds	*Outputs:* Model 1: Outpatient care-adjusted patient days,Case-mix adjusted discharges Model 2: LDF-scores (DRG-scores)
Orientation: Input orientation	*Returns to scale:* Variable returns to scale (VRS)	Model 1: The average efficiency level is 96 %. The efficiency for operative wards is on average 95 %, whilst for non-operative wards it is 96.5 %. Model 2: The average efficiency level is 70 %. The efficiency for operative wards and non-operative wards is 73 % and 67 % respectively.	
Linna, Häkkinen, Peltola, Magnussen, Anthun, Kittelsen, Roed, Olsen, Medin, and Rehnberg (2010)			
Country: Finland, Denmark, Norway, and Sweden	*DMU:* 184. Hospitals in Finland, Norway, Denmark, and Sweden	*Inputs:* 1. Costs in real term, using wage and consumer price indices to adjust operating costs	*Outputs:* 1. Measured as (DRG) weighted discharges in inpateint care, day surgery, day-care, 2. No. of outpatient visits
Orientation: Input orientation	*Returns to scale:* Model 1 - Constant returns to scale (CRS) Model 2 - Variable returns to scale (VRS)	*Results:* Model 1 - CRS: The average efficiency in the four countries were; Finland between 0.73 and 0.80, Denmark between 0.68 and 0.80, Norway between 0.64 and 0.65, and Sweden between 0.53 and 0.65. Model 2 - VRS: Overall the VRS model showed the same results as the CRS model, only with higher efficiency scores. Finland between 0.86 and 0.88, Denmark between 0.77 and 0.85, Norway between 0.75 and 0.80, and Sweden between 0.64 and 0.75.	
Ketabi (2009)			
Country: Iran	*DMU:* 23. Hospital Cardiac care units (CCU)	*Inputs:* 1. Average no. of active beds, 2. Medical equipment, 3. Personnel (such as doctors, nurses, and technicians), 4. Technological capabilities	*Outputs:* 1. Bed occupancy percentage, 2. Average length of stay, 3. Total percentage of survival, 4. Performance ratio
Orientation: Input orientation	*Returns to scale:* Variable returns to scale (VRS)	*Results:* 12 of the 23 CCUs were classified as efficient, whilst the remaining 11 were classified as inefficient. None of the CCUs had lower efficiency scores than 0.88.	
Al-Shayea (2011)			
Country: Saudi-Arabia	*DMU:* 9. Hospital departments	*Inputs:* 1. Total salary for doctors, 2. Total salary for nurses	*Outputs:* 1. No. of served patients (inpatients and outpatients), 2. Bed productivity, 3. Turnover interval
Orientation: Output orientation	*Returns to scale:* Variable returns to scale (VRS)	*Results:* The 3 departments orthopedic, primary care, and psychology are classified as being 100 % efficient throughout the whole year out of the 9 different departments. The inefficient departments were divided into two groups; departments with efficiency scores fluctuating between 0.75 and 1, and departments with efficiency scores fluctuating between 0.08 and 0.6.	
Harrison, Coppola, and Wakefield (2004)			
Country: USA	*DMU:* Model 1: 280. Federal hospitals Model 2: 245. Federal hospitals	*Inputs:* 1. Operating expenses, 2. The no. of hospital beds, 3. Full Time Employees (FTEs), 4. The no. of clinical services (Service complexity)	*Outputs:* 1. Adjusted admissions, 2. Outpatient visits
Orientation: Input orientation	*Returns to scale:* Variable returns to scale (VRS)	*Results:* Model 1: 29 of 280 federal hospitals were efficient, whilst 251 were inefficient. Average efficiency score was 0.68. Model 2: 39 of 245 federal hospitals were efficient, whilst 206 were inefficient. Average efficiency score was 0.79.	

Table 3.2 Hospital DEA studies

Deciding on input and output concerning hospitals is a complex task, since it is difficult to find what has the greatest impact on the efficiency. Though, Wang, Ozcan, Wan, and Harrison (1999) and Hollingworth (2008) have found that the most commonly used input for hospitals are;

- ***Labour (number of full-time equivalents, FTEs)***
- ***Operational beds***
- ***Operating expenses***
- ***Service complexity (total number of diagnostic and special services)***

Whilst, when it comes to common output, Wang, Ozcan, Wan, and Harrison (1999) and Hollingworth (2008) have found that they are;

- ***Adjusted discharges (inpatient discharges)***
- ***Outpatient visits***

For instance Harrison, Coppola, and Wakefield (2004) selected inputs and outputs according to the findings in the study of Wang, Ozcan, Wan and Harrison (1999). Most of the studies in table 3.1 and table 3.2 show similar inputs and outputs, so it seems to be a clear understanding of which inputs and outputs are best suited to conduct efficiency scores in hospitals.

When it comes to the choice of orientation most of the studies in the tables have conducted DEA with an input orientation. Helmig and Lapsley (2001) defend the choice by the fact that hospitals in Germany cannot directly influence the demand of hospital services as in other industries (for example with the help of marketing techniques). Further, Ketabi (2009) justifies the choice by the fact that managers in health care services tend to have greater control over input than output. Chuang, Chang, and Lin (2011) defend the choice of input orientation with that hospitals have a social responsibility of providing medical treatment and care for the public. In addition, Roberts et al (2004) found that more resource allocation is not necessary for a better health care outcome; it is possible to reduce inputs substantially whilst remaining the same level of output. (Shetty and Pakkala 2010) These reasons in addition to the main reason for choosing an input orientation, wanting to save inputs, are mainly the reasons for the choice of input orientation for the studies presented in table 3.1 and table 3.2.

Most of the studies represented in the two tables have used a VRS DEA model, mostly based on the assumption that an increase in inputs does not cause a proportionate increase in outputs. Ketabi (2009) emphasizes that the choice was made upon this reason. In addition, Helmig and Lapsley (2001) defend their choice of VRS because market penetration within the German hospital sector is more or less impossible, since hospital advertising is prohibited. Also, concerning the German hospitals the capacity of beds must be of certain amount in order to be able to conduct hospital services for all patients. (Helmig and Lapsley 2001) Kirigia, Emrouznejad, and Sambo (2002) found SEs by calculating efficiency scores for both CRS and VRS, in order to decide on which RTS to use. Their SEs were found to be high, which showed that VRS was the right RTS to use. The hospitals were inefficient not because of wrong scale of operation, but because of inefficiency. Thus, in order to become efficient the hospitals need to either reduce their input or increase their output. (Kirigia, Emrouznejad, and Sambo 2002)

Concerning the results found in the studies, most studies show many inefficient hospitals and only a few efficient ones. For the inefficient hospitals the VRS efficiency scores are mainly above 0.70 or 70 %. Overall the studies show that the hospital sector has potential for improvements concerning the efficiency. In the study of Linna, Häkkinen, Peltola, Magnussen, Anthun, Kittelsen, Roed, Olsen, Medin, and Rehnberg (2010) where Finland, Denmark, Norway, and Sweden were studied, VRS efficiency scores for Norway in 2002 were found to be between 0.75 and 0.80 or 75 % and 80 %. This shows that also hospitals in Norway have potential for efficiency improvements.

3.4 Data Envelopment Analysis – Strengths and Limitations

There are several strengths, however also limitations concerning DEA. These strengths and limitations are something researchers must have in mind especially when conducting DEA to measure efficiency in hospitals. This is important in order to avoid an incorrect picture of efficiency.

DEA possesses several strengths when measuring efficiency. DEA allows for multiple inputs and multiple outputs, and so it can be applied in both non-profit organizations and profit organizations, and in complex organizations. (Helmig and Lapsley 2001) (Hajialiafzali, Moss, and Mahmood 2007) Thus, it is suitable for measuring efficiency in hospitals. In addition to allowing for multiple inputs and multiple outputs, DEA allows for them to be in any kind of form (number of beds, labour expenses, number of patients treated etc.) (Bhat, Verma, and Reuben 2001) (Pham 2011)

Another strength of DEA is that it does not require an assumption of any functional form. Thereby organizations that do not fit a specific functional form can measure their efficiency, and obtain a better picture of their efficiency. (Bhat, Verma, and Reuben 2001)

Finally, other strengths are that DEA allows for smaller sample sizes (less data-intensive), and that it does not require information of prices regarding input and output. (Pham 2011)

DEA also possesses several limitations when measuring efficiency. The main limitation is that the DMUs one is studying have to be comparable; otherwise the results will not be valuable. For instance, the different types of hospitals cannot in all cases be compared; teaching hospitals are not comparable with non-teaching hospitals. The main reason for this is that they require other kinds of input and output. (Hajialiafzali, Moss, and Mahmood 2007) It is also difficult to generalize based on the results found through DEA, because of the limitation of comparability. The efficiency scores conducted through DEA only give a picture of the efficiency within the sample evaluated, and thereby not a picture of the whole population. Thus, efficient performers in the sample evaluated may not be efficient within another sample. Thereby, it is difficult for DEA to find the maximum level of efficiency. (Helmig and Lapsley 2001) (Bhat, Verma, and Reuben 2001)

Another major limitation is that DEA does not allow for “noise” in the data set, and thus concludes that inefficient performers are inefficient solely because of inefficiency. For example, in hospitals patients are different, and so there may be several external explanatory variables (gender, age etc), besides inputs and outputs used in the DEA, that affect the efficiency. (Helmig and Lapsley 2001) (Nayar and Ozcan 2008) (Bhat, Verma, and Reuben 2001) Concerning age it is found that it could affect a surgical procedure, since older people (often classified as 65+) often have more diseases than young people and they often are of poorer health, and thereby, there are more risks concerning them. (Marusch, Koch, Schmidt, Steinert, Ueberrueck, Bittner, Berg, Engemann, Gellert, Arbogast, Körner, Köckerling, Gastinger, and Lippert 2005) Though, one common way to reduce this limitation is by RA, which indicates if the external explanatory variables affect the efficiency or not, and in which direction.

Further, a limitation with DEA is that it cannot handle negative values or missing values. Detailed data is not available at all levels, and therefore hard to obtain. (Hofmarcher, Paterson, and Riedel 2002) (Clement, Valdmanis, Bazzoli, Zhao, and Chukmaitov 2008)

DEA also has the limitation of being sensitive to outliers. (Pham 2011) (Bhat, Verma, and Reuben 2001) With outliers in the sample the efficiency scores conducted may give a wrong picture of the efficiency in the sample. As a result outliers are often removed from DEA, though when removing them the picture may be wrong as well.

The more inputs and outputs used in DEA, the more efficient DMUs DEA produces. (Hajialiafzali, Moss and Mahmood 2007) Thus, the illustration of efficiency may be wrong. Also, often DEA studies are conducted over a specific point in time, and so it will only give a snap-shot of for example a hospital's performance and efficiency in a specific point in time. (Pham 2011)

As seen, many of the strengths concerning DEA are its limitations. (Bhat, Verma, and Reuben 2001)

Chapter 4 Research Methodology

In this chapter the research methodology used in this master thesis will be presented. First, in section 4.1 exploratory case study will be presented. Further, section 4.2 will present the data collection. Section 4.3 will present the process of a surgical procedure, and further the mathematical formula for DEA, will be presented in section 4.4. Last, regression analysis, RA, will be presented in section 4.5.

4.1 Exploratory Case Study

In the process of conducting a research there are several elements one must take into account in order for the research to be successfully completed. There is no best way of performing a research; the importance lies in knowing what one is doing. (Saunders, Lewis, and Thornhill 2012a)

One of the main elements when conducting a research is the research design. Yin (2009a) defines research design as;

> ***"a logical plan for getting to here from there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions"***

The research design should secure that the research questions the researcher has formulated are answered. In other words, with a proper research design, poor operations or failure when answering the research questions could be avoided. (Maxwell 2005)

This master thesis can be defined as;

> ***"an exploratory case study"***

An exploratory research is useful when little information exists of the problem one is researching. In an exploratory research one investigates and tests how to carry out a problem. Whilst conducting an exploratory research new insight and data can appear, thus a researcher must be open-minded for changes. For an exploratory research this is no problem as it is flexible and adaptable to changes. In the beginning of an exploratory research the focus is "everywhere", though the deeper one gets in the research the more the focus gets specified. (Saunders, Lewis, and Thornhill 2012b)

Since there is no known and exact way one should solve the research questions, a researcher often tries and fails in the process. Some exploratory researches could end with the researchers figuring out that the research was not worth pursuing. (Saunders, Lewis, and Thornhill 2012b) An exploratory case study is known to be demanding (Saunders, Lewis, and Thornhill 2012c), and the outcome will not always be what the researcher anticipated.

Concerning the research strategy case study, Yin (2009b) defines it as;

> ***"an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident"***

Through case studies various aims can be accomplished. Case studies can be beneficial and help one in all from providing a thorough description to testing and generating theories. A case study could help one answer research questions with different formulations; however it is found that the case study strategy is particularly suitable for research questions formulated with "why" and "how". Also, case studies are shown to be appropriate both for qualitative and quantitative studies. (Näslund 2002)

It was clear from the beginning that this master thesis was an exploratory case study. The main reason was that from the beginning exploring efficiency at a hospital or several hospitals using DEA was of interest. Further, in the process of the master thesis it was clear that data from one hospital would be received, and that the data would be at a lower level than data used by most previous DEA studies in hospitals. Hence, it was clear that the data had to be carefully studied, and a process of trying and failing was necessary in order to figure out how the data could be used for DEA, and if it were in fact possible.

4. 2 Data Collection

Data collection can be defined as;

> ***"the process of acquiring subjects and gathering information needed for a study; methods of collection will vary depending on the study design"*** (TheFreeDictionary 2013b)

There are different types of data and sources of data one can use in a research. Firstly, the data could be divided into two main categories; primary data and secondary data.

Primary data can according to Hox and Boeije (2005) be defined as;

> ***"original data collected for a specific research goal"***

Secondary data can according to Hox and Boeije (2005) be defined as;

> **"data originally collected for a different purpose and reused for another question"**

Both primary and secondary data can be quantitative and/or qualitative data, and can be collected through different data sources.

In this master thesis only secondary data has been collected. When it comes to secondary data, there are several advantages and disadvantages that a researcher must be aware of before collecting data.

There are two main advantages with using secondary data (Hox and Boeije 2005);

1. The cost of searching and retrieving secondary data is low
2. Secondary data is fast accessed

There are four main disadvantages that may occur (Hox and Boeije 2005);

1. The secondary data have been used for other purposes and research problems
2. Secondary data is difficult to interpret
3. Relevant secondary data is difficult to retrieve
4. The quality of secondary data is poor

The opportunity for completing a good research with only secondary data is definitely present; however it is important that a researcher studies the secondary data sources with critical eyes.

In this master thesis the secondary data was collected through several data sources. The data collected was qualitative and quantitative. The qualitative data was collected through the following data sources;

- www-information
- Textbooks
- Journal articles
- Research reports

The quantitative data was collected through the following data source;

- St. Olavs Hospital

The first thing done was to search for relevant textbooks, journal articles, and research reports, in order to get knowledge about DEA and how it has been used previously in hospital studies. Various relevant textbooks concerning DEA were gathered, some with help from Professor James Odeck. Further, numerous journal articles and research reports were retrieved, and after studying them the most relevant were sorted out.

Further, registered data for all of the surgical procedures done at St. Olavs Hospital in the years 2006 through 2009 was received. The data set was given by Birgithe Eckermann Sandbæk, who had previously used it for another research. Even though the data set had been used before and should be somewhat clean, it was necessary to check if the data would fit the study, and that no errors were present.

To obtain information about St. Olavs Hospital and hospitals in general, in addition to some definitions, the internet was used. As the internet contains a lot of information by various sources (professors, ordinary people and organizations etc.) it was important to be critical in the use of the data found through this source.

4.3 The Process of a Surgical Procedure

When it comes to the process of a surgical procedure it varies according to how the patient is classified and what the surgical procedure is.

A surgical procedure could be performed either on an in-patient or an out-patient, where the two main differences are (May, Spangler, Strum, and Vargas 2011);

- In-patients arrive from a ward at the hospital and so their arrival is almost certain, whereas out-patients arrive from outside the hospitals and so they may arrive late or fail to arrive
- In-patients return to a ward at the hospital after the recovery process, whereas out-patients usually are discharged home the same day as the surgical procedure is performed.

Further, a surgical procedure could be a planned or an emergency surgical procedure; where planned means that the surgical procedure has been scheduled (Gupta 2007) and can wait at least three days (Kumar and Ozdamar 2004) to accommodate more urgent cases, and emergency means that the surgical procedure is caused by a sudden episode and cannot wait (it is urgent) (Gupta 2007).

In addition, a surgical procedure could be classified as a treatment or an examination. Further, the patient undergoing a surgical procedure may have one or more diagnoses, and one or more operations that have to be completed.

A surgical procedure is always assigned a team consisting of different kinds of staff. A common team mainly consists of surgeon, anesthesiologists, nurses, and other observers. The nurses are specialized in operation, and the observers are technical assistants. (Zheng, Panton, and Al-Tayeb 2012)

Further, the process of a surgical procedure, from when an in-patient arrives at the hospital until he or she is discharged, is shown in figure 4.1 below.

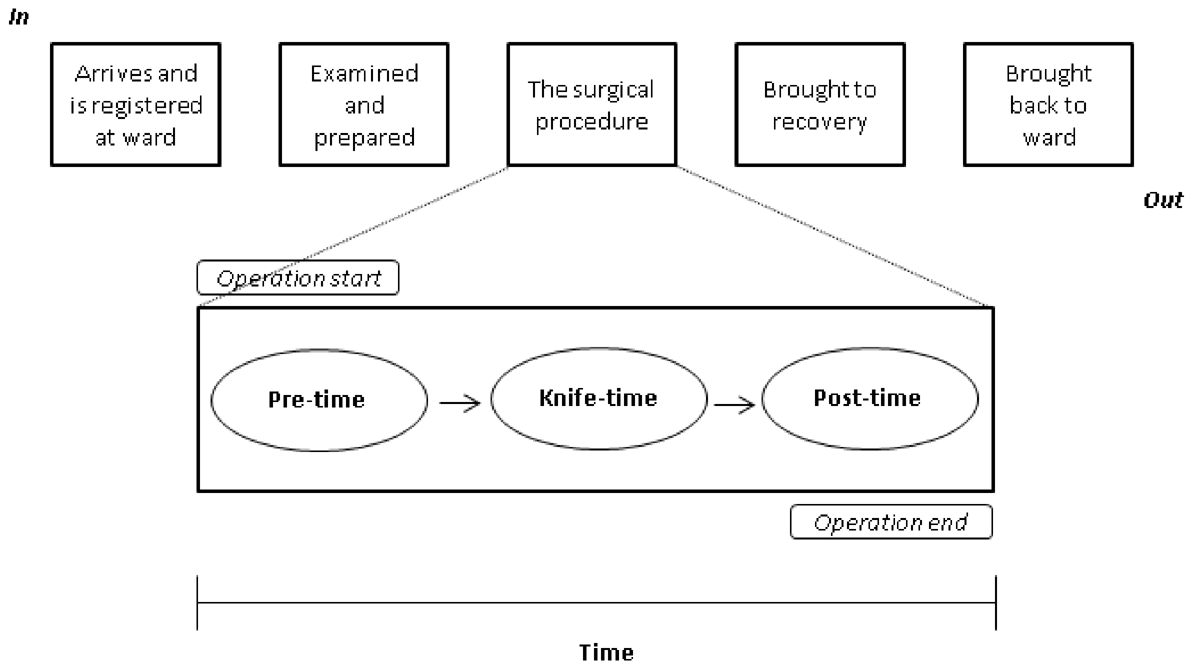

Figure 4.1 The process of a surgical procedure

As seen from figure 4.1 above, an in-patient must go through several different steps when having a surgical procedure. One of the steps, and a sub-process, is “the surgical procedure”.

Concerning “the surgical procedure”, operation start is when the in-patient arrives at the operation ward. Further, the in-patient is brought to the operation theatre where the pre-time starts. The pre-time is when the in-patient is put on the bed and given anesthesia. The knife-time is when the actual surgical procedure is performed, whilst the post-time is the waiting time it takes for the patient to wake up. In addition, between every surgical procedure there is set up time, which is the time for preparing the operation theatre for a surgical procedure.

In this master thesis the accessed data does only concern “the surgical procedure”; therefore, it is only the sub-process (“the surgical procedure”) that will be explored. In the data set from St. Olavs Hospital the set up time between “the surgical procedures” is not registered.

4.4 Data Envelopment Analysis – The Mathematical Formula

The mathematical formula for DEA differs according to which orientation and which RTS that is being used.

For instance, the general formulation for the input-oriented VRS DEA model is;

$$\theta^* = min\,\theta$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0} \qquad i = 1, 2, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0} \qquad r = 1, 2, \dots, s;$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad j = 1, 2, \dots, n.$$

Where;

DMU_0 = one of the *n* DMUs under evaluation

x_{i0} = is the *i*th input for DMU_0

y_{r0} = is the *r*th output for DMU_0

θ^* = efficiency score for DMU_0

If $\theta^* = 1$, then the DMU_0 is on the efficient frontier

$\theta^* < 1$, then the DMU_0 is not on the efficient frontier

One way of solving DEA is through excel. In this master thesis the DEA Frontier software 2007 student version is used. This student version can solve up to 100 DMUs with an unlimited number of inputs and outputs. (Zhu 2009a)

4.5 Regression Analysis

Regression analysis, RA, is a statistical tool, where the relationships between dependent and independent variables are investigated. (Greene 2003)

After calculating DEA efficiency scores as a first stage, one can run RA as a second stage. This second stage could give a picture of how external explanatory variables affect efficiency. The external explanatory variables are often variables that a manager has no control over. (Coelli, Rao, O'Donnell, and Battese 2005b)

When conducting RA as a second stage the inefficiency scores are defined as dependent variables, and the external explanatory variables are defined as independent variables.

RA indicates the direction and degree in which each external explanatory variable affects the inefficiency, and then naturally how each external explanatory variable affects the efficiency. In addition, when conducting a RA one will obtain several statistical values which will indicate how well the quality of the model is.

There are several kinds of RA, and a researcher must figure out which is the most suitable to use in his or her research. After DEA, two common second stages concerning RA are the ordinary least squares, OLS, and tobit regression. However, Hoff (2007) and John McDonald (2009) argue in their study that OLS outperforms the tobit regression model as a second stage for DEA. In addition, John McDonald (2009) emphasizes that there is "considerable merit in using familiar, easy to compute methods, such as OLS, which are understood by a broad community of people".

In addition, it is important to be aware that RA requires a certain sample in order to give reliable and valuable results.

The general formula for RA is (Zhu 2009b);

$$Y = \beta_0 + \sum_{i=1}^{m} \beta_i x_i + \varepsilon$$

Where;

Y = dependent variable

β_0 = constant

β_i = coefficient

X = independent variable

ε = error

Chapter 5 Data

In this chapter the data set from St. Olavs Hospital will be thoroughly explained. First, in section 5.1 the selection process of the data set received from St. Olavs Hospital will be presented through two steps; step 1 and step 2. In section 5.2 and 5.3 the selection of the remaining data for use in DEA and RA will be explained, respectively. Last, in section 5.4 the data remaining for use in DEA and RA will be presented and described.

5.1 Data – The Selection Process

In this master thesis data from St. Olavs Hospital is used. The data received is registered data for all the surgical procedures done in the years 2006 through 2009. In total the data set includes 84 002 surgical procedures. Overview and definitions of all variables in the data set are found in attachment 3.

In this master thesis the process studied is;

The sub-process = A surgical procedure

5.1.1 The Selection Process – Step 1

Before beginning the selection process of the data set, the data set was thoroughly studied in order to figure out what to study and what actually was possible to study. To be able to explore how to use DEA at a process level, it was decided to study at the diagnosis level. The reason was that it may be of value for the hospital. To study at an individual level would not bring value to the hospital; for the hospital to know that a certain patient treated for K43.9 aged 45 is more efficient than another patient treated for C18.2 aged 38, is not of any use. Therefore, in this master thesis the data is aggregated at the diagnosis level.

Two study alternatives were proposed;

1. Study of different main diagnoses of different departments
2. Study of different main diagnoses within one department

Both of the study alternatives were possible to study, because they could be modified to be comparable. It was found of higher interest to see if there were differences amongst different departments, than just looking into one. A reason was because if only one department were to be studied the obtained results would be more uncertain. The results would then only rely on one department, and thereby the results could show a skewed picture of how the department really is performing.

Hence, the study alternative chosen for this master thesis is the study alternative 1;

Study of different main diagnoses of different departments

When studying study alternative 1 it became clear that two departments included most of the surgical procedures. Naturally it would be smart to study those two departments. The two departments were the Department of Surgery, within the Clinic of Surgery, and the Department of Orthopedic, within the Clinic of Orthopaedy and Rheumatology. Hence, the two departments that are studied in this master thesis are;

- ***Department of Surgery***
- ***Department of Orthopedic***

In addition to that the departments included the most surgical procedures they were selected because they were the two largest departments at St. Olavs Hospital. Since these two departments are the two largest they most likely have a huge impact on St. Olavs Hospital's performance. If it was found that they are inefficient, improvements within them may give larger positive changes for St. Olavs Hospitals' performance, in contrast to two small departments.

When it comes to studying the main diagnoses it would be interesting to see how efficient one main diagnosis is, but also how efficient it is compared to other main diagnoses. In addition, a main diagnosis includes several surgical procedures and so a somewhat large portion of the data set could be kept.

Further, after concluding to study study alternative 1, the main research question and several research questions were formulated.

The main research question in this master thesis is;

How can DEA be used to explore efficiency at a process level in hospitals?

In order to explore this, several research questions came to life;

I. ***How is the combined efficiency at the process level for the two departments Department of Surgery and Department of Orthopedic at St. Olavs Hospital in the years 2006 through 2009?***
II. ***How is the efficiency at the process level for each of the two departments separately in the years 2006 through 2009?***
III. ***Is there evidence of any differences in the efficiency at the process level between the two departments in the years 2006 through 2009?***
IV. ***In which degree is the efficiency at the process level for the two departments affected by external explanatory variables in the years 2006 through 2009?***

5.1.2 The Selection Process – Step 2

In step 2 of the selection process variables that were no longer of value for neither the master thesis research questions, DEA nor the RA were removed.

The data set included several different types of variables. Some of the variables had just one value, whereas some of the variables included several options within them. For some of the variables with several options choices of which of the options to include in the data set had to be made. The main reason being, that the data needed to be comparable. In addition to this, variables with errors or missing values were removed.

The selection process is presented through the stages 1 to 5.

Stage 1:

First the two departments Department of Surgery and Department of Orthopedic were selected. All other departments were excluded from the data set. The data set then went from including 84 002 to 50 457 surgical procedures.

After choosing the two departments, there was no need for the variable department, and so it was excluded.

Stage 2:

Second, some of the sections within the two departments were excluded. The sections removed were; Others, Children, Gynecology, Medical, Pediatric, Plastic, and Back. Then 42 717 surgical procedures remained in the data set.

The reason for excluding the sections was that not all sections are comparable, since what they perform is very different.

The reasons for excluding the sections are;

- Others: was removed because of uncertainty of what it contains
- Children: was removed because surgical procedures on children differ a lot from those done on adults (children was defined age 0-18)
- Medical and Pediatric: were removed because they are distinct by mostly being shorter and less complex surgical procedures
- Gynecology was removed because according to St. Olavs Hospital the variable was not reliable because of re-organization
- Plastic and Back: were removed because they are distinct by mostly being huge and difficult surgical procedures

After choosing sections, there was no need for the variable section, and so it was excluded.

Stage 3:

Third, the variable day surgery has two options; 0 or 1. Where 0 means that the surgical procedure is not a day surgery, in other words the patient is classified as an in-patient, whilst 1 means that the surgical procedure is a day surgery, in other words the patient is classified as an out-patient. The out-patients were excluded from the data set, and so the remaining data set consisted of 31 711 surgical procedures.

The reason for excluding the out-patients is because they are not comparable with in-patients, since the surgical procedures are often smaller and simpler. In addition, it is of higher interest to study surgical procedures on in-patients because they are often longer and more difficult. In addition they require more resources.

After choosing in-patients, there was no need for the variable day surgery, and so it was excluded.

Stage 4:

Fourth, the variable degree of emergency has four options; 0, 1, 2 or 3. Where 0 means that the surgical procedure is classified as a planned surgical procedure, whilst 1-3 mean that the surgical procedure is classified as an emergency surgical procedure. The emergency surgical procedures were excluded from the data set, and so the remaining data set consisted of 17 413 surgical procedures.

The reason for excluding the emergency surgical procedures is because they will not be comparable with the planned surgical procedures. The reason being, that emergency surgical procedures are distinct because they are more hectic, difficult, and abundant than planned surgical procedures.

After choosing planned surgical procedures, there was no need for the variable degree of emergency, and so it was excluded.

After the degree of emergency was removed, there was still one surgical procedure left which seemed to be an emergency surgical procedure. The reason being that it included registered data for the variables only registered for emergencies (for instance waiting time). This surgical procedure was therefore excluded, and so the data set contained 17 412 surgical procedures.

Stage 5:

Fifth, several variables that were found of no value were excluded; the main reasons being errors and missing values.

The variables removed were;

- Date reported 1: was removed because it only has value for emergencies
- Date reported 2: was removed because it only has value for emergencies
- Time reported: was removed because it only has value for emergencies
- Waiting time: was removed because it only has value for emergencies
- Nation: was removed because of missing values
- Munic: was removed because of missing values
- County: was removed because of missing values
- Hospital: was removed because all surgical procedures were registered with the same value (Trondheim, TR)
- Ward: was removed because it had no value, since it is the surgical operation process that is studied
- Operation theatre: was removed because it is not suitable for a process level
- Assistant category 3: was removed because it had no values registered
- Assistant category 4: was removed because it had no values registered
- In time: was removed because a substitute variable was left
- Out time: was removed because it was found of no value
- Operation end 1: was removed because it was found of no value
- Knife-end: was removed because it was found of no value

5.2 Data – The Selection for DEA

There are several characteristics that must be decided upon when conducting DEA. The decisions made in this master thesis and the explanations for each of the characteristics will be presented in the following.

5.2.1 Decision Making Unit

From the study alternative 1, "study of different main diagnoses of different departments", it is clear that it is main diagnoses that will be studied. Thus, in this master thesis a DMU is defined as;

DMU = Main diagnosis

Further, which main diagnoses within each of the two departments were going to be DMUs had to be decided upon. It was emphasized to use as much of the data set as possible, whilst ensuring that the DMus were as comparable as possible.

The process of finding the DMUs

First, it was decided that the main diagnoses should contain 50 surgical procedures (in-patients) or more for all the years combined. This was done in order to obtain the best result possible (and reliable), since the data set would then include as much data as possible. In addition, this could make the DMUs more comparable. A surgical procedure that is performed many times may be more efficient than those performed unregularly and seldom, because of learning-by-doing. Therefore the criterion of 50 or more surgical procedures (in-patients) may make the DMUs somewhat comparable.

Further, a frequency table was run for the different main diagnoses, and after this 40 main diagnoses for the Department of Surgery and 15 main diagnoses for the Department of Orthopedic remained in the data set. After this 8 977 surgical procedures were left.

Second, a way to make the main diagnoses even more comparable needed to be found. It was decided that the knife-time could give an indication of the complexity of a surgical procedure, and so a descriptive statistics test was run with knife-time and main diagnosis in order to get a clear view of the complexity.

When conducting mean and median knife-times it gives a picture of what knife-time the different surgical procedures within a specific main diagnosis are located around. It was found that knife-time was not normally distributed, because of this and advices it is concluded to emphasize on only using median knife-time. From this, if main diagnoses with somewhat the same median knife-time are chosen, it can be concluded that they have somewhat the same complexity, and thereby can be compared. The time interval should not be too long since then the comparability could be harmed. It was found of most value to study main diagnoses with a certain complexity (medium to high median knife-time). Main diagnoses with a certain complexity require more resources and coordination, and therefore probably have more potential for improvement. Therefore, to study main diagnoses with a certain complexity may bring more value to St. Olavs Hospital.

From studying the results emphasizing on the mean and median knife-time for all of the main diagnoses a time interval was decided upon. The time interval chosen in order to make the main diagnoses comparable was;

Time interval = 80 – 120 minutes

Within this time interval 11 main diagnoses within the Department of Surgery and 8 main diagnoses within the Department of Orthopedic remained. Then 2 434 surgical procedures were left in the data set.

When conducting the descriptive statistics the minimum and the maximum values for each of the main diagnoses were studied as well. From this it was found that several of the main diagnoses had a minimum knife-time of 0 minutes. In addition, it was found that several of the surgical procedures had knife-time values as low as 1, 2, and 3 minutes. The low knife-time values could indicate that the patient was not treated; perhaps the surgical procedure was cancelled straight after the patient was cut open because of unforeseen factors. However, this is difficult to take into account, since the knowledge is scarce. Where to put a limit for if the patient was treated or not concerning each of the main diagnoses was difficult, and so it was decided to keep all of the values registered in knife-time. In addition, few surgical procedures had knife-time of 0 minutes, only 9 cases. (C50.9 had one in 2007, E66.9 had one in 2008, K43.9 had one in 2009, K50.0 had one in 2006, K51.9 had one in 2006, N20.0 had one in 2006, one in 2007, and one in 2009, and T84.6 had one in 2009.)

Third, it had to be checked if all of the main diagnoses were represented in all of the years 2006 through 2009. As a result of this, some of the main diagnoses were lost. Then the remaining main diagnoses amounted 10 and 7 for the Department of Surgery and Department of Orthopedic respectively. Then 2 312 surgical procedures remained in the data set.

The 17 remaining DMUs, for the two departments, which will be studied, are presented in table 5.1 below.

DMUs	
Department of Surgery	Department of Orthopedic
C18.0	M05.9
C18.2	M16.1
C50.4	M17.1
C50.9	M84.1
E66.9	T84.0
K43.9	T84.1
K50.0	T84.6
K51.9	
K80.2	
N20.0	
Total number of DMUs: 17	

Table 5.1 The DMUs

5.2.2 Input and Output

Output

After studying the data set it was decided what the output had to be for the DMUs. The definition of the output is;

Output = Number of in-patients

The choice of output was based on the knowledge gained through previous DEA studies done in hospitals and logical thinking. Common outputs in previous studies were found to be; number of beds, number of in-patients and out-patients, number of discharges or treated patients. Some of the studies include several of these as their outputs.

Even though the data set is at a lower level than most of the previous studies, it was clear that the number of in-patients could be used as an output. The number of in-patients for a main diagnosis is the number of surgical procedures done within the main diagnosis. It was logical to choose the number of in-patients since the data was pooled in different main diagnoses.

Input

Several of the variables in the remaining data set could be seen as inputs for the chosen output, either alone or combined.

Possible input variables in different forms are;

- Pre-time
- Knife-time
- Post-time
- Time (Pre-time + Knife-time + Post-time)
- Doctors (surgeons and anesthesiologists)
- Non-doctors (nurses and technical assistants)
- Staff (Doctors + Non-doctors)

These are possible inputs because they all affect the output in some way. For instance the time variables affect the number of in-patients in a certain time; if the time is low for a surgical procedure, the number of in-patients could be higher. The staff variables could also affect the number of in-patients. If more staff is available most likely the number of in-patients could be higher.

The input variables are in compliance with those commonly used in previous studies; labour and service complexity.

To test if the inputs do in fact affect the output, correlations between the inputs and outputs were calculated. The results are shown in table 5.2 below.

Output correlations						
Input	**vs**	**Output**	**2006**	**2007**	**2008**	**2009**
Knife-time	vs	Number of in-patients	0.894	0.972	0.988	0.982
Pre-time	vs	Number of in-patients	0.941	0.944	0.945	0.936
Post-time	vs	Number of in-patients	0.878	0.905	0.962	0.931
Time	vs	Number of in-patients	0.929	0.991	0.985	0.981
Doctors	vs	Number of in-patients	0.979	0.985	0.982	0.963
Non-doctors	vs	Number of in-patients	0.992	0.977	0.990	0.990
Staff	vs	Number of in-patients	0.989	0.982	0.990	0.984

Table 5.2 Output correlations

From table 5.2 on the previous page it is seen that all the inputs correlate highly with the output, which means that all of these inputs are possible to use for the chosen output.

To check the inputs even further, correlations between them were conducted. The results are shown in table 5.3 below.

Input correlations						
Input	**vs**	**Input**	**2006**	**2007**	**2008**	**2009**
Knife-time	vs	Pre-time	0.923	0.901	0.955	0.955
Knife-time	vs	Post-time	0.983	0.925	0.947	0.883
Knife-time	vs	Doctors	0.936	0.964	0.981	0.970
Knife-time	vs	Non-doctors	0.920	0.939	0.979	0.981
Knife-time	vs	Staff	0.929	0.951	0.983	0.981
Pre-time	vs	Post-time	0.893	0.797	0.859	0.766
Pre-time	vs	Doctors	0.966	0.970	0.966	0.976
Pre-time	vs	Non-doctors	0.966	0.981	0.969	0.972
Pre-time	vs	Staff	0.968	0.978	0.971	0.978
Post-time	vs	Doctors	0.920	0.908	0.947	0.851
Post-time	vs	Non-doctors	0.907	0.879	0.943	0.884
Post-time	vs	Staff	0.915	0.892	0.948	0.875
Time	vs	Doctors	0.965	0.995	0.988	0.984
Time	vs	Non-doctors	0.955	0.988	0.988	0.991
Time	vs	Staff	0.961	0.992	0.991	0.993
Doctors	vs	Non-doctors	0.991	0.993	0.988	0.983

Table 5.3 Input correlations

From table 5.3 above it is clear that all of the input correlated highly with each other. The DEA method tells that if inputs correlate only one of them may be necessary. However, in this case if the possible inputs had not correlated it would be strange, because they are naturally closely connected; for instance concerning the knife-time the time starts when the doctor starts cutting the patient, and stop when he or she is finished. Therefore more than one of the possible inputs can be chosen.

It was decided to use the grouped inputs since all the variables correlate highly with each other; in addition it was found of no use to use for instance pre-time, knife-time, and post-time as input variables when it was possible to use only time that included all of them. Therefore, the inputs in this master thesis are;

Input 1 = Time

Input 2 = Staff

5.2.3 Orientation

When it comes to orientation, both of the two options, input orientation and output orientation were possible.

Input-oriented was possible because a manager would most likely be able to control the input in some way, and thus probably be able to save input. In order to keep the same output the input must be used more efficiently. Most likely this would be done by reducing the time for a surgical procedure, rather than reducing staff. It may be hard to reduce staff since the tasks of each team member are necessary for completing a surgical procedure. For instance when it comes to time, the set up time between the surgical procedures could perhaps be reduced. In addition, hospitals struggle with increasing expenditures, and to save input could help them. Further, the time is essence for the patients and the hospital, since they both want the patient to be discharged as fast as possible.

Output-oriented was possible because it seems likely that a hospital manager would like to be able to treat more patients. However, not because of an increase in demand, though by shortening the patient waiting list. One way is to be able to treat more patients by using the inputs more efficiently, which means that each patient is treated faster. By this the hospital could maximize revenue for example by prioritizing patients with higher DRG-points. In addition, in Norway there is a free choice of hospital, and therefore if hospitals were allowed to market themselves they could have influenced the number of in-patients. Though, hospitals have little control over the output disregarding the waiting lists; no one knows exactly how many people will get sick.

It was concluded to use an input orientation because of the following reasons;

- Hospitals have more control over their input than their output
- Hospitals struggle with high expenditures
- Most previous studies have used input orientation

In addition, it may be of more value for St. Olavs Hospital to find if there are achievable cost savings concerning their input.

For these reasons the orientation used in this master thesis is;

Orientation = Input orientation

5.2.4 Returns to Scale

When deciding on which RTS to use, it was necessary to figure out which scale of operation the main diagnoses produced with. From this it could be found how much the SEs affected the inefficiency.

First, it was found how many of the main diagnoses were producing with the different scale of operations in the years 2006 through 2009, by running a DEA with an input orientation and CRS. The results are presented in table 5.4 below.

Scale of operation 2006-2009				
RTS	**2006**	**2007**	**2008**	**2009**
Increasing	10	8	7	11
Decreasing	4	7	8	3
Constant	3	2	2	3

Table 5.4 Scale of operation 2006-2009

From table 5.4 it is seen that the most common scale of operation for the main diagnoses was an increasing scale of operation. This is not the optimal scale of operation, and so it is interesting to figure out how much it means for the efficiency to produce using the wrong scale of operation.

Further, a DEA with an input orientation and VRS was run, and from the CRS and VRS runs the SEs and improvement potentials were calculated by using the efficiency scores. In addition inefficiency scores were calculated. This was done for all of the main diagnoses in the four years 2006 through 2009. The results are presented in attachment 4. However, the means for each year are shown in table 5.5 below.

Mean overview						
	Efficiency score		**Inefficiency score**		**Scale efficiency**	**Improvement potential**
	CRS	**VRS**	**CRS**	**VRS**	**CRS/VRS**	**1-SE**
2006	0.869	0.904	0.131	0.096	0.961	0.039
2007	0.860	0.913	0.140	0.087	0.942	0.058
2008	0.879	0.937	0.121	0.063	0.938	0.062
2009	0.865	0.902	0.135	0.098	0.959	0.041

Table 5.5 Mean overview

From table 5.5 it is seen that the mean efficiency scores for CRS and VRS seem to be quite equal. This is illustrated more clearly for year 2006 in attachment 5. In addition, there is room for improvement as can be seen from the mean inefficiency scores. Further, the high mean SEs prove that CRS and

VRS calculate quite equal efficiency scores. The high mean SEs indicate that the problem of inefficiency is not due to wrong scale of operation; the improvement potential of switching scale of operation is low. Thereby, inefficiency is mainly caused by something else than the scale of operation.

From this it is clear that using VRS will most likely give a better picture of the efficiency, and so in this master thesis the RTS chosen is;

Returns to scale = Variable returns scale

5.2.5 The selection for DEA – Summary

The choices made for each of the characteristics in DEA are;

- ***DMU = Main diagnosis***
- ***Output = Number of in-patients***
- ***Input 1 = Time***
- ***Input 2 = Staff***
- ***Orientation = Input orientation***
- ***RTS = VRS***

5.3 Data – The Selection for RA

The remaining data set had several variables that could be used in RA. In hospitals there are many factors that hospitals have no control over, especially concerning the patient. These may affect the efficiency of a surgical procedure in a positive or negative direction.

There are several possible external explanatory variables in the data set;

- Gender
- Age
- Treatment or Examination
- ASA
- Anesthesia type
- Degree of contamination
- Weekday
- Number of diagnosis codes
- Number of operation codes
- Operation start
- Knife-start

It is necessary to check if it was possible to use these external explanatory variables in RA. In general, it was found that the data was not normally distributed, and thereby when conducting values for RA median values are found and used.

5.3.1 Gender

Gender may have an effect on the efficiency of a surgical procedure. However, the effect should not be destined by if the patient is male or female, since males and females are alike except the genitals. If the gynecological surgical procedures were included however, there could maybe have been a distinct difference between the male and female effect on efficiency.

Some of the main diagnoses are diagnoses that only concerns females. Hence two of the main diagnoses were removed for the RA, as these may harm the picture of how much and in what way gender affect the efficiency. The main diagnoses removed were C50.4 and C50.9. Concerning C50.9 there was one surgical procedure registered as male, however as the diagnosis concerns only females, it was concluded that this variable was registered incorrectly.

For the RA gender was defined as; male = 0, and female = 1. Each main diagnosis includes many surgical procedures, and so each main diagnosis was registered with the value 0 (male) or 1 (female) which they had the most of.

There were some main diagnoses that included the same amount of males and females, in one or more of the years. These were excluded from the RA; the main diagnoses excluded were C18.2 and K43.9.

The assumption made regarding gender is;

- ***Gender – Main diagnoses with a majority of males will be equally efficient as those with a majority of females***

5.3.2 Age

Age may have an effect on the efficiency of a surgical procedure. Further, the older a patient is the less efficient the surgical procedure may be. Since there perhaps are more complications combined with operating on an old patient, because an old patient may have more illnesses and be weaker than a young patient. In addition, the anesthesia time (within pre-time and post-time) may be longer for an older patient than for a younger patient.

For RA the median age was found for each of the main diagnoses. In addition, young patients were defined to be of age 19-64, whilst old patients were defined to be of age 65-100.

The assumption made regarding age is;

- ***Age – Main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients***

5.3.3 Treatment or Examination

Whether the surgical procedure is a treatment or an examination may have an effect on the efficiency. Further, if the surgical procedure is a treatment the less efficient the surgical procedure may be, since a treatment most probably will be more complex and thereby more difficult than an examination.

When the values for RA were conducted the median showed that most surgical procedures in all of the main diagnoses were treatments, and thereby all of the DMUs had the same value. Therefore this external explanatory variable was excluded.

5.3.4 ASA

Which degree of ASA a surgical procedure has may have an effect on the efficiency. A high degree of ASA in a surgical procedure may affect the efficiency negatively, since the higher ASA the more planning and caution must be taken into account. In addition to that the surgical procedure may be more complex.

Further, whilst the values for the RA were conducted missing values were found. Thus, this external explanatory variable was excluded.

5.3.5 Anesthesia Type

Which type of anesthesia that is used in a surgical procedure may have an effect on the efficiency. Since there are such different anesthesia types, all from general anesthetic to local anesthetic, these may have different effects on how long and complex a surgical procedure is. Therefore what kind of anesthesia type it is, may affect the efficiency differently. For instance, for some local anesthesia methods one has to wait 10 minutes until the effect starts, whilst general anesthesia methods take only a minute. Thus, general anesthesia will use less total time compared to some of the local anesthesia.

Further, whilst the values for RA were conducted, missing values were found. Thus, this external explanatory variable was excluded.

5.3.6 Degree of Contamination

Which degree of contamination a surgical procedure has may have an effect on the efficiency. A high degree of contamination in a surgical procedure may affect the efficiency negatively, since the higher contamination in a surgical procedure the more complex and difficult it may be. Thereby, the higher degree of contamination the less efficient a surgical procedure may be. In addition, it is worth mentioning that there is longer set-up time when the degree of contamination is high.

For the RA the median degree of contamination was found for each of the main diagnoses.

The assumption made regarding degree of contamination is;

- ***Degree of contamination – Main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination***

5.3.7 Weekday

Which day it is may have an effect on the efficiency of a surgical procedure. Some of the days have perhaps more planned surgical procedures than others; also the employees may be more awake and focused in the beginning of a week than later. However, since the employees at hospitals work in shifts (not usual work hours from Monday to Friday 9-17), which day it is may therefore not have any effect on the efficiency of a surgical procedure.

Further, this external explanatory variable was found of no value at the diagnosis level. Thus, this external explanatory variable was excluded.

5.3.8 Number of Diagnosis Codes

The number of diagnosis codes may have an effect on the efficiency of a surgical procedure. The more diagnoses (diseases) a patient has, the less efficient the surgical procedure may be, since the surgical procedure may be more complex and therefore last longer.

When the values for RA were conducted the median showed that most surgical procedures in all of the main diagnoses had one diagnosis code, and thereby all of the DMUs had the same value. Therefore, this external explanatory variable was excluded.

5.3.9 Number of Operation Codes

The number of operation codes may have an effect on the efficiency of a surgical procedure. The more operation codes a patient has, the less efficient the surgical procedure may be, since the surgical procedure may be more complex and therefore last longer.

For the RA the median number of operation codes was found for each of the main diagnoses.

The assumption made regarding number of operation codes is;

- ***Number of operation codes – Main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes***

5.3.10 Operation Start

The operation start of a surgical procedure may have an effect on the efficiency. Employees may be less efficient later in the day than earlier. However, since the employees at hospitals work in shifts and thereby start at different times, which time it is may therefore not have any effect on the efficiency of a surgical procedure.

Since the employees work in shifts and the length of surgical procedures differ, this external explanatory variable was found of low value. Thus, the external explanatory variable was excluded.

5.3.11 Knife-start

The knife-start of a surgical procedure may have an effect on the efficiency. Employees may be less efficient later in the day than earlier. However, since the employees at hospitals work in shifts and thereby start at different times, which time it is may therefore not have any effect on the efficiency of a surgical procedure.

In addition to the reasons under the external explanatory variable operation start, this external explanatory variable was also excluded since the efficiency scores in DEA will be calculated with the variables time (pre-time + knife-time + post-time). It will not make sense to use this variable since it will not start from the beginning. Thus, the external explanatory variable was excluded.

5.3.12 The selection for RA – Summary

The external explanatory variables found of highest value to study in RA are;

- ***Gender***
- ***Age***
- ***Degree of contamination***
- ***Number of operation codes***

Further, the assumptions for each of the different external explanatory variables are;

- ***Gender – Main diagnoses with a majority of males will be equally efficient as those with a majority of females***
- ***Age – Main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients***
- ***Degree of contamination – Main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination***
- ***Number of operation codes – Main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation code***

In addition, the DMUs are made comparable by choosing the time interval 80 to 120 minutes with help from median knife-time. Since the 17 DMUs have varying median knife-times within this time interval, it is desirable to check if this has any effect on the DEA results. Therefore, the median knife-time is included as a control variable in the RA. It is desirable that RA shows the median knife-time to have no effect on the efficiency since this will imply that the DMUs are comparable.

5.4 Data – Presentation of the Variables

The variables chosen for use in DEA and RA will be presented in the sections 5.4.1 and 5.4.2, respectively.

Table 5.6 below shows the variables that have been chosen for DEA and RA.

The variables		
Label	**Variable**	**Definition**
Decision making unit	Main diagnosis	The main reason for the surgical procedure
Output	Number of in-patients	The total number of surgical procedures for each DMUs
Input	Time	The sum of pre-time + knife-time + post-time
Input	Staff	The sum of doctors + non-doctors
External explanatory variable	Gender	Female or male patient
External explanatory variable	Age	The age of the patient
External explanatory variable	Degree of contamination	The degree of wound
External explanatory variable	Number of operation codes	The number of operation codes done in a surgical procedure
Control variable	Median knife-time	The median knife-time of a main diagnosis

Table 5.6 The variables

5.4.1 Data – For DEA

The Decision Making Unit

An overview of the DMUs and their definitions is shown in table 5.7 below.

Description of the DMUs			
Department of Surgery		Department of Orthopedic	
Main diagnosis	Definition	Main diagnosis	Definition
C18.0	Coecum	M05.9	Seropositive rheumatoid arthritis unspecified
C18.2	Colon ascending part	M16.1	Other primary coxarthrosis
C50.4	Upper-outer quadrant of breast	M17.1	Other primary gonarthrosis
C50.9	Breast unspecified	M84.1	Nonunion of fracture (pseudarthrosis)
E66.9	Obesity unspecified	T84.0	Mechanical complication of internal joint prosthesis
K43.9	Ventral hernia without obstruction or gangrene	T84.1	Mechanical complication of internal fixation device of bones of limb
K50.0	Crohn disease of small intestine	T84.6	Infection and inflammatory reaction due to internal fixation device (any site)
K51.9	Ulcerative colitis unspecified		
K80.2	Calculus of gallbladder without cholecystitis		
N20.0	Calculus of kidney		

Table 5.7 Description of the DMUs

The Input and Output

Descriptive statistics for the inputs and output for each year were conducted, in addition to all the years combined in order to get a picture of the variation within the main diagnoses.

Table 5.8 below shows the descriptive statistics made for all of the years 2006 through 2009.

Descriptive statistics 2006-2009					
		Mean	St. deviation	Min	Max
Input	Staff	150	120	25	547
Input	Time	6 486	5 513	1 130	25 642
Output	Number of in-patients	34	26	6	110

Table 5.8 Descriptive statistics 2006-2009

In general, as seen in table 5.8 on the previous page, the inputs and the output have quite high standard deviations, and minimum and maximum values that are far apart. This can either indicate a high fluctuation between the different years or that the main diagnoses have very different input and output values. Since it is unclear whether the variation in table 5.8 on the previous page is caused by fluctuation between the different years or an actual variation between the different main diagnoses, it is interesting to see the descriptive statistics for each of the years alone.

Table 5.9 below shows the descriptive statistics for year 2006, descriptive statistics for the rest of the years can be found in attachment 6.

Descriptive statistics 2006					
		Mean	St. deviation	Min	Max
Input	Staff	161	109	31	443
Input	Time	7 254	5 336	1 309	23 211
Output	Number of in-patients	38	26	8	101

Table 5.9 Descriptive statistics 2006

As it is seen from table 5.9 the standard deviations are still quite high, which shows that there is a big difference in the amount of inputs and output for the different main diagnoses. This can also indicate that the high standard deviation, in table 5.8 above for all of the years, is mainly caused by difference from main diagnosis to main diagnosis and not yearly differences.

Further, to get a picture of how the inputs used and the output produced by all of the main diagnoses have varied; the means in total and for the different years were found. The results are shown in table 5.10 below.

Mean overview 2006-2009			
	Staff	Time	Number of in-patients
All years	150	6 486	34
2006	161	7 254	38
2007	139	6 174	32
2008	165	7 018	37
2009	133	5 499	29

Table 5.10 Mean overview

From table 5.10 on the previous page, it is seen that both the inputs and output vary from year to year, like a wave. In addition it is seen that the difference between the years 2008 and 2009 is greater than between other years. It is seen that in the year 2009 the inputs and output declined much more than in the year 2007.

Since there is such a huge variation in the inputs and output, there could be an outlier in the data set. The data set was therefore studied and T84.1 was found to be a possible outlier. A DEA was therefore run with and without it to check if there were any differences in the results. Both of the DEA tests gave the same efficient and inefficient main diagnoses, and the difference in mean efficiency was as small as 0.005. Thus, we concluded to keep all of the main diagnoses.

What to expect from the data set regarding efficiency is difficult to predict. Since the relationship between the inputs and output is somewhat the same in all of the years the efficiency could be relatively alike as well, though it is not known if the efficiency scores are low or high.

In addition, it is not known how the efficiency scores are between the main diagnoses. Since the variation in the data set is so high, it could perhaps be expected that there is variation in the efficiency scores as well. However, a main diagnosis producing a low output may be just as efficient as a main diagnosis producing a high output. Therefore, there is a possibility that the variation in the efficiency scores is low.

5.4.2 Data – For RA

When it comes to the external explanatory variables, overview tables were made for each year. The tables show for each main diagnosis; which gender there was most of, median age, median degree of contamination, median number of operation codes, and median knife-time. These can be seen in attachment 7.

A table showing the amount of each of the options within each of the external explanatory variables for all of the years was conducted as well. This is shown in table 5.11 below.

External explanatory variables overview 2006-2009									
	Gender		Age		Degree of contamination		Number of operation codes		Median knife-time
	Amount of male	Amount of female	Amount of young (≤ 64)	Amount of old (≥ 65)	Amount with degree 1	Amount with degree more than 1	Amount of 1	Amount of more than 1	
2006	4	9	11	2	12	1	6	7	
2007	3	10	10	3	7	6	5	8	
2008	4	9	10	3	9	4	6	7	
2009	4	9	9	4	7	6	6	7	
Median	4	9	10	3	8	5	6	7	101

Table 5.11 External explanatory variables overview

From table 5.11 it is clear that when it comes to gender there are more surgical procedures done on females than on males. When it comes to age, it seems like most of the surgical procedures are on young people rather than old people. It seems like most of the surgical procedures have a degree of contamination of 1, than of more than 1. Concerning the number of operation codes there have been more surgical procedures on patients with more than 1 operation code, than on patients with only 1 operation code. Last, the median knife-time has the same value for each of the DMUs in all of the years, though it is found that the median of the median knife-times is 101 minutes.

Chapter 6 Analysis

In this chapter the results will be presented and analysed. In the sections 6.1 to 6.4 the results regarding the research questions will be presented and analysed. Each section will be finished off with a summary of the results.

The DEA results will be presented and analysed under the assumption that the DMUs are fully comparable. This is done in order to show how DEA and RA results for the years 2006 through 2009 may be interpreted and understood. Though, it is important to remember that this is a partial analysis, and therefore that the results cannot be generalized.

- *Concerning DEA; an input-oriented DEA model with VRS has been run for each of the four years.*
- *Concerning RA; an OLS regression model has been run for each of the four years.*

The following rules are used when analysing the results;

- *A 95 % confidence interval will be used (mean ± (2 x st.dev), α = 0.05)*

  t-ratio > ± 1.96, p-value < 0.05, significant

  t-ratio < ± 1.96, p-value > 0.05, not significant

- *A low standard deviation indicates that the data points tend to be very close to the mean, whilst a high standard deviation indicates that the data points are spread out over a large range of values*

- *F – test: Test of variance*

  H0: no difference in variance

  H1: difference in variance

  If $F < F_{critical}$, keep H0

  If $F > F_{critical}$, reject H0

- *T – test: Test of mean*

  H0: no difference in mean

  H1: difference in mean

  If $T < T_{critical}$, or $T > -T_{critical}$, keep H0

  If $T > T_{critical}$, or $T < -T_{critical}$, reject H0

6.1 Data Envelopment Analysis Results – I

I. ***How is the combined efficiency at the process level for the two departments Department of Surgery and Department of Orthopedic at St. Olavs Hospital in the years 2006 through 2009?***

6.1.1 DEA Results I – 2006

First, the efficiency scores for all of the main diagnoses in year 2006 were found. Table 6.1 below shows the efficiency scores for all of the main diagnoses.

2006		
Main diagnosis	**Efficiency score**	**Inefficiency score**
C18.0	0.858	0.142
C18.2	0.791	0.209
C50.4	0.908	0.092
C50.9	0.928	0.072
E66.9	0.737	0.263
K43.9	1	0
K50.0	0.844	0.156
K51.9	1	0
K80.2	0.798	0.202
N20.0	0.995	0.005
M05.9	1	0
M16.1	0.785	0.215
M17.1	1	0
M84.1	0.855	0.145
T84.0	1	0
T84.1	0.993	0.007
T84.6	0.882	0.118

Table 6.1 Efficiency scores 2006

From table 6.1 it is clear that 5 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 12 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.864 or 86.4 %. All of the 12 inefficient main diagnoses have potential for improvement in different degrees. For instance N20.0 has the potential for improvement in efficiency of 0.005 or 0.5 %, whilst K80.2 has the potential for improvement in efficiency of 0.202 or 20.2 %.

Second, in order to get a better overview of the efficiency in 2006 for all of the main diagnoses, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.1 below.

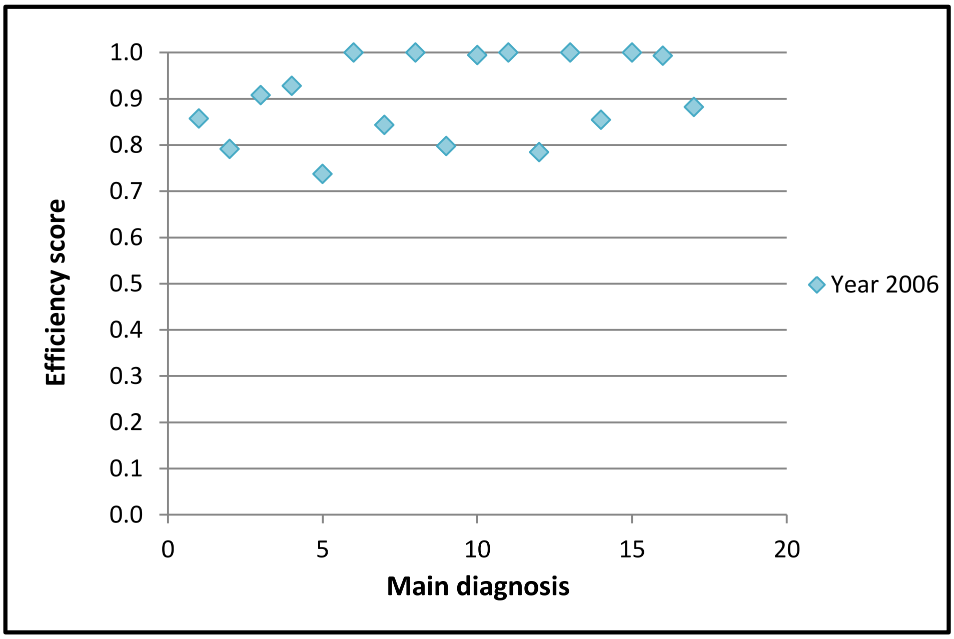

Figure 6.1 Efficiency scores 2006

From figure 6.1 it is seen that there is a variation in the efficiency of the different main diagnoses. The efficiency scores for all of the main diagnoses in 2006 are as seen all located between 0.7 and 1 or 70 % and 100 %. Though, there is only 1 main diagnosis that is close to the lower limit of 0.7 or 70 %, whilst the others are located around 0.8 or 80 % and upwards. From table 6.1 on the previous page, it is found that there are 5 efficient main diagnoses. However, figure 6.1 clearly shows that there are 2 main diagnoses that are very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses has been through year 2006, a descriptive statistics was made. The results are shown in table 6.2 below.

2006		
	Efficency	**Inefficiency**
Mean	0.904	0.096
Stdev	0.093	
95 % CI	0.904 ± (2 x 0.093)	
Min	0.737	
Max	1	

Table 6.2 Descriptive statistics 2006

As table 6.2 on the previous page shows, the mean efficiency for year 2006 was 0.904 or 90.4 %. This indicates that there is a mean improvement potential in efficiency of 0.096 or 9.6 %. The standard deviation is 0.093 or 9.3 % and gives a 95 % confidence interval of 0.904 ± (2 x 0.093). In other words, the probability of locating a main diagnosis not in this interval is less than 5 %. However, since the minimum value is 0.737 or 73.7 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency.

6.1.2 DEA Results I – 2007

First, the efficiency scores for all of the main diagnoses in year 2007 were found. Table 6.3 below shows the efficiency scores for all of the main diagnoses.

2007		
Main diagnosis	**Efficiency score**	**Inefficiency score**
C18.0	1	0
C18.2	0.922	0.078
C50.4	1	0
C50.9	1	0
E66.9	0.853	0.147
K43.9	0.856	0.144
K50.0	0.917	0.083
K51.9	1	0
K80.2	0.828	0.172
N20.0	1	0
M05.9	0.954	0.046
M16.1	0.802	0.198
M17.1	0.801	0.199
M84.1	0.826	0.174
T84.0	1	0
T84.1	0.795	0.205
T84.6	0.964	0.036

Table 6.3 Efficiency scores 2007

From table 6.3 it is clear that 6 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 11 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.865 or 86.5 %. All of the 11 inefficient main diagnoses have potential for improvement in different degrees. For instance T84.6 has the potential for improvement in efficiency of 0.036 or 3.6 %, whilst M16.1 has the potential for improvement in efficiency of 0.198 or 19.8 %.

Second, in order to get a better overview of the efficiency in 2007 for all of the main diagnoses, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.2 below.

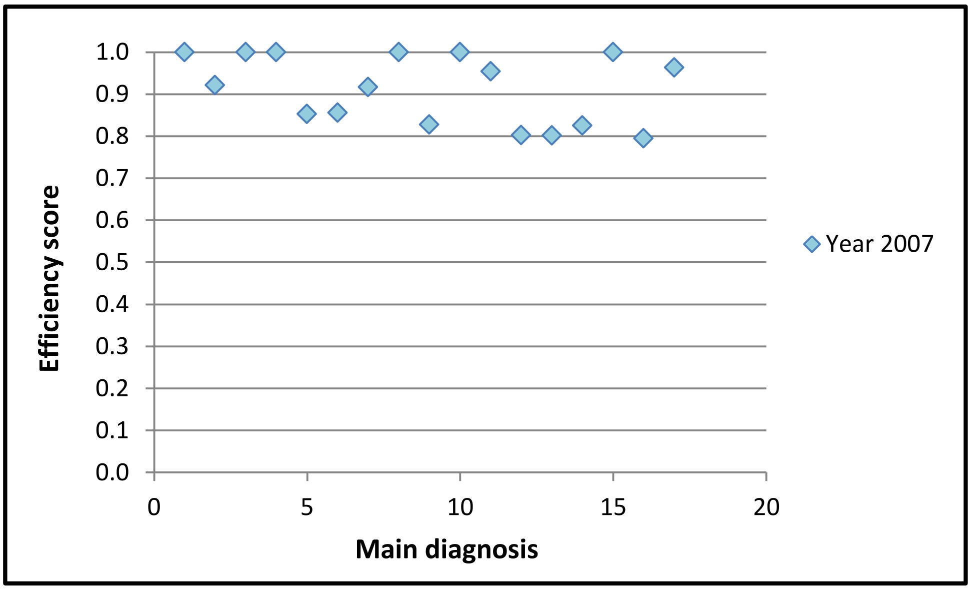

Figure 6.2 Efficiency scores 2007

From figure 6.2 it is seen that there is a variation in the efficiency of the different main diagnoses. The efficiency scores for all of the main diagnoses in 2007 are all located between approximately 0.8 and 1 or 80 % and 100 %. From table 6.3 on the previous page, it is found that there are 6 efficient main diagnoses; these are clearly shown in figure 6.2. Further, it seems that there are 2 main diagnoses which are very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses has been through year 2007, a descriptive statistics was made. The results are shown in table 6.4 below.

2007		
	Efficency	Inefficiency
Mean	0.913	0.087
Stdev	0.083	
95 % CI	0.913 ± (2 x 0.083)	
Min	0.795	
Max	1	

Table 6.4 Descriptive statistics 2007

As table 6.4 on the previous page shows, the mean efficiency for year 2007 was 0.913 or 91.3 %. This indicates that there is a mean improvement potential in efficiency of 0.087 or 8.7 %. The standard deviation is 0.083 or 8.3 % and gives a 95 % confidence interval of 0.913 ± (2 x 0.083). However, since the minimum value is 0.795 or 79.5 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency.

6.1.3 DEA Results I – 2008

First, the efficiency scores for all of the main diagnoses in year 2008 were found. Table 6.5 below shows the efficiency scores for all of the main diagnoses.

2008		
Main diagnosis	**Efficiency score**	**Inefficiency score**
C18.0	0.845	0.155
C18.2	0.850	0.150
C50.4	0.988	0.012
C50.9	1	0
E66.9	1	0
K43.9	0.898	0.102
K50.0	1	0
K51.9	1	0
K80.2	0.814	0.186
N20.0	1	0
M05.9	1	0
M16.1	0.901	0.099
M17.1	0.850	0.150
M84.1	0.845	0.155
T84.0	1	0
T84.1	0.938	0.062
T84.6	1	0

Table 6.5 Efficiency scores 2008

From table 6.5 above it is clear that 8 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 9 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.881 or 88.1 %. All of the 9 inefficient main diagnoses have potential for improvement in different degrees. For instance C50.4 has the potential for improvement in efficiency of 0.012 or 1.2 %, whilst K80.2 has the potential for improvement in efficiency of 0.186 or 18.6 %.

Second, in order to get a better overview of the efficiency in 2008 for all of the main diagnoses, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.3 below.

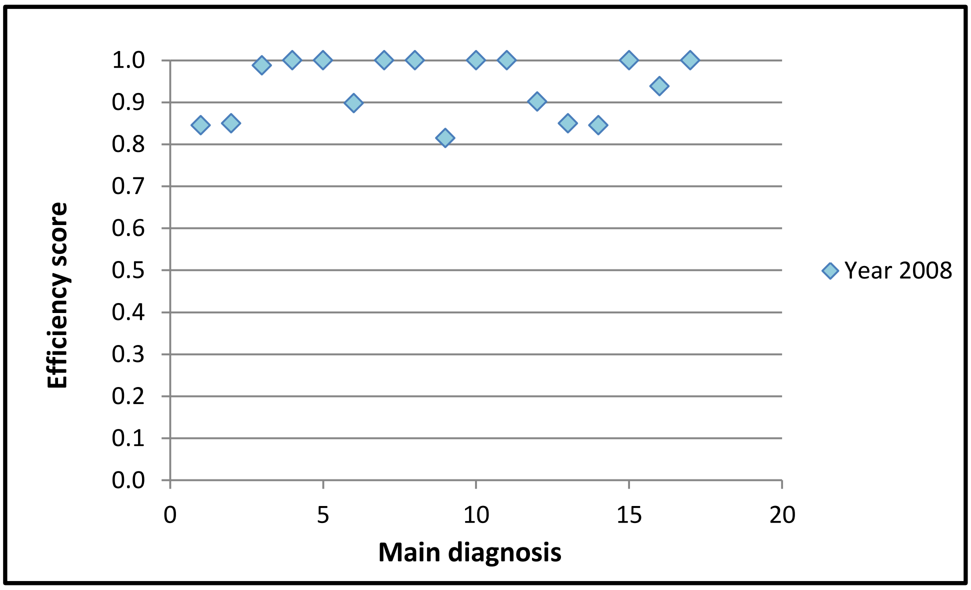

Figure 6.3 Efficiency scores 2008

From figure 6.3 it is seen that there is a variation in the efficiency of the different main diagnoses. The efficiency scores for all of the main diagnoses in 2008 are all located above 0.8 or 80 %. From table 6.5 on the previous page it is found that there are 8 efficient main diagnoses, these are clearly shown in figure 6.3. Further, it is seen that there is 1 main diagnosis which seem to be very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses has been through year 2008, a descriptive statistics was made. The results are shown in table 6.6 below.

2008		
	Efficency	Inefficiency
Mean	0.937	0.063
Stdev	0.073	
95 % CI	0.937 ± (2 x 0.073)	
Min	0.814	
Max	1	

Table 6.6 Descriptive statistics 2008

As table 6.6 on the previous page shows, the mean efficiency for year 2008 was 0.937 or 93.7 %. This indicates that there is a mean improvement potential in efficiency of 0.063 or 6.3 %. The standard deviation is 0.073 or 7.3 % and gives a 95 % confidence interval of 0.937 ± (2 x 0.073). However, since the minimum value is 0.814 or 81.4 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency.

6.1.4 DEA Results I – 2009

First, the efficiency scores for all of the main diagnoses in year 2009 were found. Table 6.7 below shows the efficiency scores for all of the main diagnoses.

2009		
Main diagnosis	Efficiency score	Inefficiency score
C18.0	1	0
C18.2	0.781	0.219
C50.4	0.900	0.100
C50.9	0.917	0.083
E66.9	0.894	0.106
K43.9	0.893	0.107
K50.0	1	0
K51.9	0.807	0.193
K80.2	0.811	0.189
N20.0	1	0
M05.9	1	0
M16.1	0.777	0.223
M17.1	0.810	0.190
M84.1	0.841	0.159
T84.0	1	0
T84.1	0.902	0.098
T84.6	1	0

Table 6.7 Efficiency scores 2009

From table 6.7 it is clear that 6 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 11 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.849 or 84.9 %. All the 11 inefficient main diagnoses have potential for improvement in different degrees. For instance C50.9 has the potential for improvement in efficiency of 0.083 or 8.3 %, whilst M84.1 has the potential for improvement in efficiency of 0.159 or 15.9 %.

Second, in order to get a better overview of the efficiency in 2009 for all of the main diagnoses, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.4 below.

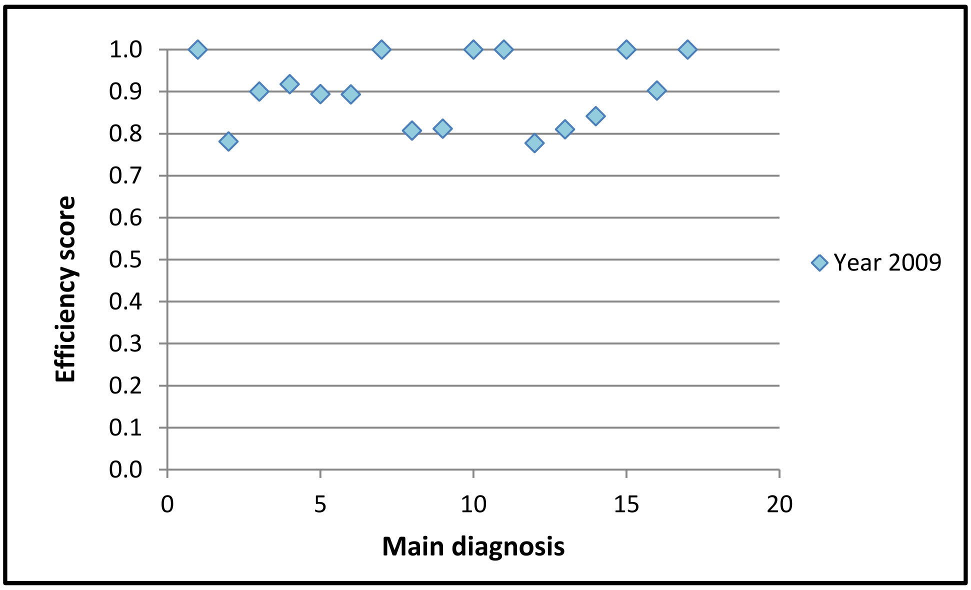

Figure 6.4 Efficiency scores 2009

From figure 6.4 it is seen that there is a variation in the efficiency of the different main diagnoses. The efficiency scores for all of the main diagnoses in 2009 are all located between approximately 0.8 and 1 or 80 % and 100 %. From table 6.7 on the previous page, it is found that there are 6 efficient main diagnoses; these are clearly shown in figure 6.4.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses has been through year 2009, a descriptive statistics was made. The results are shown in table 6.8 below.

2009		
	Efficency	Inefficiency
Mean	0.902	0.098
Stdev	0.086	
95 % CI	0.902 ± (2 x 0.086)	
Min	0.777	
Max	1	

Table 6.8 Descriptive statistics 2009

As table 6.8 on the previous page shows, the mean efficiency for year 2009 was 0.902 or 90.2 %. This indicates that there is a mean improvement potential in efficiency of 0.908 or 9.8 %. The standard deviation is 0.086 or 8.6 % and gives a 95 % confidence interval of 0.902 ± (2 x 0.086). However, since the minimum value is 0.777 or 77.7 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency.

6.1.5 DEA Results I – Summary

In order to get a better overview over the efficiency in the years 2006 through 2009, different summary tables and a scatter plot were made.

Table 6.9 below shows the summary regarding the DEA results I concerning the efficiency scores for all of the main diagnoses.

Results I - Summary				
Main diagnosis	2006	2007	2008	2009
C18.0	-	1	-	1
C18.2	-	-	-	-
C50.4	-	1	-	-
C50.9	-	1	1	-
E66.9	-	-	1	-
K43.9	1	-	-	-
K50.0	-	-	1	1
K51.9	1	1	1	-
K80.2	-	-	-	-
N20.0	-	1	1	1
M05.9	1	-	1	1
M16.1	-	-	-	-
M17.1	1	-	-	-
M84.1	-	-	-	-
T84.0	1	1	1	1
T84.1	-	-	-	-
T84.6	-	-	1	1
Amount efficient	5	6	8	6
Amount inefficient	12	11	9	11

Table 6.9 Results I – Summary

Table 6.9 shows which main diagnoses were classified efficient in each of the years. As it is seen from the table the main diagnosis T84.0 was classified efficient in all of the four years. Further, the main diagnoses K51.9, N20.0, and M05.9 were all classified efficient in three of the four years. C18.0, C50.9, K50.0, and T84.6 were all classified efficient in two of the four years. There were four main diagnoses that were only classified efficient in one of the four years; they were C50.4, E66.9, K43.9, and M17.1. The remaining diagnoses C18.2, K80.2, M16.1, M84.1, and T84.1 were classified efficient in none of the four years.

Further, from table 6.9 on the previous page it is seen that year 2008 had the highest amount of efficient main diagnoses, and 2006 had the lowest. Therefore, there were most inefficient main diagnoses in year 2006. In total it is seen that in all of the four years, the amount of inefficient main diagnoses always exceeds the amount of efficient main diagnoses.

In addition, a descriptive statistics was conducted. Table 6.10 below shows the results.

Results I - Descriptive statistics						
	Min	Max	Mean efficiency score	Mean inefficiency score	Stdev	Mean efficiency score for the inefficient
2006	73.7 %	100 %	90.4 %	9.6 %	9.3 %	86.4 %
2007	79.5 %	100 %	91.3 %	8.7 %	8.3 %	86.5 %
2008	81.4 %	100 %	93.7 %	6.3 %	7.3 %	88.1 %
2009	77.7 %	100 %	90.2 %	9.8 %	8.6 %	84.9 %

Table 6.10 Results I - Descriptive statistics

From table 6.10 it is seen that the mean efficiency score in all of the years is somewhat the same, though year 2008 has the highest score, 93.7 %. Therefore, the mean inefficiency scores are also somewhat the same, though year 2009 has the highest mean potential for improvement, 9.8 %. Further, the standard deviation is not high in any of the years, which indicates that the efficiency scores for the main diagnoses do not vary much from the mean efficiency score. In addition, the standard deviation in year 2008 is the lowest, 7.3 %, thus this year has the lowest variation in the efficiency scores for the main diagnoses. This is also seen by looking at the minimum value, year 2008 has the highest minimum value, 81.4 %. On the contrary, year 2006 has the lowest minimum value, 73.7 %, and thereby the highest standard deviation, 9.3 %. Thus, in year 2006 the variation in the efficiency scores for the main diagnoses is highest.

Finally, it is seen in table 6.10 that the mean efficiency scores for the inefficient main diagnoses do not vary much in the different years. Though, year 2008 shows the highest mean efficiency score for its inefficient main diagnoses, 88.1 %, whilst the year 2009 shows the lowest, 84.9 %.

Further, to get a better overview of how the mean efficiency score was in the different years, a scatter plot was made. Figure 6.5 below shows the scatter plot.

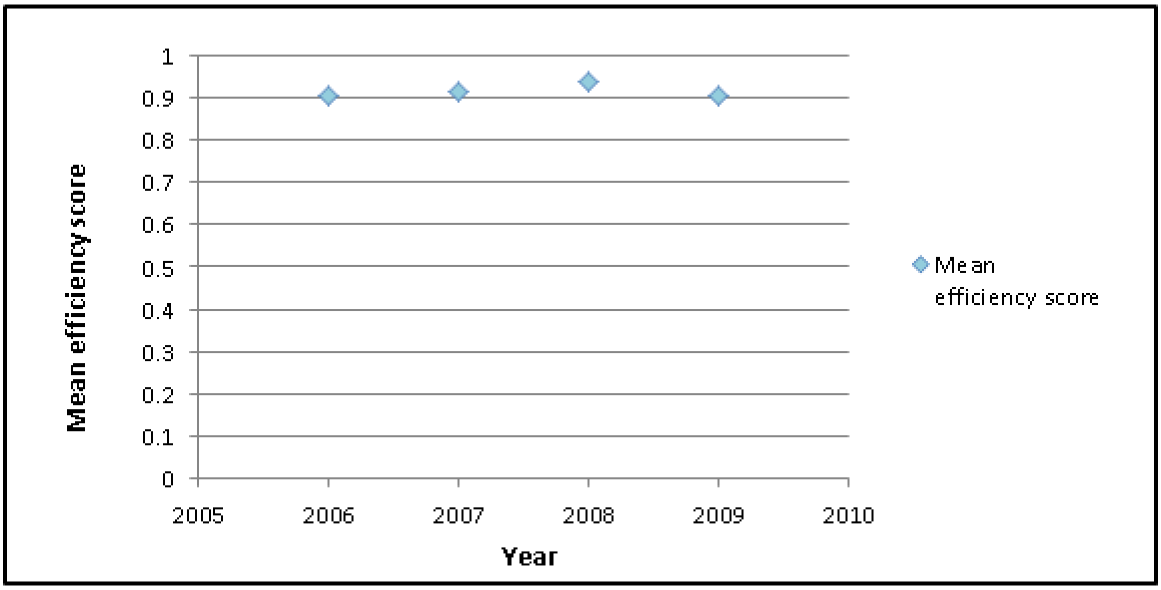

Figure 6.5 Results I - Mean efficiency scores

From figure 6.5 it is even clearer that the mean efficiency score in the different years has been much the same, and that year 2008 had the highest mean efficiency score.

6.2 Data Envelopment Analysis Results – II

II. ***How is the efficiency at the process level for each of the two departments separately in the years 2006 through 2009?***

6.2.1 DEA Results II – 2006

Department of Surgery

First, the efficiency scores for all of the main diagnoses concerning the Department of Surgery in year 2006 were found. Table 6.11 below shows the efficiency scores for all of these main diagnoses.

Department of Surgery 2006		
Main diagnosis	**Efficiency score**	**Inefficiency score**
C18.0	0.858	0.142
C18.2	0.791	0.209
C50.4	0.908	0.092
C50.9	0.928	0.072
E66.9	0.737	0.263
K43.9	1	0
K50.0	0.844	0.156
K51.9	1	0
K80.2	0.798	0.202
N20.0	0.995	0.005

Table 6.11 Efficiency scores for Department of Surgery 2006

From table 6.11 it is clear that 2 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 8 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.857 or 85.7 %. All the 8 inefficient main diagnoses have potential for improvement in different degrees. For instance C50.9 has the potential for improvement in efficiency of 0.072 or 7.2 %, whilst C18.0 has the potential for improvement in efficiency of 0.142 or 14.2 %.

Second, in order to get a better overview of the efficiency in 2006 for all of the main diagnoses in the Department of Surgery, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.6 below.

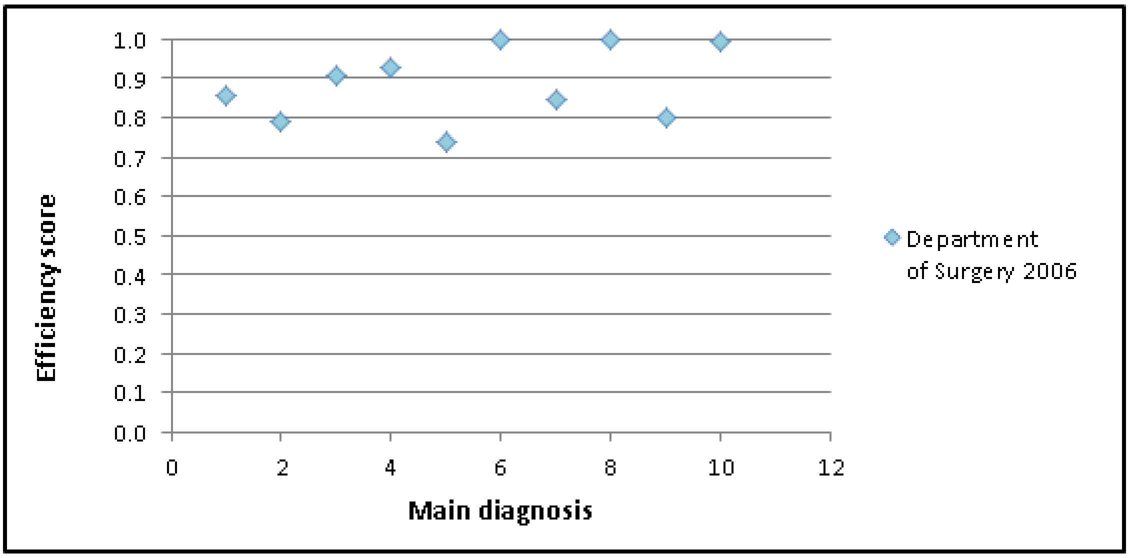

Figure 6.6 Efficiency scores for Department of Surgery 2006

From figure 6.6 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Surgery. The efficiency scores for all of the main diagnoses in 2006 are all located between 0.7 and 1 or 70 % and 100 %. From table 6.11 on the previous page, it is found that there are 2 efficient main diagnoses; these are shown in figure 6.6. In addition, the figure shows that there is 1 main diagnosis that is very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Surgery has been through year 2006, a descriptive statistics was made. The results are shown in table 6.12 below.

Department of Surgery 2006		
	Efficency	Inefficiency
Mean	0.886	0.114
Stdev	0.095	
95 % CI	0.886 ± (2 x 0.095)	
Min	0.737	
Max	1	

Table 6.12 Descriptive statistics for Department of Surgery 2006

As table 6.12 on the previous page shows, the mean efficiency for year 2006 was 0.886 or 88.6 %. This indicates that there is a mean improvement potential in efficiency of 0.114 or 11.4 %. The standard deviation is 0.095 or 9.5 % and gives a 95 % confidence interval of 0.886 ± (2 x 0.095). However, since the minimum value is 0.737 or 73.7 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Surgery.

Department of Orthopedic

First, the efficiency scores for all of the main diagnoses concerning the Department of Orthopedic in year 2006 were found. Table 6.13 below shows the efficiency scores for all of these main diagnoses.

Department of Orthopedic 2006		
Main diagnosis	**Efficiency score**	**Inefficiency score**
M05.9	1	0
M16.1	0.785	0.215
M17.1	1	0
M84.1	0.855	0.145
T84.0	1	0
T84.1	0.993	0.007
T84.6	0.882	0.118

Table 6.13 Efficiency scores for Department of Orthopedic 2006

From table 6.13 it is clear that 3 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 4 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.879 or 87.9 %. All the 4 inefficient main diagnoses have potential for improvement in different degrees. For instance T84.1 has the potential for improvement in efficiency of 0.7 %, whilst M16.1 has the potential for improvement in efficiency of 21.5 %.

Second, in order to get a better overview of the efficiency in 2006 for all of the main diagnoses in the Department of Orthopedic, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.7 below.

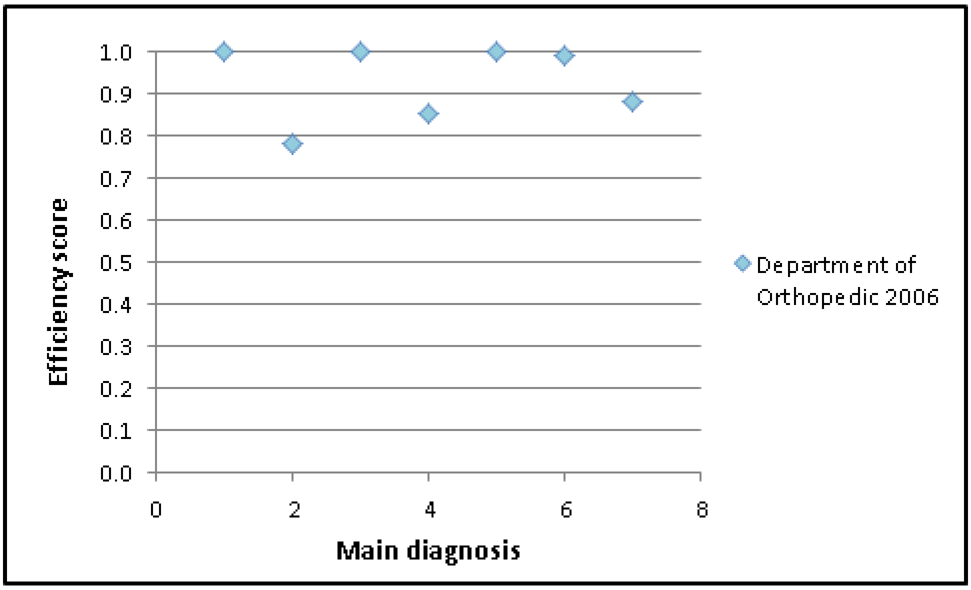

Figure 6.7 Efficiency scores for Department of Orthopedic 2006

From figure 6.7 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Orthopedic. The efficiency scores for all of the main diagnoses in 2006 are all located between approximately 0.8 and 1 or 80 % and 100 %. From table 6.13 on the previous page, it is found that there are 3 efficient main diagnoses; these are shown in figure 6.7. In addition, the figure shows that there is 1 main diagnosis that is very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Orthopedic has been through year 2006, a descriptive statistics was made. The results are shown in table 6.14 below.

Department of Orthopedic 2006		
	Efficency	Inefficiency
Mean	0.931	0.069
Stdev	0.089	
95 % CI	0.931 ± (2 x 0.089)	
Min	0.785	
Max	1	

Table 6.14 Descriptive statistics for Department of Orthopedic 2006

As table 6.14 on the previous page shows, the mean efficiency for year 2006 was 0.931 or 93.1 %. This indicates that there is a mean improvement potential in efficiency of 0.069 or 6.9 %. The standard deviation is 0.089 or 8.9 % and gives a 95 % confidence interval of 0.931 ± (2 x 0.089). However, since the minimum value is 0.785 or 78.5 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Orthopedic.

6.2.2 DEA Results II – 2007

Department of Surgery

First, the efficiency scores for all of the main diagnoses concerning the Department of Surgery in year 2007 were found. Table 6.15 below shows the efficiency scores for all of these main diagnoses.

Department of Surgery 2007		
Main diagnosis	Efficiency score	Inefficiency score
C18.0	1	0
C18.2	0.922	0.078
C50.4	1	0
C50.9	1	0
E66.9	0.853	0.147
K43.9	0.856	0.144
K50.0	0.917	0.083
K51.9	1	0
K80.2	0.828	0.172
N20.0	1	0

Table 6.15 Efficiency scores for Department of Surgery 2007

From table 6.15 it is clear that 5 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 5 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.875 or 87.5 %. All the 5 inefficient main diagnoses have potential for improvement in different degrees. For instance C18.2 has the potential for improvement in efficiency of 0.078 or 7.8 %, whilst K43.9 has the potential for improvement in efficiency of 0.144 or 14.4 %.

Second, in order to get a better overview of the efficiency in 2007 for all of the main diagnoses in the Department of Surgery, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.8 below.

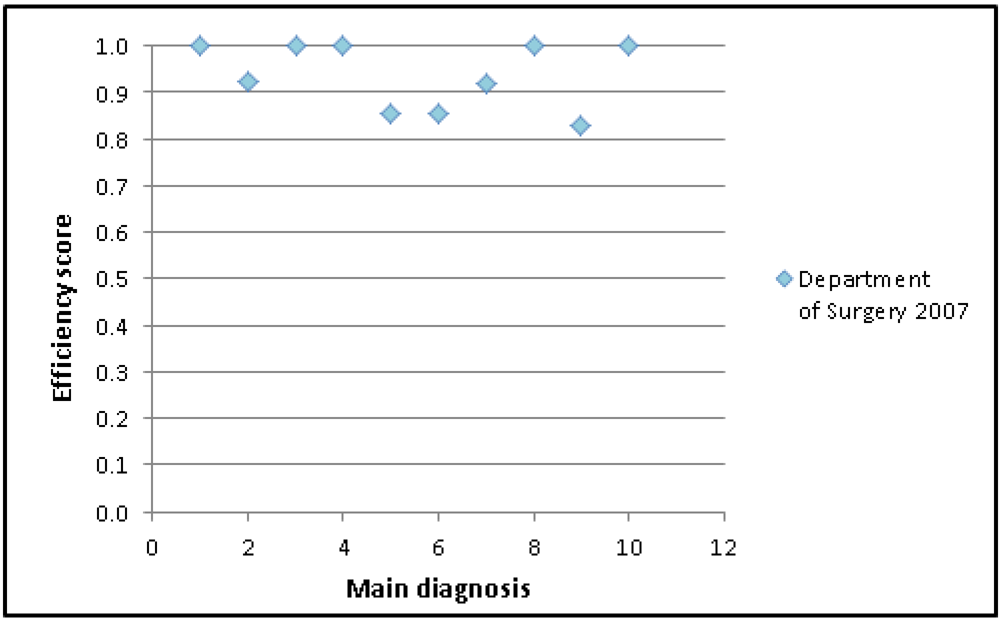

Figure 6.8 Efficiency scores for Department of Surgery 2007

From figure 6.8 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Surgery. The efficiency scores for all of the main diagnoses in 2007 are all located between 0.8 and 1 or 80 % and 100 %. From table 6.15 on the previous page, it is found that there are 5 efficient main diagnoses; these are shown in figure 6.8.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Surgery has been through year 2007, a descriptive statistics was made. The results are shown in table 6.16 below.

Department of Surgery 2007		
	Efficency	Inefficiency
Mean	0.938	0.062
Stdev	0.072	
95 % CI	0.938 ± (2 x 0.072)	
Min	0.828	
Max	1	

Table 6.16 Descriptive statistics for Department of Surgery 2007

As table 6.16 on the previous page shows, the mean efficiency for year 2007 was 0.938 or 93.8 %. This indicates that there is a mean improvement potential in efficiency of 0.062 or 6.2 %. The standard deviation is 0.072 or 7.2 % and gives a 95 % confidence interval of 0.938 ± (2 x 0.072). However, since the minimum value is 0.828 or 82.8 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Surgery.

Department of Orthopedic

First, the efficiency scores for all of the main diagnoses concerning the Department of Orthopedic in year 2007 were found. Table 6.17 below shows the efficiency scores for all of these main diagnoses.

Department of Orthopedic 2007		
Main diagnosis	**Efficiency score**	**Inefficiency score**
M05.9	0.954	0.046
M16.1	0.802	0.198
M17.1	0.801	0.199
M84.1	0.826	0.174
T84.0	1	0
T84.1	0.795	0.205
T84.6	0.964	0.036

Table 6.17 Efficiency scores for Department of Orthopedic 2007

From table 6.17 it is clear that 1 of the main diagnoses has efficiency score of 1 or 100 %, thus it is classified efficient. The remaining 6 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.857 or 85.7 %. All the 6 inefficient main diagnoses have potential for improvement in different degrees. For instance T84.1 has the potential for improvement in efficiency of 3.6 %, whilst M16.1 has the potential for improvement in efficiency of 19.8 %.

Second, in order to get a better overview of the efficiency in 2007 for all of the main diagnoses in the Department of Orthopedic, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.9 below.

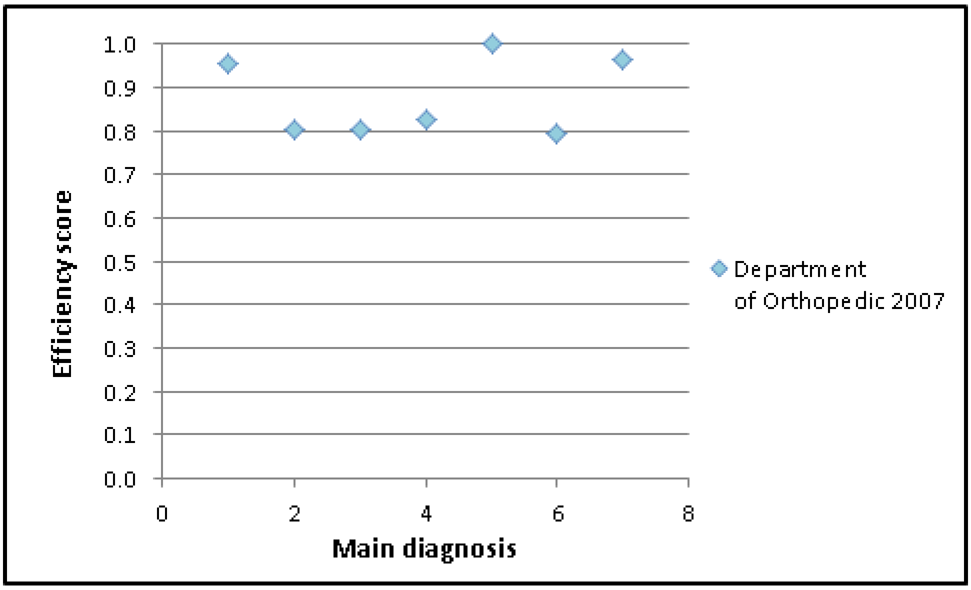

Figure 6.9 Efficiency scores for Department of Orthopedic 2007

From figure 6.9 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Orthopedic. The efficiency scores for all of the main diagnoses in 2007 are all located between approximately 0.8 and 1 or 80 % and 100 %. From table 6.17 on the previous page, it is found that there is 1 efficient main diagnosis; this is shown in figure 6.9. In addition, the figure shows that there are 2 main diagnoses that are very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Orthopedic has been through year 2007, a descriptive statistics was made. The results are shown in table 6.18 below.

Department of Orthopedic 2007		
	Efficency	Inefficiency
Mean	0.877	0.123
Stdev	0.091	
95 % CI	0.877 ± (2 x 0.091)	
Min	0.795	
Max	1	

Table 6.18 Descriptive statistics for Department of Orthopedic 2007

As table 6.18 on the previous page shows, the mean efficiency for year 2007 was 0.877 or 87.7 %. This indicates that there is a mean improvement potential in efficiency of 0.123 or 12.3 %. The standard deviation is 0.091 or 9.1 % and gives a 95 % confidence interval of 0.877 ± (2 x 0.091). However, since the minimum value is 0.795 or 79.5 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Orthopedic.

6.2.3 DEA Results II – 2008

Department of Surgery

First, the efficiency scores for all of the main diagnoses concerning the Department of Surgery in year 2008 were found. Table 6.19 below shows the efficiency scores for all of these main diagnoses.

Department of Surgery 2008		
Main diagnosis	Efficiency score	Inefficiency score
C18.0	0.845	0.155
C18.2	0.850	0.150
C50.4	0.988	0.012
C50.9	1	0
E66.9	1	0
K43.9	0.898	0.102
K50.0	1	0
K51.9	1	0
K80.2	0.814	0.186
N20.0	1	0

Table 6.19 Efficiency scores for Department of Surgery 2008

From table 6.19 it is clear that 5 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 5 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.879 or 87.9 %. All the 5 inefficient main diagnoses have potential for improvement in different degrees. For instance C50.4 has the potential for improvement in efficiency of 0.012 or 1.2 %, whilst C18.2 has the potential for improvement in efficiency of 0.150 or 15 %.

Second, in order to get a better overview of the efficiency in 2008 for all of the main diagnoses in the Department of Surgery, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.10 below.

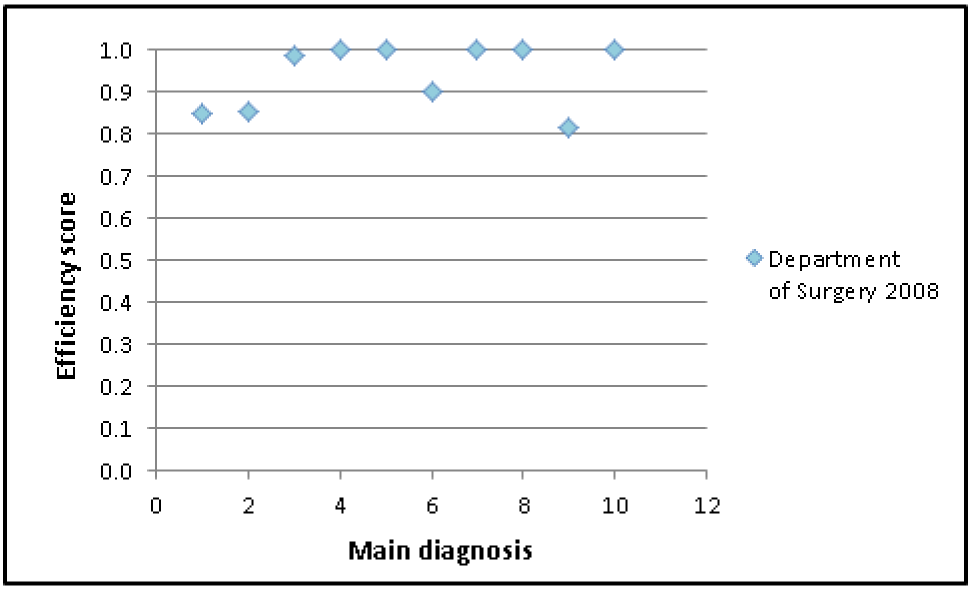

Figure 6.10 Efficiency scores for Department of Surgery 2008

From figure 6.10 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Surgery. The efficiency scores for all of the main diagnoses in 2008 are all located between 0.8 and 1 or 80 % and 100 %. From table 6.19 on the previous page, it is found that there are 5 efficient main diagnoses; these are shown in figure 6.10. In addition, the figure shows that there is 1 main diagnosis that is very close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Surgery has been through year 2008, a descriptive statistics was made. The results are shown in table 6.20 below.

Department of Surgery 2008		
	Efficency	Inefficiency
Mean	0.940	0.060
Stdev	0.078	
95 % CI	0.940 ± (2 x 0.078)	
Min	0.814	
Max	1	

Table 6.20 Descriptive statistics for Department of Surgery 2008

As table 6.20 on the previous page shows, the mean efficiency for year 2008 was 0.940 or 94 %. This indicates that there is a mean improvement potential in efficiency of 0.060 or 6 %. The standard deviation is 0.078 or 7.8 % and gives a 95 % confidence interval of 0.940 ± (2 x 0.078). However, since the minimum value is 0.814 or 81.4 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Surgery.

Department of Orthopedic

First, the efficiency scores for all of the main diagnoses concerning the Department of Orthopedic in year 2008 were found. Table 6.21 below shows the efficiency scores for all of these main diagnoses.

Department of Orthopedic 2008		
Main diagnosis	Efficiency score	Inefficiency score
M05.9	1	0
M16.1	0.901	0.099
M17.1	0.850	0.150
M84.1	0.845	0.155
T84.0	1	0
T84.1	0.938	0.062
T84.6	1	0

Table 6.21 Efficiency scores for Department of Orthopedic 2008

From table 6.21 it is clear that 3 of the main diagnoses have efficiency score of 1 or 100 %, thus it is classified efficient. The remaining 4 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.884 or 88.4 %. All the 4 inefficient main diagnoses have potential for improvement in different degrees. For instance M16.1 has the potential for improvement in efficiency of 0.099 or 9.9 %, whilst M84.1 has the potential for improvement in efficiency of 0.155 or 15.5 %.

Second, in order to get a better overview of the efficiency in 2008 for all of the main diagnoses in the Department of Orthopedic, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.11 below.

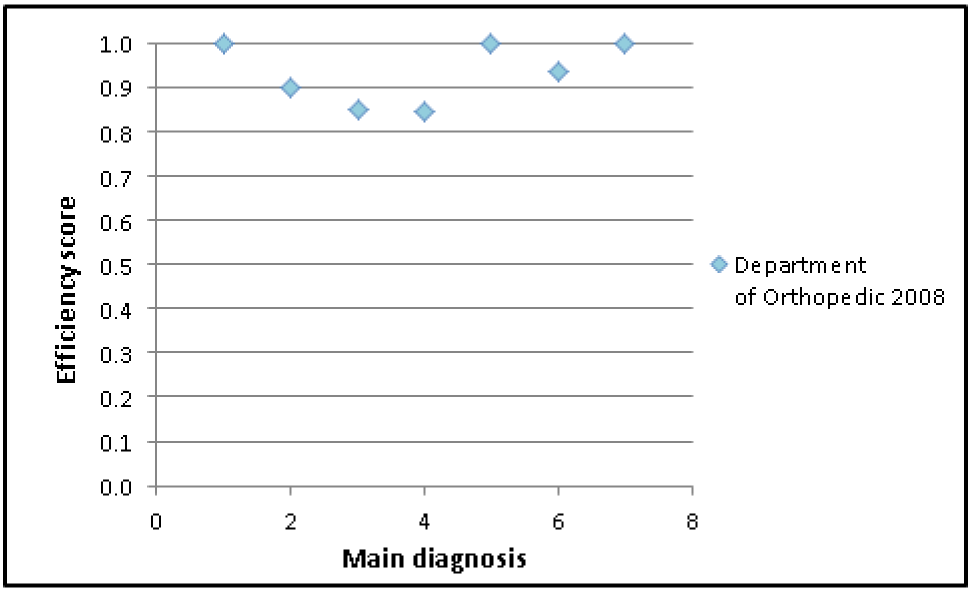

Figure 6.11 Efficiency scores for Department of Orthopedic 2008

From figure 6.11 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Orthopedic. The efficiency scores for all of the main diagnoses in 2008 are all located between 0.8 and 1 or 80 % and 100 %. From table 6.21 on the previous page, it is found that there are 3 efficient main diagnoses; these are shown in figure 6.11. In addition, the figure shows that there is 1 main diagnosis that is close to becoming efficient.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Orthopedic has been through year 2008, a descriptive statistics was made. The results are shown in table 6.22 below.

Department of Orthopedic 2008		
	Efficency	Inefficiency
Mean	0.934	0.066
Stdev	0.070	
95 % CI	0.934 ± (2 x 0.070)	
Min	0.845	
Max	1	

Table 6.22 Descriptive statistics for Department of Orthopedic 2007

As table 6.22 on the previous page shows, the mean efficiency for year 2008 was 0.934 or 93.4 %. This indicates that there is a mean improvement potential in efficiency of 0.066 or 6.6 %. The standard deviation is 0.070 or 7 % and gives a 95 % confidence interval of 0.934 ± (2 x 0.070). However, since the minimum value is 0.845 or 84.5 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Orthopedic.

6.2.4 DEA Results II – 2009

Department of Surgery

First, the efficiency scores for all of the main diagnoses concerning the Department of Surgery in year 2009 were found. Table 6.23 below shows the efficiency scores for all of these main diagnoses.

Department of Surgery 2009		
Main diagnosis	Efficiency score	Inefficiency score
C18.0	1	0
C18.2	0.781	0.219
C50.4	0.900	0.100
C50.9	0.917	0.083
E66.9	0.894	0.106
K43.9	0.893	0.107
K50.0	1	0
K51.9	0.807	0.193
K80.2	0.811	0.189
N20.0	1	0

Table 6.23 Efficiency scores for Department of Surgery 2009

From table 6.23 it is clear that 3 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 7 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.858 or 85.8 %. All the 7 inefficient main diagnoses have potential for improvement in different degrees. For instance C18.2 has the potential for improvement in efficiency of 0.021 or 2.1 %, whilst K51.9 has the potential for improvement in efficiency of 0.193 or 19.3 %.

Second, in order to get a better overview of the efficiency in 2009 for all of the main diagnoses in the Department of Surgery, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.12 below.

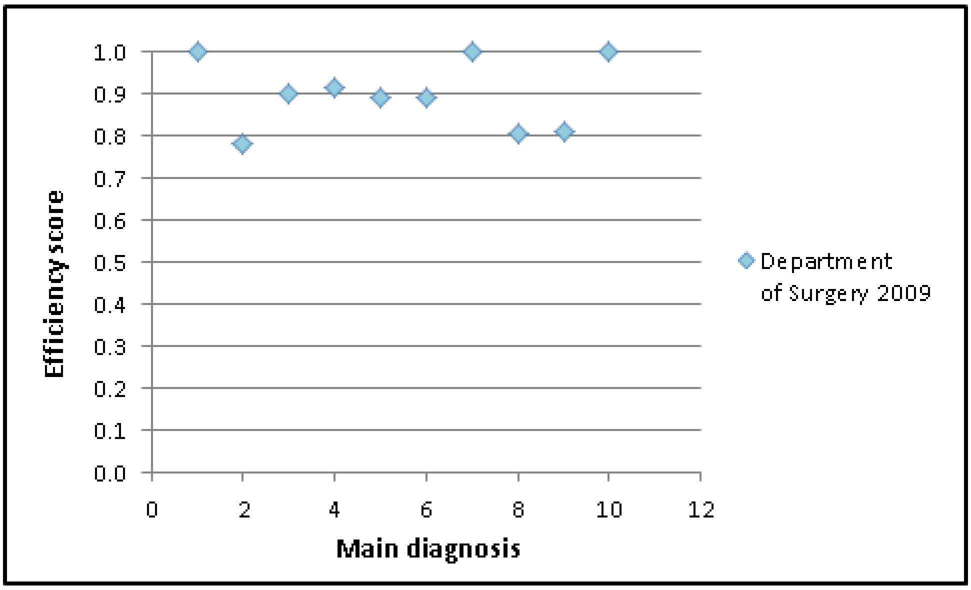

Figure 6.12 Efficiency scores for Department of Surgery 2009

From figure 6.12 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Surgery. The efficiency scores for all of the main diagnoses in 2009 are all located between approximately 0.8 and 1 or 80 % and 100 %. From table 6.23 on the previous page, it is found that there are 3 efficient main diagnoses; these are shown in figure 6.12.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Surgery has been through year 2009, a descriptive statistics was made. The results are shown in table 6.24 below.

Department of Surgery 2009		
	Efficency	**Inefficiency**
Mean	0.900	0.100
Stdev	0.082	
95 % CI	0.900 ± (2 x 0.082)	
Min	0.781	
Max	1	

Table 6.24 Descriptive statistics for Department of Surgery 2009

As table 6.24 on the previous page shows, the mean efficiency for year 2009 was 0.90 or 90 %. This indicates that there is a mean improvement potential in efficiency of 0.100 or 10 %. The standard deviation is 0.082 or 8.2 % and gives a 95 % confidence interval of 0.900 ± (2 x 0.082). However, since the minimum value is 0.781 or 78.1 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Surgery.

Department of Orthopedic

First, the efficiency scores for all of the main diagnoses concerning the Department of Orthopedic in year 2009 were found. Table 6.25 below shows the efficiency scores for all of these main diagnoses.

Department of Orthopedic 2009		
Main diagnosis	**Efficiency score**	**Inefficiency score**
M05.9	1	0
M16.1	0.777	0.223
M17.1	0.810	0.190
M84.1	0.841	0.159
T84.0	1	0
T84.1	0.902	0.098
T84.6	1	0

Table 6.25 Efficiency scores for Department of Orthopedic 2009

From table 6.25 it is clear that 3 of the main diagnoses have efficiency score of 1 or 100 %, thus they are classified efficient. The remaining 4 have efficiency scores lower than 1 or 100 %, thus they are classified inefficient. In addition, the mean efficiency score for the inefficient main diagnoses is 0.833 or 83.3 %. All the 4 inefficient main diagnoses have potential for improvement in different degrees. For instance T84.1 has the potential for improvement in efficiency of 0.098 or 9.8 %, whilst M16.1 has the potential for improvement in efficiency of 0.223 or 22.3 %.

Second, in order to get a better overview of the efficiency in 2009 for all of the main diagnoses in the Department of Orthopedic, a scatter plot of the efficiency scores was made. The scatter plot is shown in figure 6.13 below.

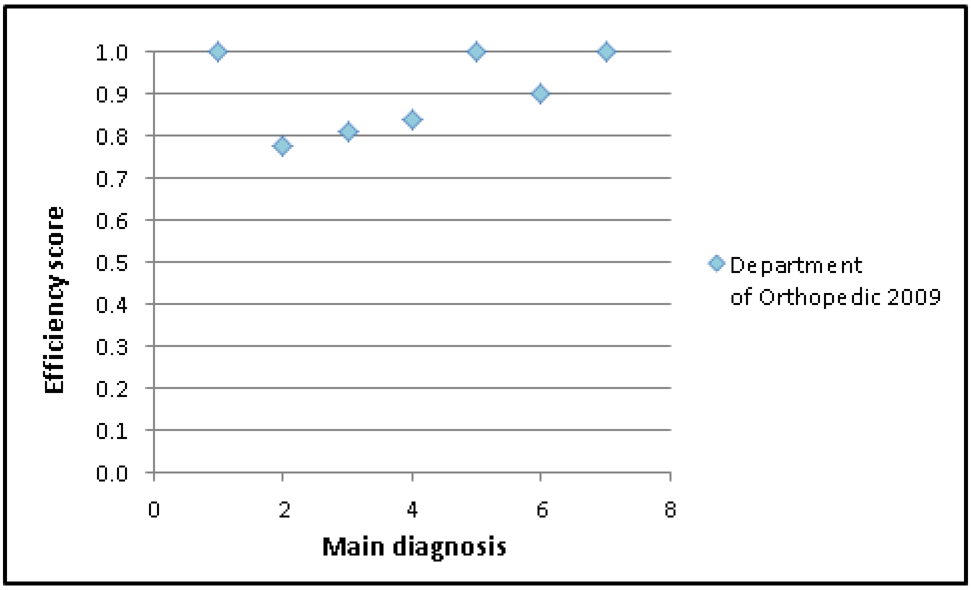

Figure 6.13 Efficiency scores for Department of Orthopedic 2009

From figure 6.13 it is seen that there is a variation in the efficiency of the different main diagnoses in the Department of Orthopedic. The efficiency scores for all of the main diagnoses in 2009 are all located between approximately 0.8 and 1 or 80 % and 100 %. From table 6.25 on the previous page, it is found that there are 3 efficient main diagnoses; these are shown in figure 6.13.

Third, in order to get an even better understanding of how the efficiency of the main diagnoses in the Department of Orthopedic has been through year 2009, a descriptive statistics was made. The results are shown in table 6.26 below.

Department of Orthopedic 2009		
	Efficency	Inefficiency
Mean	0.904	0.096
Stdev	0.097	
95 % CI	0.904 ± (2 x 0.097)	
Min	0.777	
Max	1	

Table 6.26 Descriptive statistics for Department of Orthopedic 2009

As table 6.26 on the previous page shows, the mean efficiency for year 2009 was 0.904 or 90.4 %. This indicates that there is a mean improvement potential in efficiency of 0.096 or 9.6 %. The standard deviation is 0.097 or 9.7 % and gives a 95 % confidence interval of 0.904 ± (2 x 0.097). However, since the minimum value is 0.777 or 77.7 % and is above the lower limit of the 95 % confidence interval, all of the main diagnoses (100 %) are within this interval. In addition, the standard deviation shows that there is a low degree of variation around the mean efficiency in the Department of Orthopedic.

6.2.5 DEA Results II – Summary

Department of Surgery

In order to get a better overview of the efficiency in the years 2006 through 2009 in the Department of Surgery, different summary tables and a scatter plot were made.

Table 6.9 below shows the summary regarding the DEA results II concerning the efficiency scores for all of the main diagnoses in the Department of Surgery.

Results II - Summary Department of Surgery				
Main diagnosis	2006	2007	2008	2009
C18.0	-	1	-	1
C18.2	-	-	-	-
C50.4	-	1	-	-
C50.9	-	1	1	-
E66.9	-	-	1	-
K43.9	1	-	-	-
K50.0	-	-	1	1
K51.9	1	1	1	-
K80.2	-	-	-	-
N20.0	-	1	1	1
Amount efficient	2	5	5	3
Amount inefficient	8	5	5	7

Table 6.27 Results II – Summary for Department of Surgery

Table 6.27 shows which main diagnoses within the Department of Surgery were classified efficient in each of the years. As seen in the table, none of the main diagnoses were classified efficient in all of the years. Further, the main diagnoses K51.9 and N20.0 were both classified efficient in three of the four years. C18.0, C50.9, and K50.0 were all classified efficient in two of the four years. There were three main diagnoses that were only classified efficient in one of the four years; they are C50.4, E66.9, and K43.9. The remaining diagnoses C18.2 and K80.2 were both classified efficient in none of the four years.

Further, from table 6.27 it is seen that the years 2007 and 2008 had the highest amount of efficient main diagnoses, and year 2006 had the lowest. Therefore, there were most inefficient main diagnoses in year 2006. In total, it is seen that for two of the years, 2006 and 2009, the amount of inefficient main diagnoses exceeds the amount of efficient main diagnoses, and for the two other years, 2007 and 2008, the amount of inefficient main diagnoses is equal to the amount of efficient main diagnoses.

In addition, a descriptive statistics was conducted. Table 6.28 below shows the results.

Results II - Descriptive statistics Department of Surgery						
	Min	Max	Mean efficiency score	Mean inefficiency score	Stdev	Mean efficiency score for the inefficient
2006	73.7 %	100 %	88.6 %	11.4 %	9.5 %	85.7 %
2007	82.8 %	100 %	93.8 %	6.2 %	7.2 %	87.5 %
2008	81.4 %	100 %	94 %	6 %	7.8 %	87.9 %
2009	78.1 %	100 %	90 %	10 %	8.2 %	85.8 %

Table 6.28 Results II - Descriptive statistics for Department of Surgery

From table 6.28 it is seen that the mean efficiency score in all of the years is somewhat the same, though year 2008 has the highest score, 94 %. Therefore, the mean inefficiency scores are also somewhat the same, though year 2006 has the highest mean potential for improvement, 11.4 %. Further, the standard deviation is not high in any of the years, which indicates that the efficiency scores for the main diagnoses do not vary much from the mean efficiency score. In addition, the standard deviation in year 2007 is the lowest, 7.2 %, thus this year has the lowest variation in the efficiency scores for the main diagnoses. This is also seen by looking at the minimum value, year 2007 has the highest minimum value, 82.8 %. On the contrary, year 2006 has the lowest minimum value, 73.7 %, and thereby the highest standard deviation, 9.5 %. Thus, in year 2006 the variation in the efficiency scores for the main diagnoses is highest.

Finally, it is seen in table 6.28 that the mean efficiency scores for the inefficient main diagnoses do not vary much in the different years. Though, year 2008 shows the highest mean efficiency score for its inefficient main diagnoses, 87.9 %, whilst year 2006 shows the lowest, 85.7 %.

Further, to get a better overview of how the mean efficiency score was in the different years, a scatter plot was made. Figure 6.14 below shows the scatter plot.

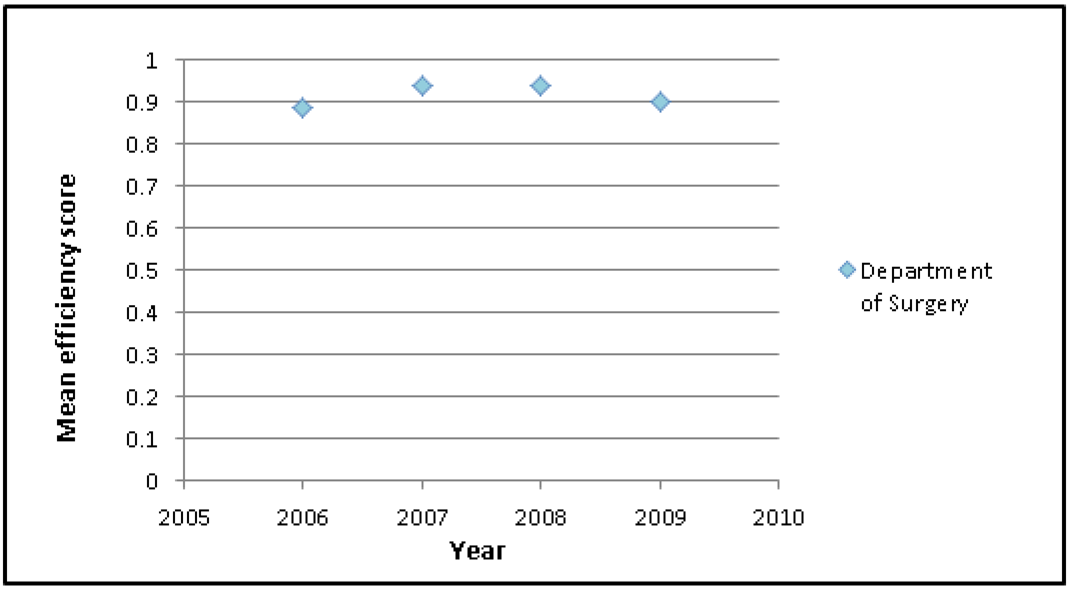

Figure 6.14 Results II - Mean efficiency scores for Department of Surgery

From figure 6.14 it is even clearer that the mean efficiency score in the different years has been somewhat the same. However, it is harder to see which of the years 2007 or 2008 has the highest mean efficiency score, though from table 6.28 on the previous page it is clear that year 2008 has the highest mean efficiency score.

Department of Orthopedic

In order to get a better overview of the efficiency in the Department of Orthopedic in the years 2006 through 2009, different summary tables and a scatter plot were made.

Table 6.29 below shows the summary regarding the DEA results II concerning the efficiency scores for all of the main diagnoses in the Department of Orthopedic.

Results II - Summary Department of Orthopedic				
Main diagnosis	2006	2007	2008	2009
M05.9	1	-	1	1
M16.1	-	-	-	-
M17.1	1	-	-	-
M84.1	-	-	-	-
T84.0	1	1	1	1
T84.1	-	-	-	-
T84.6	-	-	1	1
Amount efficient	3	1	3	3
Amount inefficient	4	6	4	4

Table 6.29 Results II – Summary for Department of Orthopedic

Table 6.29 shows which main diagnoses were classified efficient in each of the years. As seen in the table the main diagnosis T84.0 was classified efficient in all of the four years. Further, the main diagnosis M05.9 was classified efficient in three of the four years. T84.6 was classified efficient in two of the four years. There is one main diagnosis that was only classified efficient in one of the four years; it is M17.1. The remaining diagnoses M16.1, M84.1, and T84.1 were classified efficient in none of the four years.

Further, from table 6.29 it is seen that the years 2006, 2008, and 2009 had the highest amount of efficient main diagnoses, and year 2007 had the lowest. Therefore, there were most inefficient main diagnoses in year 2007. In total, it is seen that in all of the different years the amount of inefficient main diagnoses always exceed the amount of efficient main diagnoses.

In addition, a descriptive statistics was conducted. Table 6.30 below shows the results.

Results II - Descriptive statistics Department of Orthopedic						
	Min	Max	Mean efficiency score	Mean inefficiency score	Stdev	Mean efficiency score for the inefficient
2006	78.5 %	100 %	93.1 %	6.9 %	8.9 %	87.9 %
2007	79.5 %	100 %	87.7 %	12.3 %	9.1 %	85.7 %
2008	84.5 %	100 %	93.4 %	6.6 %	7.0 %	88.4 %
2009	77.7 %	100 %	90.4 %	9.6 %	9.7 %	83.3 %

Table 6.30 Results II - Descriptive statistics for Department of Orthopedic

From table 6.30 it is seen that the mean efficiency score in all of the years is somewhat the same, though year 2008 has the highest score, 93.4 %. Therefore, the mean inefficiency scores are also somewhat the same, though year 2007 has the highest mean potential for improvement, 12.3 %. Further, the standard deviation is not high in any of the years, which indicates that the efficiency scores for the main diagnoses do not vary much from the mean efficiency score. In addition, the standard deviation in year 2008 is the lowest, 7 %, thus this year has the lowest variation in the efficiency scores for the main diagnoses. This is also seen by looking at the minimum value, year 2008 has the highest minimum value, 84.5 %. On the contrary, year 2009 has the lowest minimum value, 77.7 %, and thereby the highest standard deviation, 9.7 %. Thus, in year 2009 the variation in the efficiency scores for the main diagnoses is highest.

Finally, it is seen in table 6.30 that the mean efficiency scores for the inefficient main diagnoses do not vary much in the different years. Though, year 2008 shows the highest mean efficiency score for its inefficient main diagnoses, 88.4 %, whilst year 2009 shows the lowest, 83.3 %.

Further, to get a better overview of how the mean efficiency score was in the different years, a scatter plot was made. Figure 6.15 below shows the scatter plot.

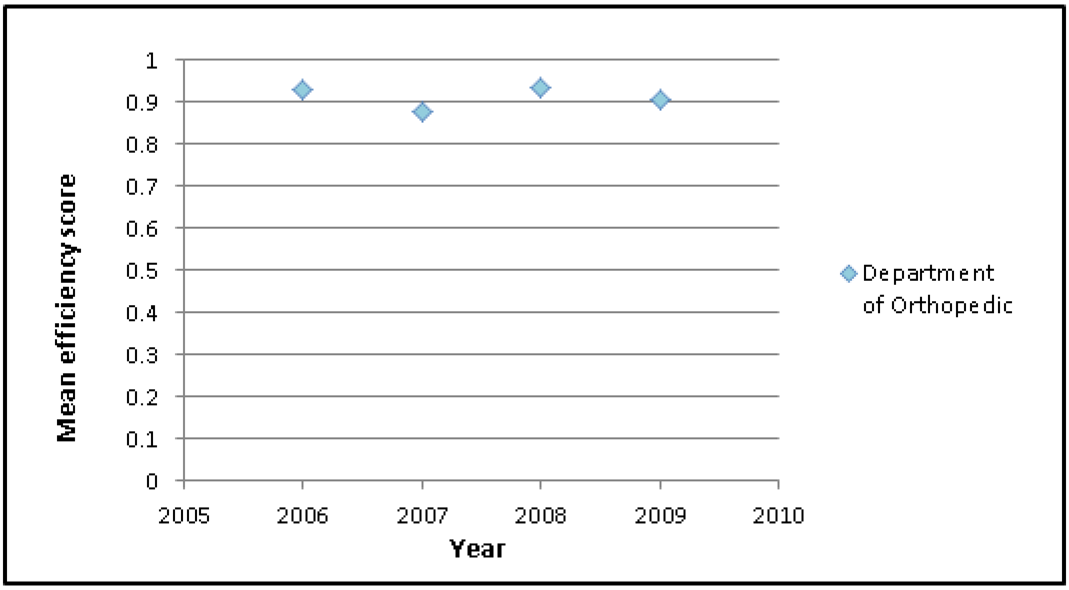

Figure 6.15 Results II - Mean efficiency scores for Department of Orthopedic

From figure 6.15 it is even clearer that the mean efficiency scores in the different years have been somewhat the same. However, it is harder to see which of the years 2006 or 2008 has the highest mean efficiency score, though from table 6.30 on the previous page it is clear that year 2008 has the highest mean efficiency score.

6.3 Data Envelopment Analysis Results – III

III. ***Is there evidence of any differences in the efficiency at the process level between the two departments in the years 2006 through 2009?***

6.3.1 DEA Results III – 2006

First, in order to see if there is any difference between the two departments Department of Surgery and Department of Orthopedic, a descriptive statistics was made. The results are shown in table 6.31 below.

Descriptive statistics 2006		
	Department of Surgery	Department of Orthopedic
Min	0.737	0.785
Max	1	1
Mean efficiency score	0.886	0.931
Mean inefficiency score	0.114	0.069
Stdev	0.095	0.089
Mean efficiency score for the inefficient	0.857	0.879

Table 6.31 Descriptive statistics 2006

From table 6.31 it is seen that there is a difference in the mean efficiency score between the two departments; the Department of Orthopedic has the highest score of 0.931 or 93.1 %. Naturally, there is a difference in the inefficiency scores as well, where the Department of Surgery has almost twice as much potential for improvement in efficiency as the Department of Orthopedic; the Department of Surgery has an improvement potential of 0.114 of 11.4 %, whilst the Department of Orthopedic has an improvement potential of 0.069 or 6.9 %.

Further, Department of Orthopedic has the lowest standard deviation of 0.089 or 8.9 % and the highest minimum of 0,785 or 78.5 %, which indicate that there is less variation in the Department of Orthopedic than in the Department of Surgery. In addition, the mean efficiency score for the inefficient main diagnoses in the Department of Orthopedic is higher, 0.879 or 87.9 %, than that of the Department of Surgery, 0.857 or 85.7 %. Thus, the inefficient main diagnoses in the Department of Orthopedic have higher efficiency scores, than those in the Department of Surgery.

Second, a scatter plot was made in order to get a better picture of any difference in the efficiency in the two departments Department of Surgery and Department of Orthopedic. Figure 6.16 below shows the scatter plot.

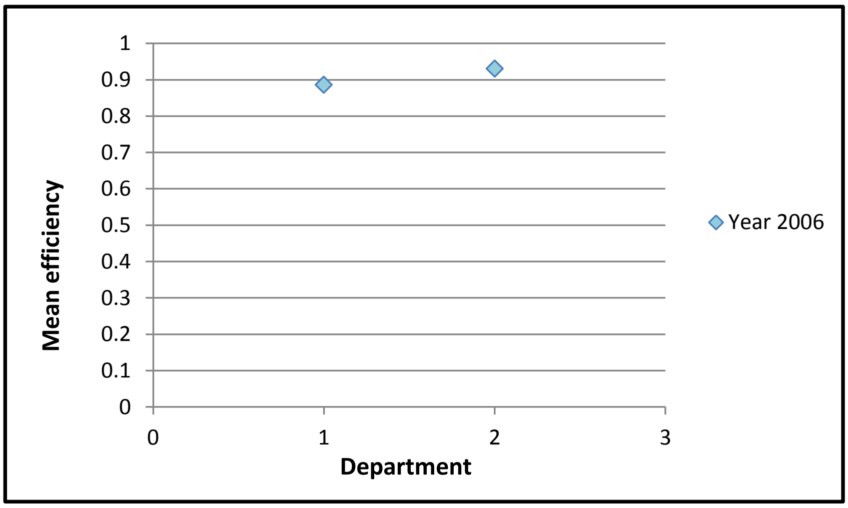

Figure 6.16 Mean efficiency scores 2006

In figure 6.16 the Department of Surgery is defined as department 1, whilst Department of Orthopedic is defined as department 2. From figure 6.16 it looks like there is a difference in the mean efficiency of the two departments, thus there could be a difference in the efficiency between the two departments.

Third, in order to clarify if there is a difference in the efficiency between the two departments, statistical tests were run. The results are shown in table 6.32 below.

Statistical tests 2006			
	Observed value	Critical value	Decision
F-test	1.135	4.099	Keep H0
T-test	-0.98	-2.135	Keep H0

Table 6.32 Statistical tests 2006

From table 6.32 it can be seen from the results regarding the F-test that there is no difference in the variance between the two departments. Further, the T-test shows that there is no difference in the mean efficiency scores between the two departments. Thus, there is no statistical difference in the efficiency between the two departments.

6.3.2 DEA Results III – 2007

First, in order to see if there is any difference between the two departments Department of Surgery and Department of Orthopedic, a descriptive statistics was made. The results are shown in table 6.33 below.

Descriptive statistics 2007		
	Department of Surgery	Department of Orthopedic
Min	0.828	0.795
Max	1	1
Mean efficiency score	0.938	0.877
Mean inefficiency score	0.062	0.123
Stdev	0.072	0.091
Mean efficiency score for the inefficient	0.875	0.857

Table 6.33 Descriptive statistics 2007

From table 6.33 it is seen that there is a difference in the mean efficiency score between the two departments; the Department of Surgery has the highest score of 0.938 or 93.8 %. Naturally, there is a difference in the inefficiency scores as well, where the Department of Orthopedic has almost twice as much potential for improvement in efficiency as the Department of Surgery; the Department of Orthopedic has an improvement potential of 0.123 or 12.3 %, whilst the Department of Surgery has an improvement potential of 0.062 or 6.2 %.

Further, Department of Surgery has the lowest standard deviation of 0.072 or 7.2 % and the highest minimum of 0.828 or 82.8 %, which indicate that there is less variation in the Department of Surgery than in the Department of Orthopedic. In addition, the mean efficiency score for the inefficient main diagnoses in the Department of Surgery is higher, 0.875 or 87.5 %, than that of the Department of Orthopedic, 0.857 or 85.7 %. Thus, the inefficient main diagnoses in the Department of Surgery have higher efficiency scores, than those in the Department of Orthopedic.

Second, a scatter plot was made in order to get a better picture of any difference in the efficiency in the two departments Department of Surgery and Department of Orthopedic. Figure 6.17 below shows the scatter plot.

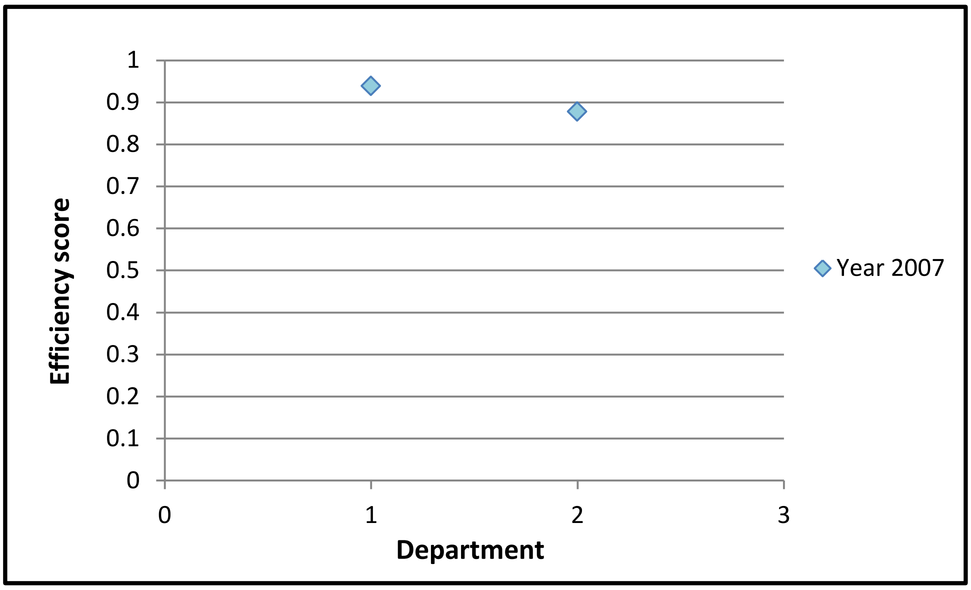

Figure 6.17 Mean efficiency scores 2007

In figure 6.17 the Department of Surgery is defined as department 1, whilst Department of Orthopedic is defined as department 2. From figure 6.17 it looks like there is a difference in the mean efficiency of the two departments, thus there could be a difference in the efficiency between the two departments.

Third, in order to clarify if there is a difference in the efficiency between the two departments, statistical tests were run. The results are shown in table 6.34 below.

Statistical tests 2007			
	Observed value	Critical value	Decision
F-test	0.624	0.296	Reject H0
T-test	1.463	2.201	Keep H0

Table 6.34 Statistical tests 2007

From table 6.34 it can be seen from the results regarding the F-test that there is a difference in the variance between the two departments. Further, the T-test shows that there is no difference in the mean efficiency scores between the two departments. Thus, there is no statistical difference in the efficiency between the two departments, since the T-test is based on the results in the F-test.

6.3.3 DEA Results III – 2008

First, in order to see if there is any difference between the two departments Department of Surgery and Department of Orthopedic, a descriptive statistics was made. The results are shown in table 6.35 below.

Descriptive statistics 2008		
	Department of Surgery	Department of Orthopedic
Min	0.814	0.845
Max	1	1
Mean efficiency score	0.940	0.934
Mean inefficiency score	0.060	0.066
Stdev	0.078	0.070
Mean efficiency score for the inefficient	0.879	0.884

Table 6.35 Descriptive statistics 2008

From table 6.35 it is seen that there is a slightly difference in the mean efficiency score between the two departments; the Department of Surgery has the highest score of 0.940 or 94 %. Naturally, there is a difference in the inefficiency scores as well, where the Department of Orthopedic has just a slightly more potential for improvement in efficiency than the Department of Surgery; the Department of Orthopedic has an improvement potential of 0.066 or 6.6 %, whilst the Department of Surgery has an improvement potential of 0.060 or 6 %.

Further, Department of Orthopedic has the lowest standard deviation of 0.070 or 7 % and the highest minimum of 0.845 or 84.5 %, which indicate that there is less variation in the Department of Orthopedic than in the Department of Surgery. In addition, the mean efficiency score for the inefficient main diagnoses in the Department of Orthopedic is higher, 0.884 or 88.4 %, than that of the Department of Surgery, 0.879 or 87.9 %. Thus, the inefficient main diagnoses in the Department of Orthopedic have higher efficiency scores, than those in the Department of Surgery.

Second, a scatter plot was made in order to get a better picture of any difference in the efficiency in the two departments Department of Surgery and Department of Orthopedic. Figure 6.18 below shows the scatter plot.

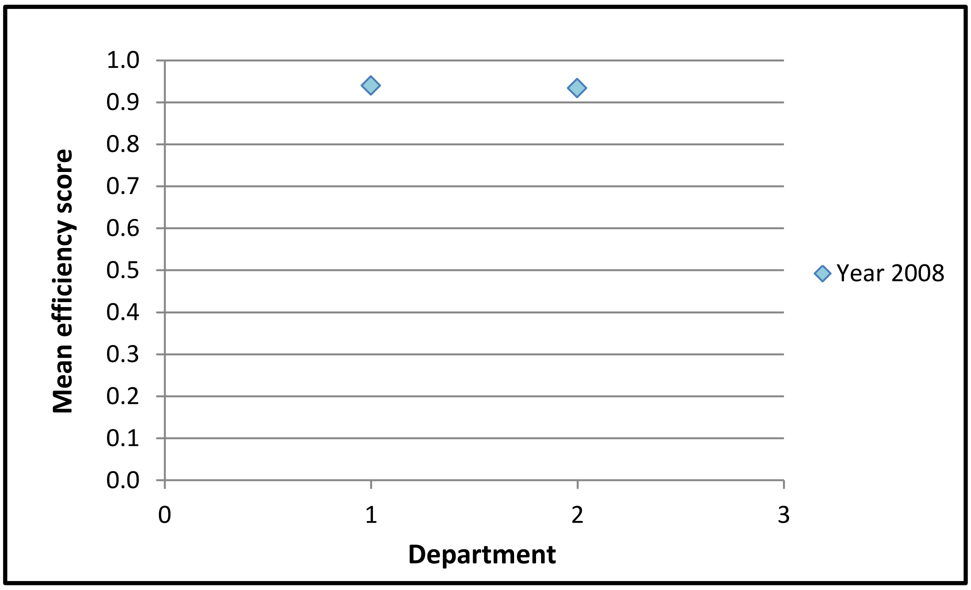

Figure 6.18 Mean efficiency scores 2008

In figure 6.18 the Department of Surgery is defined as department 1, whilst Department of Orthopedic is defined as department 2. From figure 6.18 it looks like there is a slightly difference in the mean efficiency of the two departments, thus there could be a difference in the efficiency between the two departments.

Third, in order to clarify if there is a difference in the efficiency between the two departments, statistical tests were run. The results are shown in table 6.36 below.

Statistical tests 2008			
	Observed value	Critical value	Decision
F-test	1.258	4.099	Keep H0
T-test	0.162	2.131	Keep H0

Table 6.36 Statistical tests 2008

From table 6.36 it can be seen from the results regarding the F-test that there is no difference in the variance between the two departments. Further, the T-test shows that there is no difference in the mean efficiency scores between the two departments. Thus, there is no statistical difference in the efficiency between the two departments.

6.3.4 DEA Results III – 2009

First, in order to see if there is any difference between the two departments Department of Surgery and Department of Orthopedic, a descriptive statistics was made. The results are shown in table 6.37 below.

Descriptive statistics 2009		
	Department of Surgery	Department of Orthopedic
Min	0.781	0.777
Max	1	1
Mean efficiency score	0.900	0.904
Mean inefficiency score	0.100	0.096
Stdev	0.082	0.097
Mean efficiency score for the inefficient	0.858	0.833

Table 6.37 Descriptive statistics 2009

From table 6.37 it is seen that there is a slightly difference in the mean efficiency score between the two departments; the Department of Orthopedic has the highest score of 0.904 or 90.4 %. Naturally, there is a difference in the inefficiency scores as well, where the Department of Surgery has a slightly more potential for improvement in efficiency than the Department of Orthopedic; the Department of Surgery has an improvement potential of 0.100 or 10 %, whilst the Department of Orthopedic has an improvement potential of 0.096 or 9.6 %.

Further, Department of Surgery has the lowest standard deviation of 0.082 or 8.2 % and the highest minimum of 0.781 or 78.1 %, which indicate that there is less variation in the Department of Surgery than in the Department of Orthopedic. In addition, the mean efficiency score for the inefficient main diagnoses in the Department of Surgery is higher, 0.858 or 85.8 %, than that of the Department of Orthopedic, 0.833 or 83.3 %. Thus, the inefficient main diagnoses in the Department of Surgery have higher efficiency scores, than those in the Department of Orthopedic.

Second, a scatter plot was made in order to get a better picture of any difference in the efficiency in the two departments Department of Surgery and Department of Orthopedic. Figure 6.19 below shows the scatter plot.

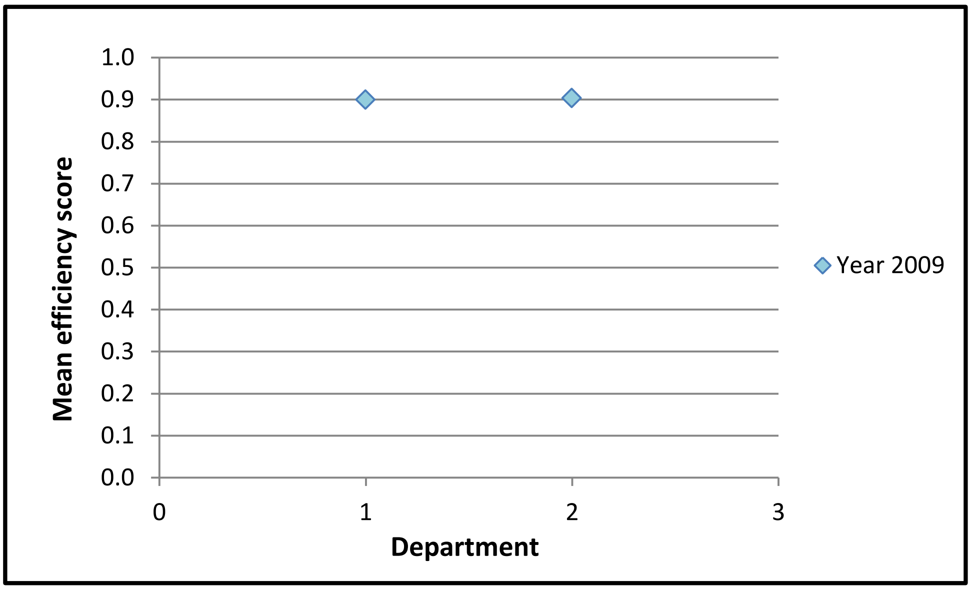

Figure 6.19 Mean efficiency scores 2009

In figure 6.19 the Department of Surgery is defined as department 1, whilst Department of Orthopedic is defined as department 2. From figure 6.19 it is difficult to see if there is a difference in the mean efficiency of the two departments, though there could be a difference in the efficiency between the two departments.

Third, in order to clarify if there is a difference in the efficiency between the two departments, statistical tests were run. The results are shown in table 6.38 below.

Statistical tests 2009			
	Observed value	**Critical value**	**Decision**
F-test	0.722	0.296	Reject H0
T-test	-0.091	-2.178	Keep H0

Table 6.38 Statistical tests 2009

From table 6.38 it can be seen from the results regarding the F-test that there is a difference in the variance between the two departments. Further, the T-test shows that there is no difference in the mean efficiency scores between the two departments. Thus, there is no statistical difference in the efficiency between the two departments, since the T-test is based on the results in the F-test.

6.3.5 DEA Results III – Summary

In order to see if there is a difference in the efficiency between the two departments in the four years, statistical tests were conducted for each of the years. The results are shown in table 6.39 below.

Results III - Summary				
	2006	**2007**	**2008**	**2009**
F-test	Keep H0	Reject H0	Keep H0	Reject H0
T-test	Keep H0	Keep H0	Keep H0	Keep H0
Conclusion	No difference	No difference	No difference	No difference

Table 6.39 Results III - Summary

From table 6.39 it is clear that no statistical differences between the two departments were found in any of the four years. Even though the F-test showed for the years 2007 and 2009 that there was a difference in the variance between the two departments.

6.4 Regression Analysis Results – IV

IV. In which degree is the efficiency at the process level for the two departments affected by external explanatory variables?

In chapter 5 Data, various assumptions in which degree and direction the efficiency is affected by the different external explanatory variables were made;

- ***Gender – Main diagnoses with a majority of males will be equally efficient as those with a majority of females***

- ***Age – Main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients***

- ***Degree of contamination – Main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination***

- ***Number of operation codes – Main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes***

In addition, the median knife-time is included as a control variable to check how comparable the DMUs are. It is desirable that RA results show the median knife-time to have no effect on the efficiency.

6.4.1 RA Results IV – 2006

In order to explore in which degree the external explanatory variables affect the efficiency of the main diagnoses at the two departments in year 2006, RA was made. The results are shown in table 6.40 below.

Regression analysis 2006				
Explanatory variable	**Coefficients**	**Standard error**	**t stat**	**p-value**
Gender	0.089	0.069	1.287	0.239
Age	-0.003	0.002	-1.146	0.289
Degree of contamination	0.079	0.065	1.220	0.262
Number of operation codes	-0.025	0.054	-0.466	0.655
Median knife-time	0.003	0.002	1.392	0.207

Table 6.40 Regression analysis 2006

From table 6.40 it is seen that gender has a coefficient of 0.089 and a t stat of 1.287. In addition, the p-value is 0.239. These results indicate that gender has a very low positive effect on inefficiency. Thus, there is a decrease in efficiency from males to females. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of males will be equally efficient as those with a majority of females" cannot be rejected.

When it comes to age it has a coefficient of -0.003 and a t stat of -1.146. In addition, the p-value is 0.289. Further, these results indicate that age has a negative effect, though almost not existent, on inefficiency. Thus, there is an increase in efficiency from young to old patients; the older the patient is, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients" cannot be rejected.

From table 6.40 it is seen that degree of contamination has a coefficient of 0.079 and a t stat of 1.220. In addition, the p-value is 0.262. These results indicate that degree of contamination has a very low positive effect on inefficiency. Thus, there is a decrease in efficiency from low to high degree of contamination. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination" cannot be rejected.

When it comes to the number of operation codes it has a coefficient of -0.025 and a t stat of -0.466. In addition, the p-value is 0.655. Further, these results indicate that number of operation codes has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from 1 operation code to more operation codes; the more operation codes the patient has, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes" cannot be rejected.

From table 6.40 on the previous page it is seen that median knife-time has a coefficient of 0.003 and a t stat of 1.392. In addition, the p-value is 0.207.This means that median knife-time has a positive effect, though almost not existent, on inefficiency. Thus, there is a decrease in efficiency from low to high median knife-time. However, this is not significant and seen from the t stat and p-value. Therefore, it can be assumed that the main diagnoses are comparable.

In addition, as seen from the low statistical values in attachment 8 for year 2006, the regression model is of low quality. For instance, the negative adjusted R^2 indicates a very poor model fit.

6.4.2 RA Results IV – 2007

In order to explore in which degree the external explanatory variables affect the efficiency of the main diagnoses at the two departments in year 2007, RA was made. The results are shown in table 6.41 below.

Regression analysis 2007				
Explanatory variable	Coefficients	Standard error	t stat	p-value
Gender	0.017	0.068	0.251	0.809
Age	-0.003	0.003	-0.979	0.360
Degree of contamination	-0.137	0.049	-2.811	0.026
Number of operation codes	-0.089	0.049	-1.819	0.112
Median knife-time	-0.002	0.002	-0.912	0.392

Table 6.41 Regression analysis 2007

From table 6.41 it is seen that gender has a coefficient of 0.017 and a t stat of 0.251. In addition, the p-value is 0.809. These results indicate that gender has a very low positive effect on inefficiency. Thus, there is a decrease in efficiency from males to females. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of males will be equally efficient as those with a majority of females" cannot be rejected.

When it comes to age it has a coefficient of -0.003 and a t stat of -0.979. In addition, the p-value is 0.360. Further, these results indicate that age has a negative effect, though almost not existent, on inefficiency. Thus, there is an increase in efficiency from young to old patients; the older the patient is, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients” cannot be rejected.

From table 6.41 on the previous page it is seen that degree of contamination has a coefficient of -0.137 and a t stat of -2.811. In addition, the p-value is 0.026.These results indicate that degree of contamination has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from low to high degree of contamination. In addition, this is significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination” is rejected***.***

When it comes to the number of operation codes it has a coefficient of -0.089 and a t stat of -1.819. In addition, the p-value is 0.112. Further, these results indicate that number of operation codes has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from 1 operation code to more operation codes; the more operation codes the patient has, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes” cannot be rejected.

From table 6.41 on the previous page it is seen that median knife-time has a coefficient of -0.002 and a t stat of -0.912. In addition, the p-value is 0.392.These results indicate that median knife-time has a negative effect, though almost not existent, on inefficiency. Thus, there is an increase in efficiency from low to high median knife-time. However, this is not significant as seen from the t stat and p-value. Therefore, it can be assumed that the main diagnoses are comparable.

In addition, as seen from the low statistical values in attachment 8 for year 2007, the regression model is of low quality. For instance, the very low adjusted R^2 indicates a poor model fit.

6.4.3 RA Results IV – 2008

In order to explore in which degree the external explanatory variables affect the efficiency of the main diagnoses at the two departments in year 2008, RA was made. The results are shown in table 6.42 below.

Regression analysis 2008				
Explanatory variable	Coefficients	Standard error	t stat	p-value
Gender	-0.037	0.057	-0.655	0.534
Age	0.001	0.002	0.582	0.579
Degree of contamination	-0.025	0.043	-0.573	0.584
Number of operation codes	-0.014	0.049	-0.296	0.776
Median knife-time	0	0.002	-0.176	0.866

Table 6.42 Regression analysis 2008

From table 6.42 it is seen that gender has a coefficient of -0.037 and a t stat of -0.655. In addition, the p-value is 0.534. These results indicate that gender has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from males to females. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of males will be equally efficient as those with a majority of females" cannot be rejected.

When it comes to age it has a coefficient of 0.001 and a t stat of 0.582. In addition, the p-value is 0.579. Further, these results indicate that age has a positive effect, though almost not existent, on inefficiency. Thus, there is a decrease in efficiency from young to old patients; the older the patient is, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients" cannot be rejected.

From table 6.42 it is seen that degree of contamination has a coefficient of -0.025 and a t stat of -0.573. In addition, the p-value is 0.584. These results indicate that degree of contamination has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from low to high degree of contamination. However, this is not significant as seen from the t stat and p-value. So, the assumption that "main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination" cannot be rejected.

When it comes to the number of operation codes it has a coefficient of -0.014 and a t stat of -0.296. In addition, the p-value is 0.776. Further, these results indicate that number of operation codes has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from 1 operation code to more operation codes; the more operation codes the patient has, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes” cannot be rejected.

From table 6.42 on the previous page it is seen that median knife-time has a coefficient of 0 and a t stat of -0.176. In addition, the p-value is 0.866. These results indicate that median knife-time has a negative effect, though not existent, on inefficiency. Thus, there is an increase in efficiency from low to high median knife-time. However, this is neither significant as seen from the t stat and p-value, nor present. Therefore, it can be assumed that the main diagnoses are comparable.

In addition, as seen from the low statistical values in attachment 8 for year 2008, the regression model is of low quality. For instance, the negative adjusted R^2 indicates a very poor model fit.

6.4.4 RA Results IV – 2009

In order to explore in which degree the external explanatory variables affect the efficiency of the main diagnoses at the two departments in year 2009, RA was made. The results are shown in table 6.43 below.

Regression analysis 2009				
Explanatory variable	**Coefficients**	**Standard error**	**t stat**	**p-value**
Gender	-0.029	0.090	-0.321	0.758
Age	-0.002	0.002	-0.831	0.434
Degree of contamination	-0.151	0.083	-1.815	0.112
Number of operation codes	-0.095	0.057	-1.688	0.135
Median knife-time	0	0.002	0.044	0.966

Table 6.43 Regression analysis 2009

From table 6.43 it is seen that gender has a coefficient of -0.029 and a t stat of -0.321. In addition, the p-value is 0.758. These results indicate that gender has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from males to females. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a majority of males will be equally efficient as those with a majority of females” cannot be rejected.

When it comes to age it has a coefficient of -0.002 and a t stat of -0.831. In addition, the p-value is 0.434. Further, these results indicate that age has a negative effect, though almost not existent, on inefficiency. Thus, there is an increase in efficiency from young to old patients; the older the patient is, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients” cannot be rejected.

From table 6.43 on the previous page it is seen that degree of contamination has a coefficient of -0.151 and a t stat of -1.815. In addition, the p-value is 0.112.These results indicate that degree of contamination has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from low to high degree of contamination. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination” cannot be rejected***.***

When it comes to the number of operation codes it has a coefficient of -0.095 and a t stat of -1.688. In addition, the p-value is 0.135. Further, these results indicate that number of operation codes has a very low negative effect on inefficiency. Thus, there is an increase in efficiency from 1 operation code to more operation codes; the more operation codes the patient has, the more efficient the surgical procedure is. However, this is not significant as seen from the t stat and p-value. So, the assumption that “main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes” cannot be rejected.

From table 6.43 on the previous page it is seen that median knife-time has a coefficient of 0 and a t stat of 0.044. In addition, the p-value is 0.966.These results indicate that median knife-time has a positive effect, though not excitant, on inefficiency. Thus, there is a decrease in efficiency from low to high median knife-time. However, this is neither significant as seen from the t stat and p-value, nor present. Therefore, it can be assumed that the main diagnoses are comparable.

In addition, as seen from the low statistical values in attachment 8 for year 2009, the regression model is of low quality. For instance, the very low adjusted R^2 indicates a poor model fit.

6.4.5 RA Results IV – Summary

In order to get a better overview of how the external explanatory variables affect the efficiency in the different years, the conclusions from the RA results are gathered in a summary in table 6.44 below.

Results IV - Summary				
	2006		2007	
Gender	Not significant	Negative effect on efficiency	Not significant	Negative effect on efficiency
Age	Not significant	Positive effect on efficiency	Not significant	Positive effect on efficiency
Degree of contamination	Not significant	Negative effect on efficiency	Significant	Positive effect on efficiency
Number of operation codes	Not significant	Positive effect on efficiency	Not significant	Positive effect on efficiency
Median knife-time	Not significant	Negative effect on efficiency	Not significant	Positive effect on efficiency
	2008		2009	
Gender	Not significant	Positive effect on efficiency	Not significant	Positive effect on efficiency
Age	Not significant	Negative effect on efficiency	Not significant	Positive effect on efficiency
Degree of contamination	Not significant	Positive effect on efficiency	Not significant	Positive effect on efficiency
Number of operation codes	Not significant	Positive effect on efficiency	Not significant	Positive effect on efficiency
Median knife-time	Not significant	Positive effect on efficiency	Not significant	Negative effect on efficiency

Table 6.44 Results IV – Summary

In general, all of the external explanatory variables had very low effects (in either direction) on efficiency in all of the years. The external explanatory variable degree of contamination had the highest value of -0.151 for year 2009, which shows that the efficiency is not much affected by degree of contamination.

From table 6.44 it is seen that gender has a negative effect on efficiency in the years 2006 and 2007,whilst the years 2008 and 2009 shows that gender has a positive effect on efficiency. Though, the effect is not significant in any of the years. Thus, the assumption that “main diagnoses with a majority of males will be equally efficient as those with a majority of females” cannot be rejected.

Further, it is seen that age has a positive effect on efficiency in all years except 2008. Though, the effect is not significant in any of the years. Thus, the assumption that "main diagnoses with a majority of old patients will be less efficient than those with a majority of young patients" cannot be rejected.

Degree of contamination has a positive effect on efficiency in all years except 2006. Though, the effect is only significant in year 2007. Thus, the assumption that "main diagnoses with a majority of surgical procedures with higher degree of contamination will be less efficient than those with a majority of lower degree of contamination" can only be rejected for one of the four years.

Number of operation codes is shown to have a positive effect on efficiency in all of the years. However, the effects are not significant in any of the years. Thus, the assumption that "main diagnoses with a higher number of operation codes are less efficient than those with a lower number of operation codes" cannot be rejected.

From table 6.44 on the previous page it is seen that median knife-time has a negative effect on efficiency in the years 2006 and 2009,whilst the years 2007 and 2008 shows that median knife-time has a positive effect on efficiency. Though, the effect is not significant in any of the years. Therefore, it can be assumed that the main diagnoses are comparable.

In addition, the RA results showed that the regression model was of low quality and a poor fit in all of the years.

Chapter 7 Discussion

In this chapter there is three discussion parts. First in section 7.1, Part I, the DEA and RA results concerning the different research questions will be discussed. Second, in section 7.2, Part II, the choices made, and difficulties and limitations with DEA and RA will be discussed. Third, and last, in section 7.3, Part III, the main research question will be discussed, in which it will be emphasized on which variables might be ideal for DEA at a process level.

7.1 Part I

The study of Linna, Häkkinen, Peltola, Magnussen, Anthun, Kittelsen, Roed, Olsen, Medin, and Rehnberg (2010) found that hospitals in Norway had efficiency scores between 75 % and 80 % in 2002. From this it was expected that the efficiency scores for the main diagnoses studied would perhaps be somewhat at the same level, given that the sample studied is representative for the main diagnoses at St. Olavs Hospital.

7.1.1 Discussion of Result I

Result I concerned the research question;

I. How is the combined efficiency at the process level for the two departments Department of Surgery and Department of Orthopedic at St. Olavs Hospital in the years 2006 through 2009?

The mean efficiency score in each of the years 2006 to 2009 was quite high; between 90.2 % and 93.7%. This indicates that the efficiency of the main diagnoses has been high. The lowest efficiency score found was in year 2006, and it was no lower than 73.7%. In addition, it was found that there was low variation between the main diagnoses. The inefficiency of the main diagnoses is quite low, and so perhaps not many changes need to be done in order to improve, and become 100 % efficient. In addition, since the efficiency has shown to be high, it seems that St. Olavs Hospital has utilized their resources well.

However, even though the results show high efficiency through the years it does not necessarily mean that the main diagnoses really are as efficient. One reason being that the efficiency scores are based on a small and specific sample of main diagnoses. If main diagnoses from other departments were to be included as well, perhaps the main diagnoses would come out less efficient. Also, if the main diagnoses were compared with the same main diagnoses at other hospitals, they could come out less efficient as well. In addition, the procedure when using DEA at the process level and the available data may have resulted in unreliable and overstated efficiency scores.

In order to obtain a best possible picture of how the efficiency really is a much larger sample should be gathered and several hospitals should be involved. In addition, DEA at a process level needs to be explored even more in order to get the best possible solution for how to measure efficiency at such a level. Therefore, the efficiency results obtained for St. Olavs Hospital must not be taken too literally, and further decisions should not be taken based on these results alone. Hence, the obtained efficiency results in this master thesis are perhaps not reliable, thus not of high value.

However, the real efficiency scores for the main diagnoses will probably never be found. Since DEA always calculates one performer or more in the sample as efficient (100 %), and most likely no surgical procedure is 100 % efficient and could be classified efficient. For example when a patient gets anesthesia the whole surgical team is waiting for the patient to go to sleep so they can start the surgery. For some of the staff this waiting time might be used more efficiently. This may also be the case for the technical assistants, they may have to wait for the patient to wake up before they could clean and set up the operating theatre. Therefore, in hospitals waiting time is not always seen as being inefficient use of time, and waste.

7.1.2 Discussion of Result II

Result II concerned the research question;

II. How is the efficiency at the process level for each of the two departments separately in the years 2006 through 2009?

The mean efficiency score in the Department of Surgery was quite high in all of the years 2006 to 2009; between 88.6 % and 94 %. This indicates that the efficiency of the main diagnoses at the Department of Surgery has been high. The lowest efficiency score found was in year 2006, and it was no lower than 73.7%. In addition, it was found that there was low variation between the main diagnoses. The inefficiency of the main diagnoses is quite low, and so perhaps not many changes need to be done in order to improve, and for the main diagnoses within the Department of Surgery to become 100 % efficient. In addition, since the efficiency has shown to be high, it seems that the Department of Surgery has utilized their resources well.

The mean efficiency score in the Department of Orthopedic was quite high in all of the years 2006 to 2009; between 87.7 % and 93.4 %. This indicates that the efficiency of the main diagnoses at the

Department of Orthopedic has been high. The lowest efficiency score found was in year 2009, and it was no lower than 77.7%. In addition, it was found that there was low variation between the main diagnoses. The inefficiency of the main diagnoses is quite low, and so perhaps not much changes needs to be done in order to improve, and for the main diagnoses within the Department of Orthopedic to become 100 % efficient. In addition, since the efficiency has shown to be high, it seems that the Department of Orthopedic has utilized their resources well.

The efficiency was found to be high in both of the two departments, however as mentioned in section 7.1.1 Result I the efficiency may not be correct for several reasons, and then perhaps the efficiency results obtained in this master thesis are perhaps not reliable, thus not of high value.

7.1.3 Discussion of Result III

Result III concerned the research question;

III. Is there evidence of any differences in the efficiency at the process level between the two departments in the years 2006 through 2009?

No statistical differences in the efficiency between the two departments were found in the different years. However, there was proven to be a variation in the two departments' efficiency scores in the years 2007 and 2009. From this it is implied that the two departments utilize their resources equally well.

Though, if the sample studied had been larger and other variables had been available, the results may have shown a difference between the two departments. Also, if the two departments were compared with the same departments at other hospitals, the results may have shown a difference. However, in general the efficiency of main diagnoses independent of department is most likely somewhat the same as the results show for the 17 DMUs studied, and so even though a larger sample or other variables were to be included the results might not show any differences.

7.1.4 Discussion of Result IV

Result IV concerned the research question;

IV. In which degree is the efficiency at the process level for the two departments affected by external explanatory variables in the years 2006 through 2009?

The RA concerning the external explanatory variables gender, age, degree of contamination, and number of operation codes, and the control variable median knife-time showed somewhat varying results.

Concerning gender, age, number of operation codes, and median knife-time there were found no significant effects on efficiency in any of the years. Therefore, the assumptions made for these external explanatory variables cannot be rejected. It is neither proven if the assumptions are wrong nor right, and thereby the assumptions must be kept.

Concerning the degree of contamination it showed a significant result in year 2007. It was found that it had a significant positive effect on the efficiency. However, since three of four years showed not significant results, it is not clear if the assumption for the external explanatory variable is wrong or right. Therefore, the assumption is kept until it is more strongly proven otherwise.

Finally, the RA results showed that the external explanatory variables did not affect the efficiency in any direction in any drastic way. The coefficients for all of the external explanatory variables in all of the years were very low. This may indicate that the external explanatory variables are not the main cause of the inefficiency of the main diagnoses, which was also shown by the statistical values. The statistical values showed that the regression model was of low quality and a poor fit in all of the years. Therefore, the RA results are not fully reliable, and so if the RA was conducted in a different way the results may have shown that the external explanatory variables cause inefficiency after all. Though, there may be other external explanatory variables that cause inefficiency as well.

7.2 Part II

In this part the choices made concerning DEA, and the difficulties and limitations encountered with DEA, will be discussed. In addition, the difficulties with RA will be discussed.

7.2.1 Data Envelopment Analysis

Exploring hospital DEA at a process level has been challenging because of no prior studies regarding this. Problems appeared at different stages, which led to time-consuming re-calculations.

Decision Making Unit

Two different types of DMUs were evaluated in section 5.1.1 The selection process – step 1; main diagnoses and patients. Though, it was quickly found that the best DMU to study and that would bring the most value was main diagnoses.

Further, the process of making the DMUs as comparable as possible has been done as good as possible with our knowledge. However, the criterion that the main diagnoses had to contain 50 or more surgical procedures (in-patients) should perhaps have been lower in order to capture more of the main diagnoses. In hospitals there are numerous different main diagnoses, and therefore many of them just contain a few surgical procedures (in-patients). However, if the criterion was lowered perhaps the DMUs would have been less comparable. A main diagnosis that is conducted often may be more efficient than a main diagnosis conducted seldom.

In addition, the time interval concerning median knife-time, 80 to 120 minutes, should perhaps have been shorter in order to maximize the comparability. Though, the RA results show that the median knife-time did not affect the efficiency, however the statistical values in RA showed that the regression models are of low quality and a poor fit in all of the years. Also, to only use the median knife-time as criterion for complexity is perhaps not enough. In addition to the median knife-time, it may be beneficial to range the different main diagnoses according to the complexity of what is performed.

To include the surgical procedures (in-patients) with knife-time 0 minutes and other low values may have resulted in skewed efficiency results. Thereby, these surgical procedures (in-patients) should perhaps have been excluded, since a low knife-time value may imply that the surgical procedure was not completed. However, there were only 9 out of 2 312 surgical procedures with knife-time of 0, and so to include them has perhaps not skewed the efficiency results drastically after all.

Some of the main diagnoses might have been technologically improved much more than others and thereby are distinct, and to include them may have been wrong and made a skewed picture of the efficiency. For example the main diagnosis T84.0, which was mentioned to be a possible outlier, was shown to be efficient (100 %) in all of the four years, perhaps this is a main diagnosis that should not have been included.

Even though choices were made in order to make the DMUs as comparable as possible with the available data set, the question of comparability may still be present. Other variables must most likely be included in order to strengthen the comparability, and thus get a more correct picture of how the efficiency is.

Input and Output

There were limited options of variables that could be defined as output in the data set, when the main diagnoses were chosen as DMUs. The only output option possible was the one chosen; number of in-patients. However, as this has been defined as output in several prior hospital DEA studies this was not seen as a problem. Though, if other variables were available in the data set, perhaps other or additional output variables would have been chosen. This might strengthen the results since the results then would rely on more data.

Concerning the inputs there were a few options to choose from in the data set after the output was defined. The main variables that affect the output were chosen; time and staff. From the data set it was clear that it was the two variables that would explain the output the best; in addition staff has been frequently used as an input in prior hospital DEA studies. Though, if other variables were available in the data set, perhaps other or additional input variables would have been chosen. This might strengthen the results since the results then would rely on more data.

Orientation

The choice of using an input orientation is justified by several reasons. Hospitals tend to have more control over their inputs than their outputs. They focus on utilizing their resources in the best possible way, and their situation make them focused on making savings. In addition, the majority of prior hospital DEA studies has used input orientation. Though, if the situation were to be different as if hospitals could market themselves and focus on making profit, perhaps an output orientation would have been the appropriate choice of orientation. Then the focus of hospitals could be to prioritize those surgical procedures with high DRG-points.

Returns to scale

The procedure for selecting CRS or VRS was according to theory, and the results showed clearly that VRS would be the appropriate choice. The reason being that the inefficiency mainly was not explained by wrong scale of operation. Therefore, it was interesting to check how much inefficiency was present under VRS before checking if the inefficiency was caused by any external explanatory variables and to which degree. However, if other input or output variables were included or changed, perhaps the choice of RTS would have been different.

7.2.2 Regression Analysis

Of all the possible external explanatory variables in the data set, only a few could be tested because of various reasons; a main reason being missing values. In addition, the fact that the data was pooled at the diagnosis level brought different challenges. This may be reflected in the RA results, which differ somewhat from what was assumed prior to running RA.

For instance, a main diagnosis includes several surgical procedures conducted on males and females, however the value put in RA did not reflect this. The value just reflected which gender there was most of. The RA results showed gender to have varying effect on efficiency, which may be a result of the values put into RA. If RA was run at a lower level (a surgical procedure (in-patient) as DMU), the value put into RA would reflect the actual case and variation better, and the results for the different years might have been less varying.

The value for number of operation codes was chosen to be the median number of operation codes for a main diagnosis. This made so that the value in RA only reflected which number of operation codes was most common in the different main diagnoses, and so the value was mainly 1 or 2. The RA results showed that number of operation codes had a positive effect on efficiency, which is a bit strange. The higher number of operation codes the patient has, the more time most likely is required, and thus as time was an input this should lead to less efficiency. The reason for the obtained results is most likely due to the values put into RA. If RA was run at a lower level (a surgical procedure (in-patient) as DMU), the value put into RA might reflect the difference and variation in number of operation codes better. Then the values put into RA would be from 1 to 6, and then the results might show that higher number of operation codes results in less efficiency.

Also the other external explanatory variables suffered from the same challenges as gender and number of operation codes, which the RA results showed.

The values put into RA are likely the reason for the poor and unreliable RA results. Another reason is the small sample size; only 13 DMUs were included. In order to obtain stronger and more reliable RA results, one should perhaps avoid pooled data, and test a larger sample. Also, another type of RA should perhaps be used.

Further, perhaps other external explanatory variables, than those available in the data set from St. Olavs Hospital, could be of interest to test in RA. To have information about for instance a patient's weight may be of value in order to check how this affects the efficiency. If this variable was included in the data set, the assumption would have been that main diagnoses with a majority of surgical procedures with high weight will be less efficient than those with a majority of lower weight. The reason being that surgical procedures done on patients that weigh much are more time-consuming and difficult than those that weigh less.

It may also be interesting to include a variable telling how experienced the staff is. Then it could be studied whether or not how experienced the staff is affects the efficiency of main diagnoses. The assumption would be that more experienced staff will perform a surgical procedure more efficient than less experienced staff. Meaning that, main diagnoses with a majority of surgical procedures with highly experienced staff will be more efficient than those with a majority of lower experienced staff. However, the standardized execution for many surgical procedures may compensate some for this.

7.3 Part III

The main research question was;

How can DEA be used to explore efficiency at a process level in hospitals?

Conducting DEA at a process level in hospitals has been difficult. It is clear that other variables, than those available in the data set from St. Olavs Hospital, most likely are needed in order to achieve a more correct and reliable picture of the efficiency at a process level. The question is which variables would be ideal for conducting DEA at a process level in hospitals.

In general, DEA at a process level may most likely be better with economic variables. This entails for economic variables telling something about revenue and costs concerning a surgical procedure (in-patient) to be present in the data set. For instance, to have information about DRG-points for the different diagnosis codes could help with comparability and hence help obtain a better picture of the efficiency. The labour cost, operation cost for running the operation theatres, and the cost of equipment could also help with comparability and then help obtain a better picture of the efficiency. Having economic variables could increase the number of inputs and outputs, and may contribute to a better and more reliable measure of the efficiency at a process level. In addition, a variable telling something about the degree of technology used could perhaps make it easier to choose comparable main diagnoses. The degree of technology could tell something about the complexity of the different diagnoses. Generally, the data registered when a patient goes through the process of a surgical procedure should be studied to further explore which variables might be relevant in DEA.

It is important to understand which variables are correct for measuring efficiency at a process level in order to obtain valuable results. In other words, one should try to find what precisely affects the efficiency of the DMUs studied at a process level. When studying how to conduct DEA at a process level the best idea would perhaps be to make a team consisting of people with expertise within DEA and hospitals.

If DEA at a process level in hospitals is developed and becomes reliable, the results may be used for decision-making and improvement of resource utilization. If the results imply that there is room for improvements, the hospital could study the process of the surgical procedure in order to find where improvements could be made. Perhaps re-engineering of the process is possible, and thereby the time could be used more efficiently.

Conclusion and Further thoughts

This master thesis is an exploratory case study in which the purpose has been to explore how DEA can be used at a process level in hospitals. A data set from St. Olavs Hospital has been used in order to test this.

The mean efficiency scores found, with DEA, for the 17 DMUs (main diagnoses) in the two departments were high for the four years studied, between 90.2 % and 93.7 %. Further, the mean efficiency scores for the two departments separately were high as well. The mean efficiency scores for the 10 DMUs in the Department of Surgery fluctuated between 88.6 % and 94 %, whilst the mean efficiency scores for the 7 DMUs in the Department of Orthopedic fluctuated between 87.7 % and 93.4 %. In addition, no statistical differences were found between the two departments; Department of Surgery and Department of Orthopedic. The RA results showed that none of the external explanatory variables gender, age, degree of contamination, and number of operation codes, and the control variable median knife-time were the cause of the low inefficiency. Thus, it is not clear what caused the inefficiency in the main diagnoses in the four years studied.

It is not possible to draw any certain conclusions of the DEA and RA results, since this is a partial analysis. Also, the small sample size makes it difficult to draw any certain conclusions of the DEA and RA results. Further, that only DMUs at St. Olavs Hospital are studied makes the DEA results not as reliable.

Through the process of exploring how DEA can be used to explore efficiency at a process level in a hospital it is found that it is possible in some ways. However, further research is necessary. In order for St. Olavs Hospital to obtain more reliable DEA results for the 17 main diagnoses studied, future research should compare the main diagnoses with the same main diagnoses at other hospitals. In addition, other or additional input and output variables (DRG-points, labour costs etc.) should be included in DEA in order to achieve a more reliable picture of the efficiency. In general, future research should study even further how DEA can be used to explore efficiency at a process level in hospitals.

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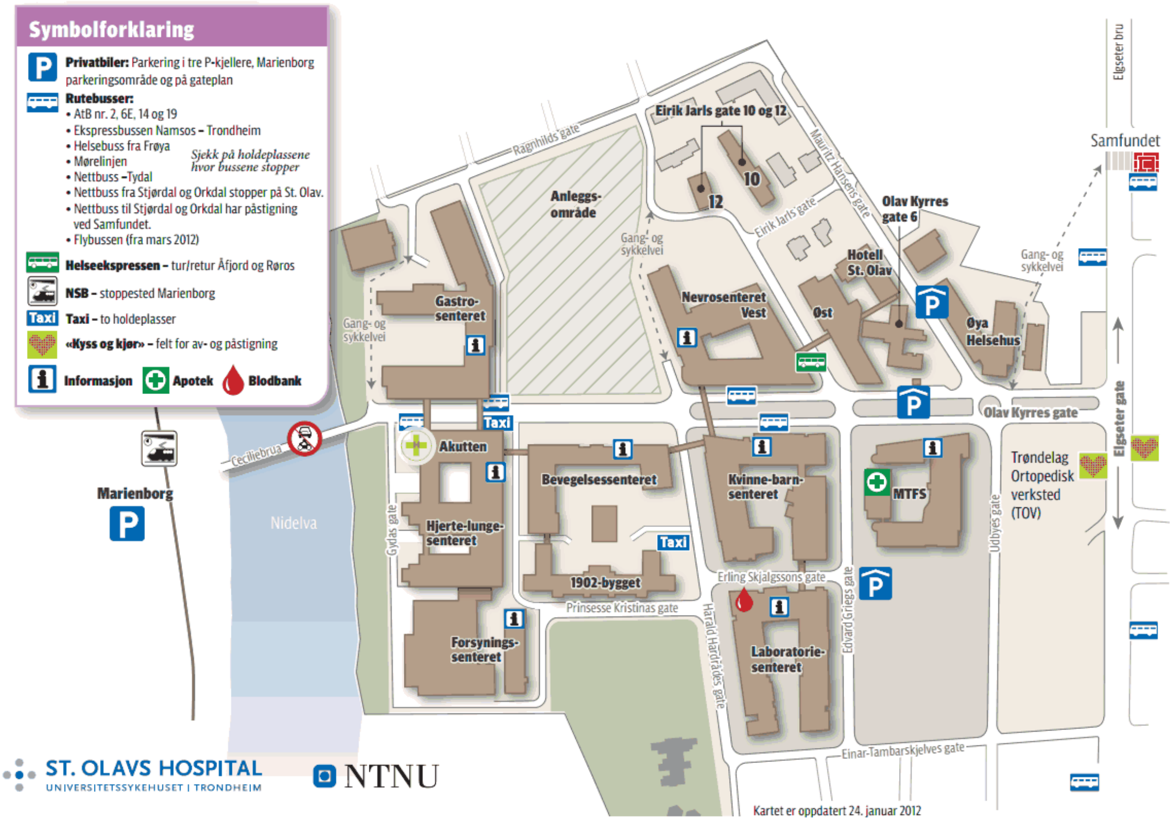
Attachments

Chapter 2 St. Olavs Hospital

Attachment 1 Map of St. Olavs Hospital



Chapter 3 Literature Review

Attachment 2 Tables of studies

Sikka, Luke, and Ozcan (2009)			
Country: USA	*DMU:* 343. Clusters	*Inputs:* 1. Total no. of beds, 2. Capital assets measured by service mix (sum of reported services provided for each hospital), 3. FTE labor resources, 4. Total nonlabor expenses	*Outputs:* 1. Case-mix-adjusted admissions, 2. Outpatient visits
Orientation: Input	*Returns to scale:* Constant returns to scale (CRS)	*Results:* 20 clusters were classified efficient, the remaining 323 were classified inefficient. The average efficiency score for all clusters was 0.75. The inefficient clusters had an average efficiency of 0.73.	
White and Ozcan (1996)			
Country: USA	*DMU:* 170 hospitals (41 catolic, 114 secular, 15 other)	*Inputs:* 1. Hospital size, 2. Labour, 3. Supply expenses, 4. Service complexity	*Outputs:* 1. Adjusted discharges, 2. Outpatient visits (including outpatient surgeries)
Orientation: Input	*Returns to scale:* Constant returns to scale (CRS)	*Results:* 18 of 170 hospitals were classified efficient, whilst the remaining 152 were classified inefficient. Church hospitals had an average efficiency of 0.81, whilst secular hospitals had an average efficiency of 0.76. Church-owned hospitals tended to be more efficient than the secular hospitals.	
Wang, Ozcan, Wan, and Harrison (1999)			
Country: USA	*DMU:* Hospital groups (small population, medium population, large population)	*Inputs:* 1. Service Complexity (the total no. of diagnostic and special services), 2. Operational beds, 3. Labour, 4. Operating expenses	*Outputs:* 1. Adjusted Discharges, 2. Outpatient Visits
Orientation:	*Returns to scale:*	*Results:* Results suggest that large hospital markets generally demonstrated higher inefficiency. Average technical efficiency across the hospital markets was relatively constant ranging from 0.74 to 0.89.	
Ajlouni, Zyoud, Jaber, Shaheen, Al-Natour, and Anshasi (2013)			
Country: Jordan	*DMU:* 15. Public hospitals	*Inputs:* 1. Annual no. of bed days (bed days * 365), 2. No. of physicians per year (FTEs), 3. Number of health personnel per year (etc. nurses, lab, technicians, physical therapists and pharmacists (FTEs))	*Outputs:* 1. Annual no. of patient days, 2. No.of minor surgical operations per year, 3. No. of major surgical operations per year
Orientation:	*Returns to scale:*	*Results:* The results indicate that the average efficiency score of hospitals is varied and ranges between 0.73 and 1. In 2006 7 hospitals were classfied efficient, whilst 8 were classified inefficient. For year 2007 the numbers were 9 and 6 respectively. In year 2008 8 hospitals were classified efficient, whilst the remaining 7 were classified inefficient.	
Weng, Wu, Blackhurst, and Mackulak (2009)			
Country: USA	*DMU:* 65. Hospitals	*Inputs:* 1. Bed days, 2. Physicians, 3. Health personnel	*Outputs:* 1. No. of patient days, 2. No. of minor operations, 3. No. of major operations
Orientation: Input	*Returns to scale:* Constant returns to scale (CRS)	*Results:* 19 of 65 hospitals are efficient in at least one panel for the three window sizes. Smaller window sizes will provide a more accurate assessment of temporal data, and will generate better benchmarks using the panel-based benchmarking approach.	
Olesen and Petersen (2002)			
Country: Denmark	*DMU:* 70. Danish hospitals	*Inputs:* 1. Observed cost	*Outputs:* 1. Number of discharges in each group of discharges
Orientation:	*Returns to scale:*	*Results:* 32 hospitals were classified efficient on the 5 % probability level, 23 on the 10 % level, and 5 on the 20 % level for trimmed data. 42 hospitals were classified efficient on the 5 % level, 27 on the 10 % level, and 8 on the 20 % level for untrimmed data.	

Chuang, Chang, and Lin (2011)			
Country: Vietnam	*DMU:* 82. Hospitals	*Inputs:* 1.Number of patient beds, 2. Number of physicians, 3.Number of nurses, 4. Number of other medical professionals	*Outputs:* 1. Number of inpatient days, 2. Number of outpatient/emergency visits, 3. Number of person-time using expensive medical devices (quality), 4. In-hospital survival rate (quality)
Orientation: Input	*Returns to scale:*	*Results:* 23 hospitals were classified efficient, whilst the remaining 59 were classified inefficient.	
Wilson, Kerr, Bastian, and Fulton (2012)			
Country: USA	*DMU:* 183. Critical access hospitals (CAHs)	*Inputs:* 1. Total FTEs, 2. Total square feet, 3. Total expenses	*Outputs:* 1. Total patient revenue, 2. Total RHC visits, 3. Total patient days
Orientation: Input	*Returns to scale:* Variable returns to scale (VRS)	*Results:* 18 of 183 (9.8 %) hospitals were classified efficient, whilst the remaining 165 were classified inefficient. The average efficiency score was 0.705 with a standard deviation of 0.613. The efficiency scores varied from 0.329 to 1.	
Lynch and Ozcan (1994)			
Country: USA	*DMU:* 853. Hospitals	*Inputs:* 1. Service complexity, 2. Hospital size, 3. Labour (FTEs), 4. Supply	*Outputs:* 1. Adjusted dicharges, 2. Outpatient visits, 3. Training
Orientation:	*Returns to scale:*	*Results:* 28 of 66 closed hospitals were classified as inefficient, whilst 825 of 1469 open hospitals were classified inefficient. Closed inefficient hospitals had an average efficiency of 0.73, whilst open inefficient hospitals had an efficiency of 0.78.	
Shetty and Pakkala (2010)			
Country: India	*DMU:* 19. States	*Inputs:* 1. Per capita health expenditure, 2. HCPMP, 3. % of population below poverty line, 4. Literacy rate	*Outputs:* 1. Infant mortality rate (IMR), 2. Life expectancy at birth
Orientation: Input	*Returns to scale:*	*Results:* 11 of 19 states were classified efficient, the remaining 8 were classified inefficient Two categories of states responsible for poor health outcomes of the country are revealed. One category of states makes inefficient use of health inputs and the second category of states has only inadequate healthcare resources. There is a need to restructure health policies in order to provide the best healthcare services in the country by efficient use of available resources.	
Bhat, Verma, and Reuben (2001)			
Country: India	*DMU:* 41 (20 District hospitals, 21 grat-in-aid hospitals)	*Inputs:* 1. Capital, 2. Technology, 3. Staff	*Outputs:* 1. Medico legal cases, 2. Laboratory cases, 3. In patients, 4. Out-patients, 5. Maternal and child health cases
Orientation: Input	*Returns to scale:* Constant returns to scale (CRS)	*Results:* 10 of 20 distric hospitals were classified efficient, whilst the remaning 10 were classified inefficient. The mean efficiency score was reported to be 0.85. 13 of 21 grant-in-aid hospitals were found to be efficient, whilst the remaining 8 were clqassified inefficient. The mean efficiency for the grant-in-aid hospitals was 0.89. The overall efficiency levels of grant-in-aid institutions are higher than the district level hospitals. The grant-in-institutions are relatively more efficient than the public hospitals. These differences are statistically significant.	
Giokas (2002)			
Country: Greece	*DMU:* Hospitals	*Inputs:* 1. Total cost (in euros)	*Outputs:* 1. Inpatient days, 2. Outpatient visits, 3. Ancillary services
Orientation: Input	*Returns to scale:* Constant returns to scale (CRS)	*Results:* The results clearly indicate the superiority of the combination of DEA and GP over the combination of DEA and RA. The methodology was applied to estimate the efficient marginal costs of hospital services (inpatient days, outpatient visits, ancillary services) of public general hospitals in Greece.	

Chapter 5 Data

Attachment 3 Overview and definitions of the variables

Overview and definitions of the variables			
Variable	**Definition**	**Variable**	**Definition**
Operation Date 1	Date of operation, numbers	**Degree of Contamination**	1,2,3,4; Degree of wound
Operation Date 2	Date of operation, text	**Main Diagnosis**	Patient illness
Date reported 1	Date operation reported, numbers	**Additional Diagnosis Code 2**	Additional patient illness
Date reported 2	Date operation reported, text	**Additional Diagnosis Code 3**	Additional patient illness
Gender	Male or Female	**Additional Diagnosis Code 4**	Additional patient illness
Age 1	Age of patient, 1	**Additional Diagnosis Code 5**	Additional patient illness
Age 2	Age of patient, 2	**Operation Code 1**	Procedure done
Nation	Nation of patient	**Operation Code 2**	Procedure done
Munic	Munic of patient	**Operation Code 3**	Procedure done
County	County of patient	**Operation Code 4**	Procedure done
Degree of Emergency	0,1,2,3; 0; planned operations, 1,2,3; emergencies	**Operation Code 5**	Procedure done
Weekday	Day of the operation	**Operation Code 6**	Procedure done
Operation Start 1	Time of operation start,1	**Assitant Category 3**	-
Operation End 1	Time of operation end, 1	**Assitant Category 4**	-
Knife-time	Surgical time	**Main Surgeon**	Surgeon
Pre-time	Preparation time	**Additional Surgeon 1**	Surgeon
Post-time	Waking up time	**Additional Surgeon 2**	Surgeon
Time	Preparation time + Surgical time + Waking up time	**Additional Surgeon 3**	Surgeon
Waiting time	In time - Time reported	**Additional Surgeon 4**	Surgeon
Hospital	Location	**Operation Nurse**	Nurse specialized in operation
Department	Which department in the hospital	**Nurse 1**	Nurse
Section	Which section in the hospital	**Nurse 2**	Nurse
Ward	Which ward in the hospital	**Nurse 3**	Nurse
Day Surgery	0; in-patient, 1; out-patient	**Anesthesia Type**	Type of drug
Time reported	Time operation reported	**ASA**	1,2,3,4,5; How stable the patient is
In time	When patient arrives operation theatre	**Anesthesia Start**	Time of anesthesia start
Out time	When patient leaves operation theatre	**Operation Start 2**	Time of operation start, 2
Operation Theatre	Where the patient is operated	**Operation End 2**	Time of operation end, 2
Treatment or Examination	Type of operation	**Anesthesia End**	Time of anesthesia end

Chapter 5 Data

Attachment 4 Scale efficiency and improvement potential 2006-2009

2006						
	Efficiency score		Inefficiency score		Scale efficiency	Improvement potential
Main diagnosis	CRS	VRS	CRS	VRS	CRS/VRS	1-SE
C18.0	0.853	0.858	0.147	0.142	0.995	0.005
C18.2	0.774	0.791	0.226	0.209	0.978	0.022
C50.4	0.896	0.908	0.104	0.092	0.988	0.012
C50.9	0.876	0.928	0.124	0.072	0.944	0.056
E66.9	0.734	0.737	0.266	0.263	0.996	0.004
K43.9	0.829	1	0.171	0	0.829	0.171
K50.0	0.827	0.844	0.173	0.156	0.980	0.020
K51.9	0.925	1	0.075	0	0.925	0.075
K80.2	0.777	0.798	0.223	0.202	0.974	0.026
N20.0	0.991	0.995	0.009	0.005	0.996	0.004
M05.9	1	1	0	0	1	0
M16.1	0.764	0.785	0.236	0.215	0.974	0.026
M17.1	1	1	0	0	1	0
M84.1	0.850	0.855	0.150	0.145	0.995	0.005
T84.0	0.817	1	0.183	0	0.817	0.183
T84.1	0.993	0.993	0.007	0.007	1	0
T84.6	0.860	0.882	0.140	0.118	0.976	0.024
Mean	0.869	0.904	0.131	0.096	0.963	0.037

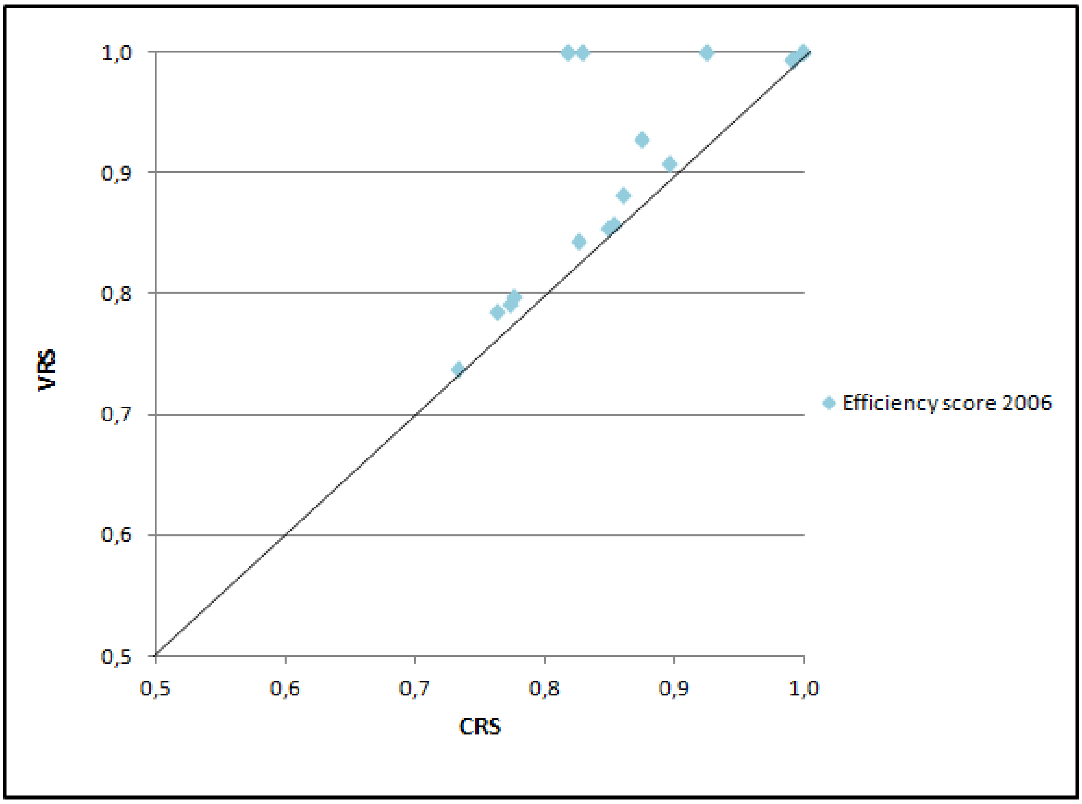
2007						
	Efficiency score		Inefficiency score		Scale efficiency	Improvement potential
Main diagnosis	CRS	VRS	CRS	VRS	CRS/VRS	1-SE
C18.0	1	1	0	0	1	0
C18.2	0.903	0.922	0.097	0.078	0.979	0.021
C50.4	0.893	1	0.107	0	0.893	0.107
C50.9	1	1	0	0	1	0
E66.9	0.759	0.853	0.241	0.147	0.890	0.110
K43.9	0.853	0.856	0.147	0.144	0.996	0.004
K50.0	0.893	0.917	0.107	0.083	0.974	0.026
K51.9	0.861	1	0.139	0	0.861	0.139
K80.2	0.812	0.828	0.188	0.172	0.981	0.019
N20.0	0.946	1	0.054	0	0.946	0.054
M05.9	0.895	0.954	0.105	0.046	0.938	0.062
M16.1	0.762	0.802	0.238	0.198	0.950	0.050
M17.1	0.777	0.801	0.223	0.199	0.970	0.030
M84.1	0.815	0.826	0.185	0.174	0.987	0.013
T84.0	0.759	1	0.241	0	0.759	0.241
T84.1	0.791	0.795	0.209	0.205	0.995	0.005
T84.6	0.901	0.964	0.099	0.036	0.935	0.065
Mean	0.860	0.913	0.140	0.087	0.944	0.056

2008						
	Efficiency score		Inefficiency score		Scale efficiency	Improvement potential
Main diagnosis	CRS	VRS	CRS	VRS	CRS/VRS	1-SE
C18.0	0.842	0.845	0.158	0.155	0.996	0.004
C18.2	0.765	0.850	0.235	0.150	0.900	0.100
C50.4	0.962	0.988	0.038	0.012	0.974	0.026
C50.9	0.970	1	0.030	0	0.970	0.030
E66.9	0.766	1	0.234	0	0.766	0.234
K43.9	0.891	0.898	0.109	0.102	0.993	0.007
K50.0	0.987	1	0.013	0	0.987	0.013
K51.9	1	1	0	0	1	0
K80.2	0.813	0.814	0.187	0.186	0.999	0.001
N20.0	0.960	1	0.040	0	0.960	0.040
M05.9	1	1	0	0	1	0
M16.1	0.756	0.901	0.244	0.099	0.839	0.161
M17.1	0.767	0.850	0.233	0.150	0.902	0.098
M84.1	0.789	0.845	0.211	0.155	0.934	0.066
T84.0	0.754	1	0.246	0	0.754	0.246
T84.1	0.938	0.938	0.063	0.062	0.999	0.001
T84.6	0.987	1	0.013	0	0.987	0.013
Mean	0.879	0.937	0.121	0.063	0.939	0.061

2009						
	Efficiency score		Inefficiency score		Scale efficiency	Improvement potential
Main diagnosis	CRS	VRS	CRS	VRS	CRS/VRS	1-SE
C18.0	1	1	0	0	1	0
C18.2	0.775	0.781	0.225	0.219	0.992	0.008
C50.4	0.860	0.900	0.140	0.100	0.955	0.045
C50.9	0.916	0.917	0.084	0.083	0.998	0.002
E66.9	0.875	0.894	0.125	0.106	0.979	0.021
K43.9	0.888	0.893	0.112	0.107	0.994	0.006
K50.0	1	1	0	0	1	0
K51.9	0.794	0.807	0.206	0.193	0.984	0.016
K80.2	0.796	0.811	0.204	0.189	0.981	0.019
N20.0	1	1	0	0	1	0
M05.9	0.986	1	0.014	0	0.986	0.014
M16.1	0.777	0.777	0.223	0.223	1	0
M17.1	0.798	0.810	0.202	0.190	0.984	0.016
M84.1	0.829	0.841	0.171	0.159	0.985	0.015
T84.0	0.741	1	0.259	0	0.741	0.259
T84.1	0.842	0.902	0.158	0.098	0.934	0.066
T84.6	0.828	1	0.172	0	0.828	0.172
Mean	0.865	0.902	0.135	0.098	0.961	0.039

Chapter 5 Data

Attachment 5 CRS and VRS



Chapter 5 Data

Attachment 6 Descriptive statistics 2007-2009

Descriptive statistics 2007					
		Mean	St. deviation	Min	Max
Input	Staff	139	109	25	438
Input	Time	6 174	5 185	1 443	19 757
Output	Number of in-patients	32	23	6	90

Descriptive statistics 2008					
		Mean	St. deviation	Min	Max
Input	Staff	165	150	38	547
Input	Time	7 018	6 645	1 923	25 642
Output	Number of in-patients	37	31	10	110

Descriptive statistics 2009					
		Mean	St. deviation	Min	Max
Input	Staff	133	114	27	478
Input	Time	5 499	5 070	1 130	21 733
Output	Number of in-patients	29	24	6	98

Chapter 5 Data

Attachment 7 External explanatory variables overview 2006-2009

External explanatory variables overview 2006					
Main diagnosis	Gender	Age	Degree of contamination	Number of operation codes	Median knife-time
	Male = 0 Female = 1	Young ≤ 64 Old ≥ 65			
C18.0	1	75	1	1	115
E66.9	1	41	1	1	120
K50.0	1	33	1	1	110
K51.9	0	42.5	1	1	113
K80.2	1	33.5	1	2	100
N20.0	1	59	1	2	101
M05.9	1	60	1	2	80
M16.1	1	61	1	1	100
M17.1	1	58	1	2	92.5
M84.1	0	55	1	2.5	115
T84.0	1	68	1	2	120
T84.1	0	39	1	1	89.5
T84.6	0	43	3	2	80
Amount of male/young/1	4	11	12	6	
Amount of female/old/more than 1	9	2	1	7	

External explanatory variables overview 2007					
Main diagnosis	Gender	Age	Degree of contamination	Number of operation codes	Median knife-time
	Male = 0 Female = 1	Young ≤ 64 Old ≥ 65			
C18.0	1	69	2	1	115
E66.9	1	40	2	1	120
K50.0	0	38	2	1	110
K51.9	0	39.5	2	1.5	113
K80.2	1	49	1	2	100
N20.0	1	52	2	2	101
M05.9	1	61	1	2	80
M16.1	1	63	1	1	100
M17.1	1	68	1	1	92.5
M84.1	0	42.5	1	2	115
T84.0	1	63	1	2	120
T84.1	1	76.5	1	2	89.5
T84.6	1	59	2	2	80
Amount of male/young/1	3	10	7	5	
Amount of female/old/more than 1	10	3	6	8	

External explanatory variables overview 2008					
Main diagnosis	Gender	Age	Degree of contamination	Number of operation codes	Median knife-time
	Male = 0 Female = 1	Young ≤ 64 Old ≥ 65			
C18.0	0	71.5	2	1	115
E66.9	1	40	1	1	120
K50.0	1	33	2	1	110
K51.9	0	49	1	1	113
K80.2	1	42.5	1	2	100
N20.0	1	56	2	2	101
M05.9	1	64.5	1	2	80
M16.1	1	60	1	1	100
M17.1	1	69	1	1	92.5
M84.1	0	55	1	2	115
T84.0	1	66.5	1	2	120
T84.1	0	53	1	2	89.5
T84.6	1	61	3	3	80
Amount of male/young/1	4	10	9	6	
Amount of female/old/more than 1	9	3	4	7	

External explanatory variables overview 2009					
Main diagnosis	Gender	Age	Degree of contamination	Number of operation codes	Median knife-time
	Male = 0 Female = 1	Young ≤ 64 Old ≥ 65			
C18.0	1	75	2	1	115
E66.9	1	39	2	1	120
K50.0	0	36	2	1	110
K51.9	0	51	2	1	113
K80.2	1	56	1	2	100
N20.0	0	59	2	2	101
M05.9	1	69	1	2	80
M16.1	1	61	1	1	100
M17.1	1	61	1	1	92.5
M84.1	1	48	1	2	115
T84.0	1	66.5	1	2	120
T84.1	1	76.5	1	2	89.5
T84.6	0	52	2	2	80
Amount of male/young/1	4	9	7	6	
Amount of female/old/more than 1	9	4	6	7	

Chapter 6 Analysis

Attachment 8 Results regression analysis 2006-2009

Results regression analysis 2006-2009

2006	
Regression Statistics	
Multiple R	0.639
R Square	0.408
Adjusted R Square	-0.015
Standard Error	0.099
Observations	13

2007	
Regression Statistics	
Multiple R	0.757
R Square	0.573
Adjusted R Square	0.269
Standard Error	0.074
Observations	13

2008	
Regression Statistics	
Multiple R	0.430
R Square	0.185
Adjusted R Square	-0.397
Standard Error	0.089
Observations	13

2009	
Regression Statistics	
Multiple R	0.7133
R Square	0.5088
Adjusted R Square	0.1579
Standard Error	0.0844
Observations	13