Examining the Performance of Integrated Care Pathways

On designing a method for healthcare performance quantification

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Abstract

Due to the fast rising cost, healthcare is currently an important topic on the governmental agenda of most Western countries. Several reasons can be distinguished for the fast increase in healthcare cost. Firstly, large investments in product innovation have led to increased quality, but also to increased cost of health services. Secondly, the increased performance of the healthcare sector have led to a higher life expectancy and healthcare demand. Thirdly, the aging phenomenon led to a fast growth of the demand for health services as well.

Four key actors play an important role in healthcare, namely the government, healthcare providers, health insurance companies and patients. Three of these actors (patients do not have a prominent role here, but are represented by the other key actors) agreed on reducing the cost and increasing the efficiency of health services by signing the healthcare outline agreement. Several initiatives are developed to reduce the cost and increase the efficiency of health services. These initiatives are started in the past and continued by the healthcare outline agreement. The initiatives concern the introduction of competition, the definition of integrated care pathways, the principle of Pay for Performance and demand driven healthcare. All these initiatives are to a certain extent connected to the introduction of more competition on the healthcare market among healthcare providers.

Health insurance companies have a key position in these initiatives due to their current position in healthcare where they play a central role in the provision of information to the relevant actors on the healthcare market (the provision of sound and relevant information is marked as an important precondition for fair competition). For that reason is laid down in the healthcare outline agreement that health insurance companies get the responsibility to take a dominant role in realizing lower cost and a higher efficiencies in healthcare by means of performance based healthcare procurement.

Fair decision making is a requirement for fair competition. Healthcare procurement involves all relevant information streams that are used for decision making on the healthcare market and may for that reason be a good means for restoring sound and relevant information to the healthcare market. However, healthcare procurement may only be effective in enabling fair competition when a broad set of requirements is fulfilled. These requirements should guarantee the provision of sound and relevant information to the healthcare market and broad support among the key actors on the healthcare market.

It is for the sake of fair competition important that competition takes place at the right level of detail. The right level of detail from the point of view of demand-driven healthcare is the level of the integrated care pathways as this is the level at which appropriate health services can be guaranteed. This is not possible at the institutional level of a healthcare provider. Patients (as the demand side of the healthcare market) are interested in the performance of healthcare providers for specific diseases and do not care that much about the performance of healthcare providers on the institutional level when they need to be treated for a specific disease. Healthcare performance information should be available on the integrated care pathway level in order to enable competition on this level of detail.

An important first step towards performance based procurement of health services is the definition and the quantification of criteria that measure the performance of healthcare providers on the level of the integrated care pathways. This is currently not possible due to the lack of appropriate KPIs that measure the relevant information on the right level of detail. The design objective for this research is

Design a method for the evaluation of the performance of healthcare provider transcending integrated care pathways on broadly agreed criteria which may serve as a basis for a healthcare procurement model.

This method should facilitate health insurance companies in the execution of their role on the healthcare market. First a desk research is executed in which is evaluated which KPIs are appropriate for the evaluation of the performance of healthcare providers on the relevant criteria in order to enable healthcare procurement

on sound and relevant information. Subsequently, there is discovered how the several KPIs can be quantified in order to provide the relevant information for the procurement of health services. One of the KPIs, namely the efficiency of integrated care pathways, cannot not be quantified with the help of simple performance figures that are directly accessible, but needs to be calculated. For the calculation of the efficiencies is made use of the DEA (a conservative and realistic method for calculating the efficiency of Decision Making Units (DMUs) on the basis of empirical performance data) method. This method can be used for the calculation of both the efficiency figures of integrated care pathways as the efficiency figures of individual inputs and outputs.

A method for the quantification of healthcare performance (HPQ-method) is defined with the help of the experiences and outcomes of the analyses that are executed in this research. The HPQ-method should comply with the requirements for fair competition that are defined during the analysis of the healthcare market. The HPQ-method should be seen as a first step towards a performance based procurement method for health services and may also serve as an input for a performance benchmarking study among integrate care pathways. Insight in their relative performance on the relevant KPIs may help healthcare providers to improve their performance by applying focussed investments. Issues that may pop-up around the implementation of the HPQ-method are related to the information streams that are required for the execution of the method. The main issues concern the management of the quality of internal and external information streams and the allocation of responsibilities for the execution of the steps of the method. These two issues (There are more) are key for the success of the implementation and the accuracy of the outcomes of the proposed method.

Although healthcare procurement on the level of integrated care pathways may be beneficial for the provision of sound and relevant information, it may also have some undesirable consequences for the performance of the healthcare system. Fair competition will not work when health insurance companies are clustered. This reduces the freedom of choice for the patients and strengthens the position of the health insurance companies in the contracting process with healthcare providers. In addition, healthcare procurement will not lead to fair competition as long as there exist mobility barriers for patients, healthcare employees and healthcare capital goods. The existence of imperfect information may hinder fair competition as well as it may lead to the strategic behaviour of actors that benefit from exclusive information. Furthermore, performance based procurement of health services may lead to the concentration of supply at specific point in the healthcare sector. This may damage the accessibility of the healthcare system because the number of locations where patients can be treated for a certain disease may decrease. However, the lack of capabilities to quantify the performance of low volume integrated care pathways may result in a fragmented healthcare system as well. These consequences ask for adequate policy measures that may avoid or limit the impact on the performance of the healthcare system.

More research is required on the likelihood of these consequences and the likelihood of the impact of the consequences on the performance of the helathcare system. In addition, policy measures should be discovered that are effective in coping with the negative impact of the consequences. Further research is also required on the procurement of health services and healthcare performance benchmarking in order to take full advantage of the knowledge that is gained in this research concerning the quantification of the performance of integrated care pathways.

Some limitations are experienced during the execution of this research. There should be remarked that it is not possible to use the proposed method directly for the quantification of the performance of integrated care pathways in other parts of the healthcare system. The mental healthcare providers for example has very different characteristics which makes it difficult to quantify their performance on the level of integrated pathways. There are also some technical limitations that add complexity to the quantification of the performance of integrated care pathways. For example, there may be leaking patients in healthcare that cannot be distinguished from the patients that are treated by an integrated care pathway. Secondly, the DEA method can only work with quantitative information. This has the consequence that qualitative figures need to be quantified to use them in a DEA analysis. This may lead to the loss of information which may damage the outcomes of the analysis.

There should be remarked that whether the recommendations that follow from this research lead to concrete actions is highly dependent on the political sentiment which may change after the elections in september 2012.

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Glossary

CQ-index	A KPI (see KPI) that can be used for the evaluation of the quality of health services as they are experienced by the patient.
Demand-driven healthcare	Demand-driven healthcare is the idea that patients should be free to choose for a healthcare provider that delivers health services that meets the desires of the patients best. Healthcare resources are likely to concentrate at the place where the demand for health services is the highest.
DOT	DOT stand for DBC Towards Transparency and is a new system for billing healthcare activities. In DOT it is no longer possible to register full treatments, but only individual operations. The system itself derives the treatment that is executed with the help of the registered operations. This system should increase the transparency of the performance of healthcare providers significantly.
Health service	the treatments that are executed by healthcare providers.
Healthcare market	The healthcare market is a virtual market on which contracts are made between healthcare providers and health insurance companies. The demand side on the healthcare market is formed by the patients and represented by the health insurance companies. The supply side of the healthcare market are the healthcare providers.
Healthcare outline agreement	The healthcare outline agreement is an agreement between the government, healthcare providers and health insurance companies in which they agreed on putting effort in the reduction of cost and the improvement of the quality of health services.
Informal care	Informal care are health services that are delivered by volunteers to people who can stay at home, but cannot help themselves.
Integrated care pathway	A fixed sequence of steps transcending the boundaries of healthcare providers that is used in healthcare to treat patients with a specific disease.
KPI	A KPI (Key Performance Indicator) is a single factor that is used for measuring the performance of an entity on predefined goals. KPIS are an instrument for managers on the basis of which they can take management decisions.
Pay for Performance	The idea that parties are paid for quality and not only for quantity.
Primary care	Health services that are directly accessible for everyone. These services are delivered by general practitioners and primary mental healthcare providers.
QALY	QALY stands for Quality Adjusted Life Years and is a KPI that measures the objective quality of a health service. QALY measures the number of years that a patient lives in relative health as a result of the treatment.

Secondary care	Secondary care is delivered by hospitals, independent treatment centra etc. that treat patients that are referred by a primary healthcare provider.
Supply-side healthcare	Supply-side healthcare is the idea that healthcare providers control the resources of the healthcare system and as a consequence determine the quality, quantity and geographical location of health services that are delivered to the healthcare market. Patients do not have a free choice where to be treated for a specific disease but are treated at the healthcare provider they are referred to.
Tertiary care	Tertiary care is long term care that is delivered twenty four hours per day within hospitals or clinics.

Part I

Literature Research

Chapter 1

Introduction

Currently, healthcare is a prominent topic on the governmental agenda in most modern Western societies. A significant part of the gross domestic product in these countries is spend on healthcare; furthermore these expenditures are still rising (OECD, 2009). Many people see the provision of high quality care for everybody as one of the most essential rights (Pereira, 2004). The government has the task to safeguard the accessibility, affordability and quality of healthcare for everyone. This chapter gives a general introduction to the basics of healthcare. In addition, the relevant developments in the healthcare sector in the Netherlands are described and some initiatives are discussed that should deal with the negative effects of the trends in healthcare.

1.1 The basics of healthcare

The healthcare system consists of several parts in which diverse actors play an important role. The system's parts and important actors are discussed in respectively section 1.1.1 and section 1.1.2. These paragraphs give a general description of the healthcare system's parts and actors that play an important role in healthcare. However, these topics are not discussed here in detail.

1.1.1 Healthcare system parts

The healthcare system can be split into four interlinked parts (Van der Burgt et al., 2006) which are discussed here in short.

A first part of the healthcare system is primary care. Primary care is directly accessible for everyone. This type of care is provided by general practitioners and primary mental healthcare providers. The second part of the healthcare system is called secondary care. Secondary care is delivered by hospitals and secondary mental healthcare providers. Patients can only make use of secondary care when they are referred to a secondary healthcare provider by a healthcare provider in primary care. The third part that can be distinguished is tertiary care, which is provided to patients that need long term care twenty-four hours per day within hospitals or clinics. The last part of the healthcare system is informal care. Informal care are health services that are delivered to people who can stay at home but are unable to help themselves. This type of care is mainly provided by volunteers. These four parts together form the healthcare system.

There is a general way of routing patients through the healthcare system. When people have mental or physical complaints, they first go to a primary healthcare provider like a general practitioner. General practitioners may decide to treat the patient themselves or refer the patient to a secondary healthcare provider when the complaints are serious enough or when the primary healthcare provider is not able to treat the disease himself. At the secondary healthcare provider, the patient is routed through a process of sequential steps. The patient will be referred to a tertiary healthcare provider or leave the healthcare system after the treatment at a secondary healthcare provider. The whole sequence of steps from the moment the patient enters the healthcare system at a primary healthcare provider until the moment he leaves the system is defined as an integrated care pathway.

1.1.2 Key actors in healthcare

There are several groups of actors that play an important role in healthcare which are closely related to each other. The four key actors in healthcare are in succession patients (healthcare consumers), healthcare providers, health insurance companies and the national government (Koopman and Rademakers, 2008).

Patients play an important role in the healthcare system because they are subject to the performance of the healthcare system and may therefore be directly affected by a change in the performance of healthcare providers. Each patient has a specific healthcare demand. All patients together form the demand side of the healthcare system. The healthcare providers are all organizations that deliver care to patients. Healthcare providers can be divided in primary, secondary and tertiary healthcare providers as mentioned in section 1.1.1. There are different groups of healthcare providers in each layer of the healthcare system. In secondary healthcare for example there are independent treatment centers, private clinic, hospitals and academic medical centers. A third group of actors are the health insurance companies which are linked to both the patients and the healthcare providers. Health insurance companies are responsible for the procurement of health services at the healthcare providers and have thereby an prominent position on the healthcare market. The different parts of the healthcare market on which the key actors play an important role are discussed in section 2.1.1. The role of the national government in the healthcare sector is quite different from the role of the other key actors. They stand together with several regulatory bodies above the three mentioned actors and have the responsibility to secure the core values of the healthcare system (the core values of the healthcare system are described in section 1.2). Policies that are designed by the national government influence the interaction between the three above mentioned actors.

1.2 Core values of the healthcare system

The aim of the healthcare system is to secure its core values. The healthcare system has different core values from the perspective of the different key actors in healthcare. These core values are discussed below.

The healthcare system should deliver *high quality* health services that are *accessible* and *affordable* for everyone (Howie et al., 2004). Besides that, the healthcare system should be *safe*, *robust* and *reliable* in order to guarantee the quality of health services on the longer term and under exceptional circumstances like epidemics (Ralston et al., 2005). Furthermore, the healthcare system should have the *right capacity* for handling the healthcare demand of the Dutch population. Lastly, the healthcare system should provide *appropriate* health services for all kinds of diseases[1].

Some of these core values are partly conflicting (f.e. cost and quality) and ask for a careful consideration of their relative importance when initiatives are employed that effect one of them. Initiatives that effect the core values can be expected when there is a risk that one of the core values cannot be maintained any longer. This is demonstrated by the initiatives presented in section 1.4 that have the purpose to safeguard the core values that are threatened by the developments in healthcare, mentioned in section 1.3.

1.3 Developments in the healthcare sector

There are several developments in the healthcare sector in the Netherlands that form a threat for the maintenance of the core values of the healthcare system in the future. These developments are discussed in this section.

1.3.1 Quality of health services increase

In literature often the distinction is made between investments in *product* or *process* innovation (Van Beveren and Vandenbussche, 2010; Bergfors and Larsson, 2009). Where product innovation in healthcare often leads to higher costs, will process innovation lead to the more efficient use of scarce medical resources and the reduction

[1] Health services can be seen as appropriate when their performance meets the needs and desires of the patient.

of the cost of the healthcare sector. Process innovation only took place at a limited scale while there is invested much in product innovation. The quality of healthcare has improved significantly, due to the high investments in product innovation in the last decades. The increased quality of healthcare is probably one of the major drivers for the increased life expectancy of patients (Strauss et al., 2006; Stout and Crawford, 1988). The increased quality of health services is no threat for the core values of the healthcare system as such but may have an indirect effect on the demand and cost of health services as demonstrated by section 1.3.2 and section 1.3.3.

1.3.2 Demand for health services increases

Besides the increase in quality, the demand for health services increased as well. There are two main drivers for the rising demand for health services. First there is the aging phenomenon, which means that an increasing part of the population is older than 65 years. The average yearly healthcare demand is much higher for older people than for young people. The changing demographic structure leads for that reason to a fast increase in demand for health services. In addition, quality improvements in healthcare led to a higher life expectancy. This has the consequence that when people become older, they need more healthcare during their life. However, the increased life expectancy has a lower impact on the increased demand for health services than the aging phenomenon because the number of years people live in relative health increased as well (Breyer and Felder, 2006). The aging phenomenon does not only lead to an increased demand for health services but also leads to a reduction of the labor force. The rapid increase in healthcare demand together with the decreased labor force leads to a lower work force availability. This may be a risk for the appropriateness and affordability of healthcare in the future. In addition, the costs of labor may rise rapidly when labor becomes scarce. The scarcity of well educated doctors and nurses in healthcare may limit the capacity and quality of health services in the future and may lead to higher labor cost.

1.3.3 Cost of health services increases

A last important development concerns the cost of healthcare. The current situation in healthcare is unsustainable in terms of costs. As mentioned in section 1.3.1, the quality of healthcare has risen over the last years due to huge investments in technological innovation. These investments led to the situation that the cost of health services increased rapidly. Higher cost per treatment together with a higher demand led to the rise of healthcare cost that lies much higher than inflation. There is the risk that health services will become unaffordable to many people in the future when this trend continues. In 2009 in the United States over 17.4 percent of the gross national product was spent on healthcare, which means a yearly amount of 2.3 trillion dollars (OECD, 2009). This amount is expected to rise up to 4.2 trillion dollars yearly in 2016. The same trends are present in the Netherlands where healthcare costs rose from 17.3 billion euros in 1980 to 87.1 billion euros in 2010 (Annema et al., 2012). This is about 12 percent of the gross domestic product (Annema et al., 2012). The total healthcare expenditures in the Netherlands are expected to triple until 2050 if the current trend remains intact. Policy makers are therefore continuously looking for possibilities to reduce the cost of healthcare while keeping or improving the quality of the healthcare sector.

1.4 Healthcare improvement initiatives

The previous section demonstrates the urgency for initiatives that have the purpose to safeguard the core values of the healthcare sector. The continuously rising cost of health services and the increasing surging demand asks for incentives for increasing the efficiency of healthcare (Agrell and Bogetoft, 2001) in order to reduce the cost of health services. Several initiatives are initiated by the national government in order to realize a major change in the structure of the healthcare system to reduce the negative effects of the developments that are discussed under section 1.3. That there is potential for efficiency improvement in healthcare is demonstrated by figure 1.1 and figure 1.2. These figures show that there is no positive relation between the cost and quality of healthcare.

The same emerged from a research executed by consulting firm KPMG and campaign office BKB (Ikkersheim et al., 2010). A special publication of the *Financieel Dagblad*[2] (Annema et al., 2012) discusses the potential for improvements in the efficiency of healthcare operations. The following initiatives to reduce the cost and increase the efficiency of health services are discussed here

- the increase of competition among healthcare providers and health insurance companies
- the introduction of integrated care pathways for the treatment of specific diseases
- the pay for performance principle in healthcare
- demand driven healthcare

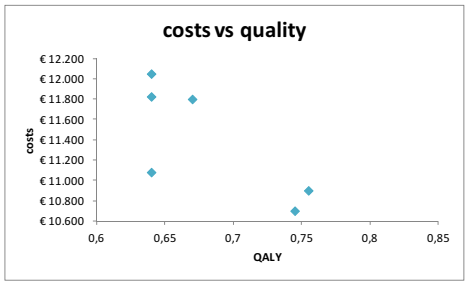


Figure 1.1 – The costs [€] (y-axis) versus the quality [Quality Adjusted Life Years] (x-axis) of the hip replacement DBC compared among seven different healthcare providers (picture retrieved from (Ikkersheim et al., 2010))

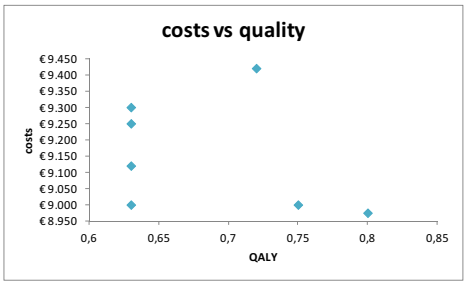


Figure 1.2 – The costs [€] (y-axis) versus the quality [Quality Adjusted Life Years] (x-axis) of the knee replacement DBC compared among seven different healthcare providers (picture retrieved from (Ikkersheim et al., 2010))

1.4.1 More competition

An important initiative is the introduction of more competition among healthcare providers and health insurance companies on the healthcare market. A market is assumed to increase its performance when competition is introduced and deregulation is applied (Vining and Boardman, 1992). The introduction of competition in healthcare may have important benefits. Research shows that prices in healthcare may decrease by up to forty percent. Subsequently, competition may offer patients the freedom to choose their own healthcare provider or health insurance company (Stevens, 2011).

The increasing cost of healthcare was the main driver for the decision to introduce competition in healthcare. Where in the past contracts between health insurance companies and healthcare providers where quite rigid; they now have become more flexible. Health insurance companies and healthcare providers have the possibility to negotiate on the price of a predefined set of treatments. Increased competition in healthcare has proven its impact on process innovation in the Netherlands. Scheduling became more efficient in hospitals that experienced competitive pressure (CPB, 2010). However, at the same time there was no demonstrable improvement in healthcare quality. That competition may have the opposite effect when the necessary prerequisites are not in place is demonstrated by the introduction of competition among dentists this year. The release of the prices of health services delivered by dentists led to a sharp rise in the prices. This may be due to the lack of information transparency about the cost and quality of services delivered by dentists (Vaartjes, 2012). This example emphasizes the necessity of guaranteeing the preconditions that enable fair competition among healthcare providers.

[2]The Financieel Dagblad is a finance oriented daily newspaper.

1.4.2 Integrated care pathways

The introduction of integrated care pathways is an important step towards a higher degree of standardization and a more efficient and transparent healthcare system.

Integrated care pathways are one of the improvements that were introduced to reduce the costs and increase the quality of the healthcare sector. They were first used in the United States and Australia in 1980 (Corkin et al., 2012). Integrated care pathways are standardized pathways in healthcare used for treating people with a specific disease (Kitchiner et al., 1996). In literature integrated care pathways are also called critical care paths, care maps or anticipated recovery paths (Kitchiner et al., 1996). Integrated care pathways help healthcare providers to deliver care at the highest quality standards by specifying experience based local best practices. They define the expected course of events in the care of a patient with a particular disease, within a certain time-scale (Coffey et al., 2005). Patients are no longer treated ad hoc for their disease but follow a predefined path. They are becoming more and more common in healthcare. The most important benefits of integrated care pathways compared to ad hoc care are that integrated care pathways

- enable the provision of high quality care for patients by specifying the best standards and experiences (Kitchiner et al., 1996)
- offer the possibility for improving healthcare by continuously revising care pathways. This is done with the help of data about patients that deviate from the pathways or data about the performance of the pathways in terms of predefined KPIs (Kitchiner et al., 1996)
- provide valuable information about the sequence of processes, resource utilization etc. (Kitchiner et al., 1996) This information can be used for process and product innovation
- give the possibility to follow patients through the process and identify patients that deviate from the standardized process (Kitchiner et al., 1996). This information can help healthcare providers to formulated local best practices
- help to minimize resource utilization in healthcare by reducing the quest for ad hoc (less automatized and therefore less efficient) planning (Corkin et al., 2012)
- help to improve resource allocation by increasing the plannability of health services
- deliver the possibility to evaluate the performance of healthcare providers for specific diseases

When adding up all these benefits, we see that integrated care pathways provide a high potential for improvements at healthcare providers. Nevertheless, despite the introduction of integrated care pathways, the cost of healthcare is still increasing with on average seven percent yearly to 12% of the gross domestic product in the Netherlands. The situation in Australia seems to be more successful where healthcare expenditures over the past years rose to *only* 8.7% of the gross national product. However, the situation in the United States ultimately demonstrates the failure to reduce costs. Reason for this difference may be differences in demographic characteristics of the population of both countries but also the current way of organizing performance responsibility in healthcare (Seinen et al., 2012) and the lack of competition among healthcare providers on their actual performance (Porter and Teisberg, 2006). This demonstrates the inter dependencies of the several cost reducing initiatives that are discussed in this chapter. The realization of the benefits of integrated care pathways may be dependent on the level of competition in healthcare. The lack of transparency about the quality of healthcare on the right level of detail may be an important reason for the abundance of competition (Jacobs et al., 2011). Currently, health insurance companies have insufficient insight in the performance of healthcare providers on the level of integrated care pathways because healthcare performance is often measured at the institutional level. Health insurance companies are therefore not able to procure health services according to the performance of healthcare providers on specific treatments (Jacobs et al., 2011). This may be an obstacle for the move towards demand driven healthcare in which transparency about the performance of healthcare providers for the treatment of specific diseases is required (see section 1.4.4).

1.4.3 Pay for Performance

This section discusses the third initiative concerning the introduction of the Pay for Performance principle in healthcare. The Dutch government, in coordination with health insurance companies and healthcare providers, agreed upon the *Bestuurlijk Hoofdlijnenakkoord Zorg*[3] (de Boer et al., 2011). In this document is agreed on a joint responsibility to put effort on limiting the growth of costs in healthcare and to increase the efficiency. The key actors will get a different role in healthcare than before in order to realize that joint responsibility. An important means to get there is improving the transparency of the performance of healthcare providers and health insurance companies. Therefore the new billing system DOT (DBC[4] Towards Transparency) has been introduced since the first of January 2012 (DOT, 2009), which makes healthcare more transparent by reducing the number of treatment combinations that can be billed by hospitals. The DOT systems facilitates no longer the registration of full treatments but only the registration of individual operations. The system itself derives a treatment form the sequence of operations that are registered in DOT. Besides the introduction of the DOT system, healthcare providers are obliged to report figures about the quality of their health services to health insurance companies, the government and patients.

Health insurance companies get a central role in the healthcare outline agreement. According to the agreement, the health insurance companies will be responsible for the procurement of high quality and appropriate (for their clients) care for an acceptable price. They form in that way an incentive for investments in innovation by healthcare providers. Healthcare providers that do not meet the requirements are forced to improve the health services they deliver or are have to disappear from the particular sub care market. The parties that will survive are the once that are able to deliver high quality health services. A more detailed description of the role of health insurance companies in the future healthcare market is given in section 2.3.1.

The introduction of the DOT system is closely related to plans of the Administration Rutte about the introduction of the Pay for Performance principle in healthcare (Lindenauer et al., 2007). This system is already proven (Grossbart, 2006) and implemented in several countries (Scott, 2007; Doran et al., 2006; Rosenthal and Dudley, 2007). In case of Pay for Performance, healthcare providers no longer receive a fixed price for the care they deliver (pay for quantity), but are paid for the quality of care they deliver.

Although not explicitly mentioned, integrated care pathways play a dominant role in the healthcare outline agreement. The purpose of this agreement is to reduce cost of healthcare by further standardizing integrated care pathways and steering towards innovation. This can be reached when health insurance companies contract healthcare providers that deliver high quality care (that meets the needs of the patient) for the treatment of specific diseases in an efficient way.

1.4.4 Demand-driven healthcare

A fourth initiative is the shift towards demand-driven healthcare. There is an important change in the policy opinion about demand-driven healthcare (Lako and Rosenau, 2009). The current configuration of the healthcare system is called supply-side healthcare. Healthcare providers are the ones who control the scarce medical resources and determine the distribution of health services in a supply-sided healthcare system. Patients do not make a choice on the basis of the performance of healthcare providers, but get their care at the healthcare provider they are referred to by their general practitioner (Lako and Rosenau, 2009). The move towards demand-driven healthcare is motivated by the idea that patients should no longer be bound to a particular healthcare provider but should be free to choose for a healthcare provider that delivers health services that meets the needs of the patient. This should lead to an increase in the accessibility and efficiency of healthcare (Burström, 2009) because health insurance companies get the role of procuring healthcare that fits to the needs of their clients. This means that they will procure healthcare at healthcare providers that deliver the best quality of care for the lowest price. Demand-driven healthcare is in that sense closely related to the idea of Pay for Performance as discussed in section 1.4.3. Healthcare resources are expected to concentrate at those positions in the healthcare

[3]The healthcare outline agreement
[4]DBC stands for Diagnosis Treatment Combination

system where the demand for health services is the highest. Healthcare demand is likely to concentrate at the healthcare providers that deliver services that meets the requirements of the patients best. However, all kinds of barriers may prevent healthcare resources from perfect allocation, like the existence of mobility barriers for people and capital and the presence of imperfect information.

1.5 Conclusions on developments in healthcare

The discussion on the developments in healthcare and the initiatives of the national government result in the following conclusions.

- There are four key parties in healthcare (patients, the government, healthcare providers and health insurance companies) that play an important role in the developments in healthcare. These parties have a key position in the healthcare sector. Careful consideration of the objectives and desires of the key actors is important to get them involved in any initiative that is deployed.
- Three important trends can be recognized in healthcare namely the increasing quality, demand and cost of health services. The increasing demand and cost of healthcare put pressure on the affordability and accessibility of health services for everyone.
- Several initiatives are developed or under development to reduce the negative effects of the trends in healthcare.
- The initiatives discussed in section 1.4.1 until section 1.4.4 are not always successful. This is demonstrated by the differences in the performance of the healthcare sector of Australia and the United States. Reasons for this may be
  - Population characteristics are an important determinant for the cost of healthcare. Differences in population composition may result in different performance figures for healthcare sectors in different countries.
  - The success of the initiatives depends on the presence of required preconditions. The initiatives are strongly interrelated. The preconditions of one initiative depend on the successful implementation of other initiatives.
    - Demand-driven healthcare requires transparency of information on the level of integrated care pathways. Patient are only treated best for a particular disease when they have that specific information. Information on the institutional level does not provide them the necessary information, because a good performing healthcare provider may under perform for the treatment of one or two specific diseases. In addition, demand-driven healthcare requires information about the performance of the whole care pathway because a general practitioner may have a good performance, where the hospital does not meet the requirements of the patient.
    - Transparency of information on the right level of detail is an important precondition for fair competition. This information can be calculated in the presence of clearly defined integrated care pathways. integrated care pathways enables the measurement of performance for the treatment of specific diseases. According to the healthcare outline agreement, health insurance companies have to procure healthcare on these performance figures.
    - Pay for performance can only be introduced when information is available on the right level of detail.
- As demonstrated by the above mentioned points, the transparency of information seems to be one of the most important precondition for the success of the proposed initiatives.

1.6 Focus of the research

One of the most important developments in healthcare is the changing role of the health insurance companies (see section 1.4.3). The new and crucial role of health insurance companies is directly or indirectly related to the four initiatives and may have impact on the success or failure of these initiatives with respect to the cost, quality and efficiency of health services.

This research focuses on the changed position of the health insurance companies and the facilitation of these companies in realizing the healthcare objectives. These objectives are defined in the healthcare outline agreement where is stated that health insurance companies are expected to procure health services that are efficient, appropriate, affordable and have a high quality (see section 1.4.3).

1.7 Readers guide

This research follows a clear structure. The first chapter gives an introduction to the healthcare system and current important developments in healthcare. Subsequently, this chapter discusses the initiatives that are deployed in order to deal with the negative effects of the developments in healthcare and to secure the core values of the healthcare system over the long term. Chapter 2 comprises a discussion on the Dutch healthcare market and the prerequisites that are set by the market conditions for the role of health insurance companies concerning the procurement of health services on predefined KPIs. The problem situation is summarized in chapter 3. This chapter comprises also the design objective and the research questions that need to be answered in order to realize the design objective. Chapter 4 comprises a discussion and examination of KPIs that are appropriate for the evaluation of the performance of healthcare providers on the right level of detail. Chapter 5 comprises an introductory discussion on the basics of the analysis technique (DEA) that is used in this research for the quantification of the efficiency of healthcare providers on the level of integrated care pathways. A discussion on the application and execution of this method on integrated care pathways is given in chapter 6. Chapter 7 presents a standardized method for the quantification of the performance of integrated care pathways as the main deliverable of this research. The consequences of the implementation of a healthcare procurement model are discussed in chapter 8. Chapter 9 presents the conclusions and recommendations of this research and the limitations are discussed in chapter 10.

Chapter 2

Healthcare Market Analysis

The initiatives that are discussed in chapter 1 have the purpose to secure the core values of the healthcare system over the long term by intervening in the market operations. The initiatives facilitate a move towards more competition on the healthcare market between healthcare providers and health insurance companies. This research focuses on the facilitation of health insurance companies in fulfilling their new role in a changing healthcare market. The health insurance companies have to operate in the changing market and to fulfill their role as defined in the healthcare outline agreement. This chapter discusses the consequences of a changing healthcare market for the role of the health insurance companies and defines the prerequisites for a method that is used by health insurance companies for the quantification of the performance of healthcare providers. Understanding the market organization and the characteristics of the Dutch healthcare market are essential for putting the role of health insurance companies into perspective and understand what is requirements should be fulfilled to facilitate the role of health insurance companies in healthcare.

This chapter starts with a description of the Dutch healthcare market and the ongoing change towards more competition. Furthermore is demonstrated that the shift towards more competition asks for the availability of information. Healthcare procurement on predefined KPIs seems to be a good means for restoring information to the market when it complies with the requirements for effective procurement. These requirements are partly determined by the responsibilities health insurance companies have and partly by the market conditions under which health insurance companies operate.

2.1 Characteristics of the healthcare market

As mentioned above, the characteristics of the healthcare market may have serious implications for a method for the quantification of healthcare performance as such a method should comply with the requirements that are set by the market organization. This section discusses the main characteristics of the Dutch healthcare sector. Section 2.1.1 gives a general description of the healthcare market. The products and its characteristics that are traded on the healthcare market are discussed in section 2.1.2. Section 2.1.3 discusses the market mechanisms that enable the trading of healthcare products on the healthcare market.

2.1.1 Healthcare market structure

Section 1.1.2 discusses the position of the key actors on the healthcare market. The healthcare market can be divided in several sub-markets with the help of figure 2.1. Three sub markets can be distinguished namely the *care market*, the *healthcare procurement market* and the *health insurance market*. These sub-markets are shortly discussed below. Each sub market has its own supply and demand side.

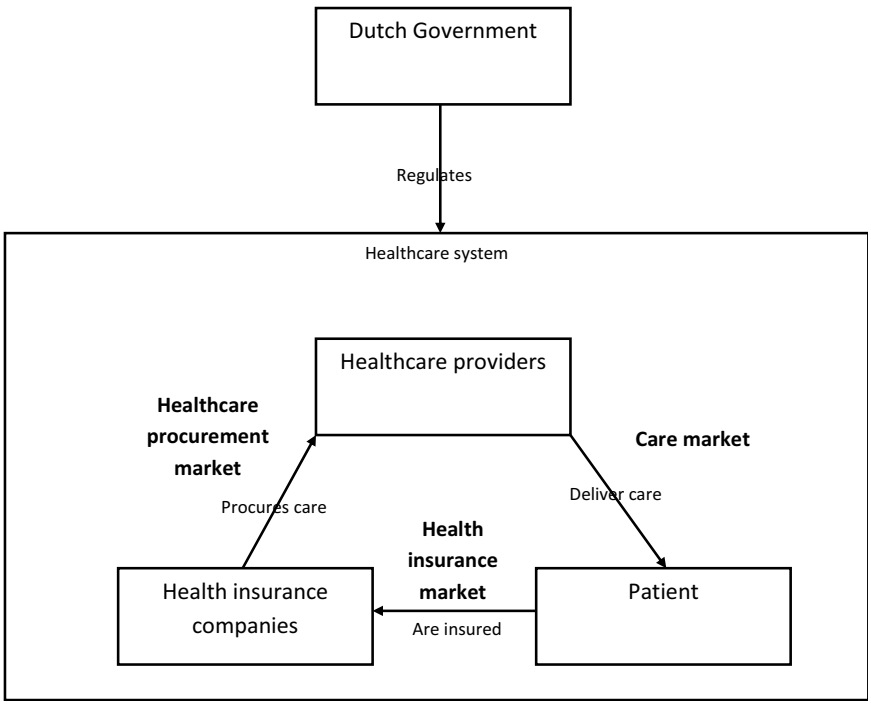


Figure 2.1 – Layout of the healthcare market (based on (Jacobs et al., 2011), p. 9)

Care market The care market is the market between healthcare providers and the patient. Patients are the demand side of this sub market and get their required care at the supply side of the market, namely the healthcare providers. Patients do not directly pay the cost of health services to the healthcare providers. The cost of care that is delivered to the patient is reimbursed by the health insurance companies.

Healthcare procurement market The sub market that exists between health insurance companies and healthcare providers is defined as the healthcare procurement market. Health insurance companies procure health services at healthcare providers according to the demand of their insured population. Health insurance companies represent in that way the demand side of the procurement market, where healthcare providers form the supply side of the market.

Health insurance market The connection between the health insurance companies and the patients is defined as the health insurance market. Patients are free to insure themselves at a specific health insurance company. The patient can here be seen as the supply side of the health insurance market, where health insurance companies (supply side of the health insurance market) deliver insurance services to the patient.

2.1.2 Healthcare products

The characteristics of the products that are traded on the healthcare market may have serious consequences for the procurement of healthcare. Dependent on the product characteristics, some product may be traded most effective in a free market (individual goods and services) where other product may require more regulation (quasi-public and public goods and services).

The healthcare product is defined as the end result delivered by an integrated care pathway after the treatment of a patient. The treatment itself is not seen as the healthcare product which is traded on the healthcare market, but as the production process that is required for the realization of the end result. This can be made clear by an example. The patient that has the diagnosis of torn muscles may get different treatments at different healthcare providers. One healthcare provider may prescribe rest and some medicines where other healthcare providers perform a surgical procedure. The desired end result is in both cases the cured patient. Competition will take place on the end-product and not on the production process that is required to reach

the end-result. However, the production process may be affected by competition on the end-product when there are practices in the production process that lead to a significant better end product. The following main characteristics can be distinguished for healthcare products

- health services are quasi public services
- The healthcare end-product is homogenous while the treatments are heterogeneous

health services are quasi collective services (Dalen and Swank, 1996). This means that healthcare product are publicly available for everyone but delivered by individual healthcare providers. Healthcare providers and health insurance companies are founded to deliver these services on behalf of the government and to fulfill a beneficial role for everyone in the society (Kooreman, 2011). The fact that health services are quasi public means that the cost of healthcare are not fairly distributed among the Dutch population. Older people have a higher demand for health services than younger people. One percent of the population consumes twenty-five percent of the cost of healthcare, where fifty percent of the population consumes only three percent of the cost of healthcare (Gordon, 2010). The healthcare end product as described above is a homogenous product, while the treatment process may be different for the integrated care pathways of different healthcare providers.

2.1.3 Market mechanisms

The healthcare market comprises several mechanisms that enable the trading of health services. The following market mechanisms are present on the healthcare market

- coordination of supply and demand of health services
- allocation of healthcare costs
- procurement of health services

The coordination of supply and demand on the healthcare market is required in order to balance supply and demand on the healthcare market. The balance of supply and demand of health services on the Dutch healthcare market is organized differently from healthcare markets in other countries. Major reason for the current construction are the characteristics of the healthcare products. As discussed in section 2.1.2, healthcare products are quasi public goods and the allocation of costs among the customers (the patient) is imperfect. The coordination of supply and demand are organized as it is in order to guarantee the accessibility of healthcare for everyone, independent of the demand for health services of an individual patient. The supply of health services by healthcare providers is fragmented due to the different focus healthcare providers have. The demand of healthcare is concentrated at health insurance companies which are responsible for the procurement of healthcare on behalf of the insured population.

The allocation of healthcare costs is an important mechanism that enables the affordability of health services for everyone. For that reason, group insurance is introduced in order to realize an even distribution of costs among the Dutch population. All people in the Netherlands pay the same premium for a certain package of health services which

Health insurance companies are responsible for the procurement of healthcare at the healthcare providers. Patients are allowed to get their care only at the healthcare providers that are contracted by their health insurance company. Healthcare is organized this way in order to make the demand for healthcare plannable. This is necessary for keeping the cost of healthcare low and increasing the efficiency of healthcare by the effective allocation of resources. Healthcare products are split up in A-segment and B-segment treatments. A-segment treatments have a fixed price. B-segment treatments have a variable price on which is negotiated between health insurance companies and healthcare providers. More and more treatments are transferred from the A-segment to the B-segment in order to increase competition among healthcare providers and drive down the prices of health services.

2.2 Shift in Dutch healthcare market

The current organization of the healthcare market seems to be inadequate in safeguarding the core values of the healthcare system. This is demonstrated by the developments discussed in section 1.3. The initiatives that are deployed facilitate a move towards a more competitive market in order to safeguard the core values of the healthcare system over the long term. This section discusses what changes are taking place on the healthcare market and what the consequences of this change are for the role of health insurance companies.

2.2.1 Current situation

For long is thought that the core values of the healthcare system can be safeguarded best by a fully regulated market. The healthcare sector was fully regulated until twenty five years ago(Enthoven and van de Ven, 2007). However, for several years, policy makers in healthcare got the insight that a fully regulated market is not the most effective way to organize the healthcare market in the Netherlands. This insight may be evidenced by the current fast rising cost of healthcare. Currently, the healthcare market is for a part strictly regulated and noncompetitive (Enthoven, 1993). However, health insurance companies and healthcare providers can negotiate about the prices of the DBCS in the B segment (see section 2.1.3) which take an increasing part of all treatments that are executed in healthcare.

Commonly it is assumed that a regulated market is a disincentive for the improvement of efficiency and the reduction of the cost of health services. There are some justifications for this assumption. The quality of information[1] in a regulated healthcare market is in general poor, as there is no direct necessity for the provision of sound information. In case of the lack of information transparency it is difficult to steer on performance improvement and to maintain norms and standards for cost and quality. Even the national government does not have full insight in the performance figures of healthcare providers. Healthcare information is asymmetric (Anderson et al., 2001). Each healthcare provider and health insurance company has its own information database. The information is stored different in the different databases and gives in that way a different picture about the performance of the healthcare system in general and healthcare providers and integrated care pathways specifically to the different key parties in healthcare. Information is for many KPIs incomplete and performance figures of healthcare providers are currently often unavailable for many KPIs.

2.2.2 Future situation

Currently there is a ongoing shift from a fully regulated healthcare market towards managed competition. This is demonstrated by the initiatives for change in healthcare towards a more competitive market as discussed in section 1.4. The move towards a different organizational form is driven by the risk of core values that cannot be maintained in the future. The core values of the healthcare sector does not change a lot over time but the priority changes due to the changing performance of the healthcare sector as a whole. The quality of healthcare rose quite rapidly in the past decades, even did the cost of health services. The priority in healthcare has therefore shifted towards the reduction of costs and the improvement of the efficiency of health services.

More competition seems to be a good means for maintaining the core values of the healthcare sector in the future as managed competition may have some serious benefits compared to a fully regulated market (Enthoven, 1993)

- More efficient allocation of resources on the market
- Lower prices due to productivity improvement and the development of cost-reducing technologies
- More flexible healthcare system that can deal with changing population characteristics (aging phenomenon)
- The healthcare system is likely to become more customer friendly (a better focus on the preferences of the patient)

[1] Information quality is often measured on the criteria transparency, symmetry, completeness and reliability.

- Customer may make cost-quality trade-offs in the future due to the insight in price and quality of healthcare services

The benefits of fair competition can only be realized when the preconditions for fair competition are present in the healthcare market. The following preconditions for fair competition should be present on the healthcare market

- large number of buyers and sellers
- low entry and exit cost
- high factor mobility
- sound and transparent information
- low transaction cost
- homogeneous products

Where most of the preconditions can be realized by unilateral actions, is the quest for information a more though issue to be dealt with. The provision of sound and relevant information asks for a mechanism that can provide this information to the healthcare market. The quest for information is discussed in more detail in section 2.2.3.

2.2.3 Quest for information

A shift towards fair competition asks for the provision of sound and relevant information to the relevant actors on the several sub markets that are discussed in section 2.1.1. All market operations on the sub-markets require information in order to facilitate fair decision making. Section discusses which topics are important when one will define what information is relevant. Section discusses the criteria that are used for the examination of the quality of information. The chapter rounds up with a discussion on which information is exactly required on the sub-markets in order to facilitate fair decision making.

2.2.3.1 Steps towards perfect information

Lack of information may distort the market and disables fair competition. Information delivers power to the demand side of the market by offering the possibility to take a deliberate choice for the procurement of goods and services. Market power at the demand side puts pressure on innovation and performance improvement at the supply side of the market. Lack of information, or *bad* information may result in unfair competition where healthcare providers can benefit from their current position without improving their performance. This is ultimately demonstrated by the introduction of competition among dentists this year where the lack of information and barriers for the accessibility of information distorts competition on and leads to the increase of prices for the client. Therefore the following topics should be realized

- Clear definition of a complete set of goals for the healthcare sector
- Clear definition of KPIs
- Measuring information on the right level of detail
- Safeguarding confidential information
- Transparency about high quality of information to relevant parties

A clear definition of the goals for the healthcare sector makes it possible to define the relevant criteria on which competition among healthcare providers should take place. Healthcare providers should not compete on irrelevant performance figures (like f.e. the exterior of the building) because that may be a barrier[2] for realizing the goals of the healthcare system and for securing the core values. Furthermore it is important to define clear KPIs. Clearly defined KPIs may help to increase the insight at both the supply and demand side of the healthcare sector in the performance of healthcare providers on predefined goals. It may help healthcare providers to improve their performance and at the same time deliver the performance insight to the demand side on which they can decide to procure healthcare. It is for that reason important that information is measured at the right level of detail. Performance figures at the institutional level does not tell a lot about the performance of a healthcare provider on specific treatments[3]. Safeguarding confidential information is an important prerequisite for fair competition. Competition cannot take place when there is transparency about all kind of production characteristics. Health insurance companies will get an undesirably powerful position in the negotiation process.

2.2.3.2 Examination of information quality

High quality information, measured on transparency, symmetry, completeness and reliability, is therefore an important prerequisite for fair competition among healthcare providers Robinson (1934). Information on the above mentioned topics should be available in the right quality in order to facilitate fair competition. Low quality information may also have a disturbing effect on competition as it may be misleading and therefore leads to the wrong decisions. The following criteria are often used for the examination of information quality. Information should be

- transparent (Angeletos and Pavan, 2004)
- symmetric
- complete (Kahn et al., 2002)
- reliable (Lee et al., 2002)

Information should be transparent in order to enable the easy interpretation of the performance figures. Transparency can be seen as the degree of accuracy of information (Angeletos and Pavan, 2004). Patients may make the wrong decision when there is a lack of transparency of information in healthcare. This may lead to unfair competition among healthcare providers. Competition will at least not function as it is meant to because patients do not automatically go to the best performing healthcare provider. Symmetry of information is especially important for the healthcare providers and health insurance companies. Healthcare providers should have insight in the performance figures on which the procurement of health services is based in order to be able to improve their performance. Information needs to be complete for all relevant KPIs in order to guarantee the procurement of health services that have the highest performance. The completeness of information is also important for patients. The customer will base his decision on available information. Both patients and health insurance companies may take the wrong decisions when relevant performance figures are missing. Unreliable information may be misleading for the patient and may in that sense lead to unfair competition among healthcare providers. Additionally, patients may become immobile when they do not trust the quality of information. They are then likely to go to the nearest healthcare provider and do not base their decision on the performance of integrated care pathways.

2.2.3.3 Required information topics

A lot of information is required in order to enable fair competition on the sub markets in healthcare. As mentioned before, fair competition requires perfect decision making, which is only possible in case of the

[2]Healthcare providers may put effort in realizing irrelevant goals instead of the relevant ones.

[3]The performance at the institutional level is the average performance of a healthcare provider. The performance on specific treatments may deviate from the average performance.

provision of perfect information. Several decisions are taken on the sub markets of the healthcare market (The sub markets are discussed in section 2.1.1). One can distinguish the following decisions

1. *healthcare procurement market*

    1.1 Which healthcare providers do I have to contract? (health insurance companies)

    1.2 What criteria determine whether I get a contract? (healthcare providers)

2. *health insurance market*

    2.1 Where to disclose my insurance? (patient)

    2.2 What are the patients needs? (health insurance companies)

3. *care market*

    3.1 Where should I get my treatment? (patient)

    3.2 What are the patients needs? (healthcare providers)

4. *general questions*

    4.1 What is the actual performance of healthcare providers? (national government)

    4.2 What are the needs of the patients? (national government)

One should remark that decisions are taken by both the supply as the demand side of the healthcare sub markets. As already stated, decision making involves a lot of information. Figure 2.2 shows what information streams are required on the healthcare market in order to facilitate decision making. The required information flows always from one or multiple actors to the actor that has to take the decision. This supply of this information should enable the relevant actors on the healthcare market to take deliberate decisions as long as the quality of information is guaranteed. The black arrows represent the norms and standards that are set by the national government. The dashed arrows represent the wishes and desires of the patients. The thin arrows represent the performance figures of the healthcare providers.

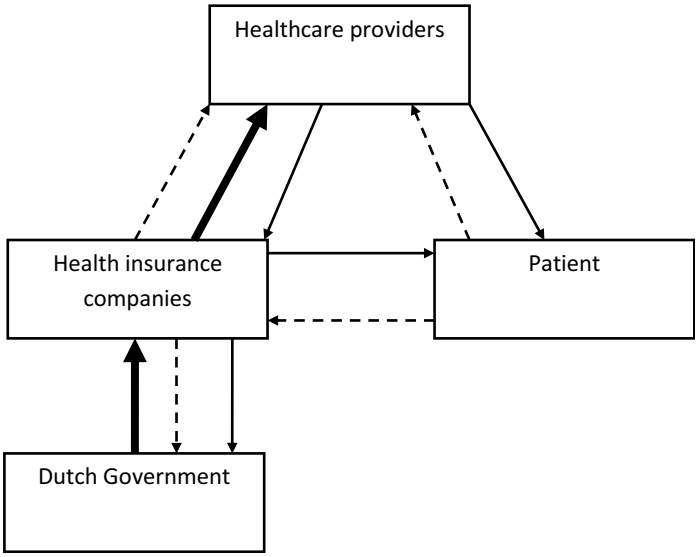


Figure 2.2 – Information streams in healthcare

Decision 1a is important for health insurance companies. They have to take care to contract healthcare providers that deliver health services that meet the desires of their insured population. This requires information about the performance of healthcare providers but also about the wishes and desires of their insured population

and about norms and standards for minimal required performance of the health services. These norms and standards are set by the national government. Decision 1b is an important decision for healthcare providers. The criteria for the procurement of health services determine what the focus of healthcare providers is by investments in quality improvements. This requires information about the desires of the patients[4] and about norms and standards for the performance of healthcare providers because healthcare providers have to comply with the norms and standards that are set by the national government. Subsequently, information about their own actual performance in comparison with competitors is required in order to be able to determine how effective innovation investments may be.

Decision 2a is a relevant decision for patients as it may determine where patients can be treated for a specific disease. A fair decision at this point requires information about the performance of the healthcare providers that are contracted by the health insurance companies. Decision 2b is a decision that is important for health insurance companies as it determines how well health insurance companies are able to attract patients that would like to be insured by a specific health insurance company. This information can be used by health insurance companies to improve their contracting policies to fit better to the needs and desires of their insured population.

Decision 3a is an important decision for patients as it determines whether they are treated for a specific disease according to their desires. This decision requires information from healthcare providers about a complete set of performance figures. This makes it possible for patients to make a trade off between different healthcare providers on the basis of criteria that are relevant for them. Decision 3b concerns the position of the healthcare providers. They have to focus on health services that meet the requirements of patients in case of fair competition, because that enables them to increase the demand for their health services.

Some additional decisions are taken by the national government that affect competition on the sub markets direct or indirect. This concerns the decision about interventions in market operations due to market failure or undesirable trends in the performance of healthcare providers or health insurance companies. This requires on one hand the information about the performance of healthcare providers and on the other hand information about the desires of patients. The national government may decide to introduce policy measures when there is a gap between the actual performance of healthcare providers and the desired performance from the point of view of the patients.

2.3 The procurement of health services

In the healthcare outline agreement is defined that health insurance companies get an important role in the procurement of health services on predefined criteria in order to reduce the cost and increase the efficiency of health services. As one can see in figure 2.2 healthcare procurement involves all information streams that are relevant for decision making on the sub markets in healthcare. In addition, health insurance companies play a central role in the supply of information as other key actors require information for making good decisions that is stored at the health insurance companies. Health insurance companies are already experienced with the procurement of health services in a different form and are for that reason probably the ones that are most experienced with the procurement tasks. Furthermore they are a kind of intermediate actor and may for that reason most suitable for the procurement of health services in which the interests of both the supply as the demand side of the healthcare market have to be taken into account. For that reason healthcare procurement by health insurance companies may be an ultimate means for restoring information to the healthcare market.

It is important for effective procurement of health services that healthcare procurement complies with the data requirements mentioned in section 2.2.2. Healthcare procurement on predefined KPIs may put pressure on healthcare providers to give insight in their performance figures because healthcare providers can only enforce a contract with health insurance companies when they deliver health services that fit to the desires of the insured population of health insurance companies.

[4]The desires of the patients determine the procurement criteria.

2.3.1 Role and responsibilities of health insurance companies

The healthcare outline agreement give a proper definition of the future[5] role and responsibilities of health insurance companies in the healthcare market. Their role and responsibilities are discussed in this section into more detail. Health insurance companies, together with the government and healthcare providers, agreed on two major responsibilities, namely

- the deliverance of appropriate care to their clients
- steering towards an efficient organization of the healthcare sector.

The first responsibility concerns the task of the health insurance companies concerning the interest of their clients. In the healthcare outline agreement, all parties agreed on the role of the health insurance companies to procure healthcare that fulfills the following criteria in the interest of their clients

- efficient
- appropriate
- low price
- high quality

The efficiency of health services concern the degree at which integrated care pathways are able to use minimal inputs to generate maximal outputs. health services are appropriate when health insurance companies procured the right quantity of high quality services for a low price. In addition, patients should be satisfied with the healthcare they get by the healthcare providers.

The second responsibility concerns the task of the health insurance companies according their steering role in the healthcare sector. According to the healthcare outline agreement, health insurance companies should steer towards a more efficient organization of the healthcare sector with the focus on the following criteria

- quality
- accessibility
- affordability

The responsibility concerning their steering role is specified into more detail. As guideline for the procurement of health services is set that the increase in cost of these service is limited at 2.5% in 2012. This guideline may be a direct incentive towards healthcare providers to become more cost effective. The focus on the quality of care should guarantee that the quality of health services will not drop. Health insurance companies should also steer at the reduction of variety in performance among healthcare providers. Furthermore, health insurance companies have the obligation to facilitate the spread and specialization of healthcare providers when this is desirable from the point of view of the quality and efficiency of health services and the innovative power of the healthcare sector.

The most important means, health insurance companies have to execute their two main responsibilities is the performance based procurement of health services. This fully changes their role on the healthcare market. a first step towards effective healthcare procurement is the provision of sound and relevant information to the healthcare market as demonstrated by figure 2.2. Health insurance companies play an active role in the provision of information. However, on the longer term, it is likely that the position of health insurance companies will become more passively. This situation is visualized by figure 2.3. This new situation may lead to a whole new infrastructure for the provision of information. Where in the past each actor in the healthcare sector stored their own information, will all information in the new situation be centrally stored. The central storage can be accessed by the key actors in the healthcare sector. This may help to solve issues about information asymmetry

[5]The healthcare outline agreement covers the period from 2012 until 2015

and information quality management may become much simpler with the help of single protocols that apply for all information that is stored in the central database[6]. Subsequently, information streams will no longer flow in one direction, but can be accessed by the relevant actors at each point in time. All actors in the healthcare system would be able to access the information that is relevant for them as a basis for decision making on the healthcare sub-markets. However, this new situation may at the same time give rise to worries about the confidentiality and security of information. Proper authorization that regulates the accessibility of information for the different parties in healthcare is for that reason a minimum requirement. Health insurance companies for example should not get access to the production information of healthcare providers, because that would distort competition. The same is true for *all* key actors on healthcare. Each actor should only get access to the information that is relevant for competition on their particular sub-market.

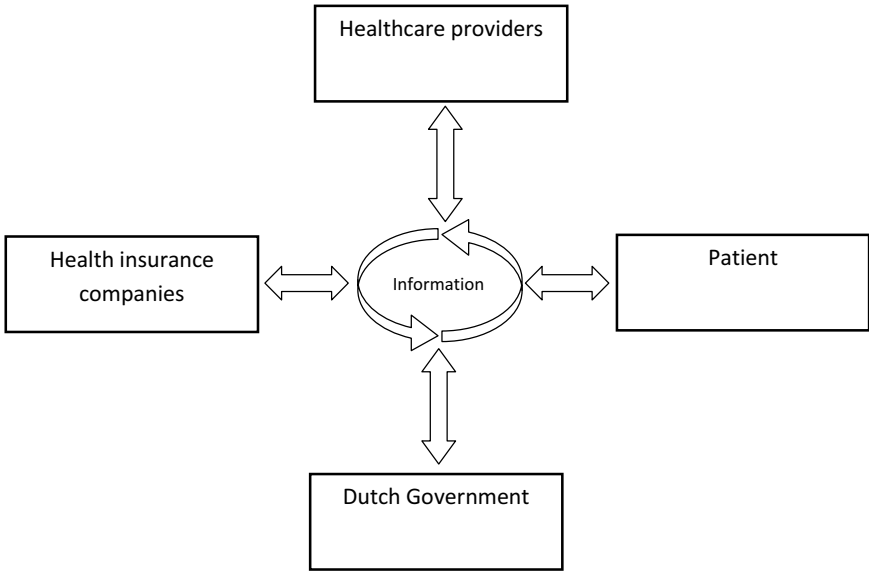


Figure 2.3 – New situation for the provision of information on the healthcare market

2.3.2 Procurement at the integrated care pathway level

As mentioned in section 2.3.1, health insurance companies has the responsibility towards their clients to procure appropriate health services. This means that health insurance companies have to procure disease specific health services. From the start of 2012, health insurance companies have to procure health services based on the actual performance of healthcare providers, in order to be able to realize their responsibility. It is for that reason important to measure the performance on the right level of detail. Figure 2.4 demonstrates the performance of different healthcare providers on the level of the specialism.

[6]The central storage may be a physical data center or f.e. the cloud.

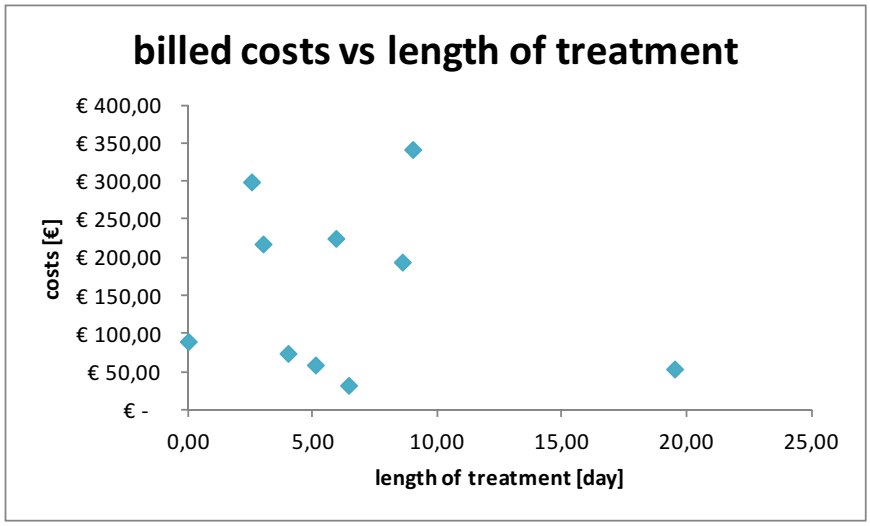


Figure 2.4 – Billed costs vs length of treatment for specialism X

Each specialism comprises a broad range of treatments. From the figure becomes clear that the performance on the specialism level becomes incomparable. One specialism may treat a complex set of treatments which affects the performance figures to a larger extent and makes it impossible to compare healthcare providers at the specialism level. health services are procured at the level of individual services. Therefore it is necessary to quantify the performance of healthcare providers on the level of specific treatments. However, there may arise a problem when a single treatment is executed by more than one healthcare provider[7]. This is often the case for more complex situations as explained in section 1.4.2. The performance of a particular healthcare provider is in that situation not longer sufficient to measure the quality of the full treatment. It is therefore important to measure the performance at the level of integrated care pathways instead of the particular healthcare provider. This enables the directed purchasing of health services that are appropriate for the patient in terms of cost, quality and efficient transformation of inputs to outputs. In addition, this makes it possible to realize fair competition on the level of integrated care pathways. This has a major benefit. Competition is no longer a matter of a particular healthcare provider but of all healthcare providers that are involved in the treatment of a particular patient. This enables the performance improvement for the whole treatment where this is impossible in the current situation, where only the performance of a particular healthcare provider is taken into account on the institutional level. Improvements at a particular healthcare provider do not necessary lead to the improvement of the whole treatment, because a particular healthcare provider is only responsible for a part of the treatment and does not control the performance of other healthcare providers that are involved in the treatment of a patient.

There is another important reason for measuring the performance on the level of integrated care pathways. Because, despite the introduction of integrated care pathways, process innovation[8] in healthcare only took place on a limited scale. This is caused by the fact that local healthcare providers only improved their products and processes with the help of local knowledge, experiences and best practices. Steering on the performance of integrated care pathways offers the possibility to compare integrated care pathways among each other on a national scale. Where currently, healthcare providers mainly improve their processes with the help of local best practices and experiences may it be possible in the future to exchange the best practices and experiences on a national scale.

The procurement of healthcare on the level of integrated care pathways has many implications for the healthcare system. This will be discussed into detail in chapter 8.

[7]The integrated care pathway is in that situation transcending the physical border of healthcare providers.
[8]Process innovation delivers the possibility to reduce cost by a more efficient treatment process design.

2.4 Implications for health insurance companies

In this chapter is demonstrated that healthcare procurement seems to be an effective means for restoring information to the healthcare market and that healthcare procurement should ultimately be executed by health insurance companies. In order to be effective in restoring information to the healthcare market by the use of healthcare procurement, the procurement of health services has to comply with a set of preconditions. The preconditions are partly determined by the healthcare market organizational form and conditions and partly by the responsibilities health insurance companies have according to the healthcare outline agreement.

The following preconditions for the procurement of health services are shaped by the responsibilities that health insurance companies have, as discussed in section 2.3.1.

- The procurement of healthcare should comply with the interest of the patient concerning the efficiency, appropriateness, price and quality of health services.
- The procurement of appropriate healthcare for the patient has to take place at the level of particular treatments instead of the institutional healthcare provider level.
- Effective procurement on the treatment level requires the quantification of performance figures on the level of healthcare provider transcending integrated care pathways.
- The procurement of health services should take place in such a way that it is an effective means for steering towards a more efficient market with the focus on quality, accessibility and affordability. This means that the quantified KPIs can be used as input for a healthcare procurement method and a performance benchmarking study[9].
- Confidential information about process related parameters of healthcare providers should not be shared among health insurance companies in order to prevent disturbance of competition. This concerns information about the production costs of healthcare and the exact process that is followed by a healthcare provider during the treatment of a patient. Insight in this information by health insurance companies may lead to a position in which health insurance companies have too much power. Healthcare providers do in that situation have no position at all in the negotiation process because there is no possibility for the exchange of information (Thompson, 1991); health insurance companies possesses all information.

The following preconditions for the procurement of health services are shaped by the healthcare market characteristics and are required in order to enable fair competition among healthcare providers on the level of integrated care pathways

- Procurement should be based on clear KPIs that measure the performance on broadly agreed goals of the healthcare system.
- Procurement on predefined KPIs should deliver transparency of information to the relevant parties (patients, healthcare providers and health insurance companies).
- A high quality of information is required in order to enable fair competition.
- The procurement itself should be a transparent process in order to facilitate fair competition among healthcare providers. Criteria for procurement should be known by all relevant parties.
- Competition takes place at the level of integrated care pathways. Procurement of health services should for that reason be an incentive for performance improvement of the performance of all healthcare providers that are involved in an integrated care pathway.

[9]There is elaborated more on this in section 9.3.1 and section 9.3.2.

2.5 Limitations to the concept of competition

Some limitations to the concept of fair competition can be recognized by analyzing the healthcare market which seems not to be easily handled by accurate management of competition, namely

- Imperfect competition on the health insurance sub market
- The never ending story of information quality management
- The quest for plannable healthcare

Competition on the sub market for health insurance is not likely to function accurate as patients do not care about which healthcare providers are contracted by their health insurance company when they are healthy. Health insurance companies have for that reason a quite strong position on this market. Especially because of the case that many of them merged. This reduced competition on the health insurance market even more. Subsequently, as mentioned in section information quality is never perfect as the gathering of information involves a lot of actions which may damage the quality of information. This has the consequence that competition is based on imperfect information. Decisions on the healthcare market are for that reason never perfect which may have its drawback on the outcomes of competition. Healthcare cost may not decrease as opposed and the efficiency of health services will never be perfect. A last point is the quest for plannable healthcare which requires long term contracts in healthcare. The consequences of the concept of plannable healthcare are discussed in more detail in section . These imperfections does not mean that competition cannot take place in healthcare, but that competition never will be perfect. This has its impact on the expected outcomes of competition[10].

[10] Competition is expected to reduce cost and increase efficiency under fair competition.

Chapter 3

Problem Description and Design Objective

The previous chapters discuss the current trends that are present in healthcare and how the initiatives that are developed to cope with those trends intervene in market operations. This chapter gives a description of the problem as it is faced by the health insurance companies as they are the party that get the main responsibility in realizing the goals that are defined in the healthcare outline agreement. Subsequently this chapter defines a design objective concerning a method that helps the health insurance companies in realizing their responsibilities.

3.1 Problem description

This research focuses on the facilitation of the new role that the health insurance companies get according to the healthcare outline agreement. However, first a problem description will be given to put the role of health insurance companies into perspective.

Section 1.3 discusses the ongoing developments in healthcare. The urgency of these developments becomes clear from the prominent place these developments have on the governmental agenda in most Western countries. These developments ask for effective measures that reduce the negative effects of the developments and guarantee the maintenance of the core values of the healthcare system over the long term. The objectives of the measures that are initiated by the government are summarized in the healthcare outline agreement. There is stated that the national government, the health insurance companies and the healthcare providers have the obligation to focus their effort on the reduction of cost and the increase of the efficiency of the healthcare sector. The document mentions that the transparency of information in healthcare should be increased in order to enable fair competition which is used as a means for the realization of the above mentioned objectives. The quest for more transparency demonstrates that the supply of information in healthcare currently does not have the right quality. A part of the required information is publicly available to everyone, but the major part is privately held or not available at all. To improve the quality of information, health insurance companies get the role of procuring healthcare on predefined criteria. Section 2.3 shows that healthcare procurement by health insurance companies on the level of integrated care pathways may be an effective means for restoring information to the healthcare market. However, a lot of prerequisites need to be fulfilled in order to be able to effectively procure healthcare on predefined criteria and deliver information that is sound and relevant. Many of these prerequisites are currently not in place and limit health insurance companies in the execution of their role.

3.2 Problem statement

The problem owner for this research is KPMG Management Consulting. They often take the role of adviser in situations as sketched in section 3.1. The problem from the perspective of the problem owner can be defined as follows:

> Cost of healthcare in the Netherlands are increasing to an untenable extent due to high investments in product innovation. The national government, in cooperation with health insurance companies and healthcare providers, are developing several initiatives to guarantee the future quality and affordability of healthcare. According to the healthcare outline agreement, health insurance companies should take a leading role in these initiatives. A proper implementation and functioning of the initiatives require transparency of information in healthcare on all sub-markets. However, there is currently a lack of transparency of information in healthcare. Health insurance companies do not have sufficient and complete information to evaluate the performance of integrated care pathways for the procurement of healthcare. They need this information in order to reach the goal of the government with respect to the objectives defined in the healthcare outline agreement according their responsibility for the procurement of healthcare that fits to the patient's interests and their ability to steer towards a more efficient healthcare system. Health insurance companies need facilitation in order to be able to execute their role defined in the healthcare outline agreement.

3.3 Desired situation

The desired situation from the point of view of the key actors in the healthcare sector is described in the healthcare outline agreement. The desired situation can be defined as a situation in which healthcare providers deliver appropriate health services to the patient in an efficient way and facilitate the initiatives of the national government towards more competition by the procurement of health services on the actual performance of healthcare providers. Health insurance companies get the responsibility for the procurement of health services on predefined criteria in order to realize these objectives.

The desired situation for KPMG can be defined as a situation in which KPMG is able to facilitate health insurance companies in their role in healthcare. This means that KPMG is able to deliver a method to health insurance companies that enable them to execute their new role in healthcare. Health insurance companies on their turn can use this information as a basis for the procurement of health services. According to section 2.4 the facilitating role of KPMG should lead to transparency of relevant information on the right level of detail for the relevant actors. This should lead to the procurement of health services on the basis of broadly agreed KPIs that measure the performance of integrated care pathways on the goals of the healthcare system. Healthcare procurement should led to the provision of sound and relevant information to the healthcare market. This information will enable fair competition among healthcare providers, which, in the end, will lead to the reduction of healthcare cost and the increase of the efficiency of health services.

3.4 Design objective and research questions

This research has the purpose to take a first step towards the desired situation in healthcare as described in section 3.3. Therefore, this research focuses on fulfilling the prerequisites that are necessary for health insurance companies to execute their role in healthcare properly, by the design and execution of a method for the quantification of healthcare performance on the integrated care pathway level. This method should function as a basis for further steps towards a broadly agreed healthcare procurement model and should enable healthcare performance benchmarking.

3.4.1 Design objective

The method that is proposed in this research should ultimately fulfill the requirements set in section 2.4 and comply with the responsibilities of the health insurance companies as defined in the healthcare outline agreement. That brings us to the following design objective:

> *Design a method for the evaluation of the performance of healthcare provider transcending integrated care pathways on broadly agreed criteria which may serve as a basis for a healthcare procurement model.*

This method may help to deliver relevant and high quality information to the healthcare market in order to

- facilitate health insurance companies to execute their new task in healthcare concerning the realization of the objective defined in the healthcare outline agreement by the procurement of health services on predefined criteria and
- restore information to the healthcare market with the purpose to facilitate the realization of the cost reducing initiatives mentioned in section 1.4.

3.4.2 Research questions

The design objective as formulated under section 3.4.1 can be realized by answering the following research questions:

1. What are the relevant goals of the healthcare system from the point of view of the key actors in the healthcare sector?
2. Which Key Performance Indicators are currently used to examine the performance of integrated care pathways on these goals?
3. What is the relative importance of the goals for different actors?
4. Which factors may have a disruptive impact on the comparability of the performance figures of integrated care pathways?
5. Which general method can be defined for the quantification of the performance of healthcare providers on the right level of detail?
6. What may be the impact of implementation of the proposed method on the performance of the healthcare system?

Providing an answer on research question one is a first important step. The relevant goals of the healthcare system from the point of view of the key actors in the healthcare sector determine which KPIs should be used by health insurance companies as a basis for the procurement of health services. Answering question two gives insight in the current available KPIs and determine whether additional KPIs are required in healthcare for measuring the performance of integrated care pathways. The relative importance of the different goals depends on the interests of the key actors in healthcare and is important for the procurement of healthcare. It is not possible to determine which alternative among all integrated care pathways is the most preferable one, without knowledge about the relative importance of the KPIs. This information is important for health insurance companies because they are responsible (according to the healthcare outline agreement) for the procurement of health services that fits best to the interest of the patient. The performance of integrated care pathways may be significantly affected by underlying differences among healthcare providers. It is important to adjust the performance of integrated care pathways in order to be able to compare the integrated care pathways among each other. The answer on research question five can be given with the help of the information that is gained by answering the previous research questions. Research question six is formulated in order to give insight in the impact of the proposed method on the performance of the healthcare system in general and the realization of the objectives defined in the healthcare outline agreement.

3.4.3 Research methods

Different complementary research methods and techniques are used to provide an answer to the research questions in section 3.4.2. The first four research questions will be answered with the help of literature and desk research. A part of the fifth question is answered with the help of the Data Envelopment Analysis (DEA) technique. This technique can help to examine the relative efficiency of a particular integrated care pathway compared to the performance of other integrated care pathways. A more extensive description of the method is given in section 5.1. Research question six will be answered with the help of the findings from the previous research questions and desk research.

3.5 Relevance of the research

The twofold relevance of this research is demonstrated in this section. Section 3.5.1 discusses the scientific relevance of the research and section 3.5.2 shows the social relevance.

3.5.1 Scientific relevance

A method for the quantification of healthcare performance at the level of healthcare provider transcending integrated care pathways has multiple scientific benefits. Firstly, this research focuses on performance evaluation at the level of integrated care pathways. Until know, no complete information was available about the performance of healthcare providers at the level of integrated care pathways (Hollingsworth et al., 1999). Performance evaluation is for that reason never performed at the level of integrated care pathways. The same is true for the Data Envelopment Analysis (DEA), which is often executed at the institutional level of healthcare providers (Zavras et al., 2002; Ozcan, 2007) but never at the level of integrated care pathways. This enables the formulation of best practices throughout the integrated care pathway on a national level. All integrated care pathways that are subject to the same performance evaluation method can simply be compared and best practices can be formulated. A second point that makes this research interesting from a scientific point of view is that performance evaluation is executed transcending the borders of healthcare providers. This adds a lot of complexity to the performance evaluation process. Issues may arise like how to assign performance to a particular healthcare provider and how to arrange contracting among healthcare providers and health insurance companies. It may also be a mathematical challenge to aggregate the performance figures of different healthcare providers to a single level of interpretation. Another point is the application of DEA in this research. DEA may not only be input for an efficiency benchmarking study, but is also used in this research for the calculation of efficiency figures that serve as a performance indicator for integrated care pathways. The efficiency values that come out of the DEA analysis may be used as one of the criteria for the procurement of health services.

3.5.2 Social relevance

Designing a method that provides insight in the performance of integrated care pathways has various social benefits which may be beneficial for all key actors in healthcare, although the focus lies at the facilitation of the role of health insurance companies. The social benefits for the four key actors are discussed below.

Health insurance companies get insight in the performance of healthcare providers on the level of the integrated care pathways. Health insurance companies need these information for the proper execution of their responsibilities towards the procurement of appropriate health services for their clients and to steer on the efficient organization of the healthcare sector. In addition, the outcomes of the analyses may be used as input for a to be defined healthcare procurement method. Insight in the performance of integrated care pathways may offer the patients the possibility to go to the healthcare provider that meets its interests best. This may result in a situation where patients get care that fits better to their interests which makes them more satisfied with the care they get. Performance figures at the institutional level are not sufficient for them, as these figures does not necessary tell anything about the performance on the treatment of specific diseases. The focus at the

performance of the integrated care pathways is for that reason beneficial for patients as it provides information on the right level of detail. The performance figures may be beneficial for healthcare providers. The figures can be used as a basis for healthcare performance benchmarking. This helps healthcare providers get insight in their actual performance, their strengths and their weaknesses. Performance figures may help them to do directed investments in order to help them improve their performance. The incentive for them to improve their performance is the strong position they get during the negotiations and the reward of lucrative contracts with health insurance companies. This research may deliver the national government both direct and indirect benefits. A direct benefit of the research may be that healthcare providers become more efficient and deliver a higher quality compared to their past performance. An indirect effect is the possibility to monitor the performance of the healthcare system on the level of individual treatments and to steer towards a more efficient healthcare system. This may help the government to take care for their task concerning the maintenance of the core values of the healthcare system over the long term.

3.6 Scope definition

A clear scope is defined in this section in order to keep focus during the execution of the research. This research presents a method for the quantification of the performance of healthcare providers at the integrated care pathway level. Integrated care pathways are in this research seen as the sequence of steps transcending the borders of healthcare providers that are executed in order to treat patients for specific diseases. This is demonstrated in Figure 3.1.

Measuring the performance on the level of integrated care pathways has the consequence that the method should be able to quantify the performance of many different healthcare providers that are involved in the treatment of a particular patient. Healthcare performance evaluation will for that reason be done on a level at which the performance of different integrated care pathways can be measured. This research is not meant to evaluate the performance of integrated care pathways on a low level of detail[1] which is irrelevant from the point of view of effective competition on the relevant goals. The integrated care pathways that are analyzed in this research belong to the physical healthcare system.

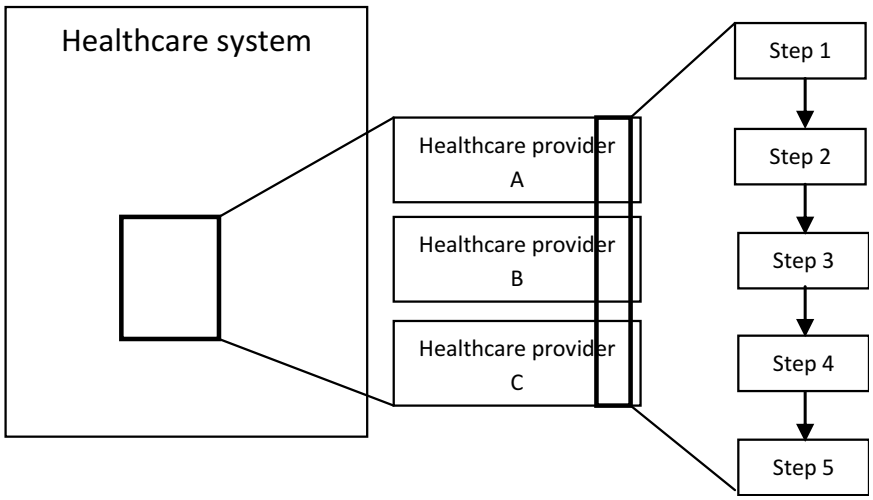


Figure 3.1 – Graphical representation of integrated care pathways

The mental healthcare system is not taken into account during the execution of this research. However, in section 10.1 will be paid attention on the application of the methods in different parts of the healthcare system and section 10.2 discusses the generalization of the proposed method to the mental healthcare system. This research focuses on a method for the quantification of healthcare performance as a first step towards

[1] Currently, sometimes more than fifty Performance Indicators (PIS) are used for the evaluation of the performance of healthcare providers for specific treatments.

a healthcare procurement model. The research has for that reason not the purpose to develop a model for healthcare procurement itself, but only a first step towards this method and towards a method for healthcare performance benchmarking. How the in this research proposed method for healthcare performance quantification can be used as an input for a healthcare procurement model and a healthcare performance benchmarking study is discussed in section 9.3.1 and section 9.3.2. This research pays extensive attention to the consequences of the implementation of the proposed method in combination with healthcare procurement but does not examine the consequences in a quantitative way. The comparability of care pathways is an important assumption for this research. Therefore, attention will be paid to factors that may have impact on the comparability of care pathways.

3.7 KPMG's consulting practice

This section discusses in short KPMG's consulting practice and demonstrates how this research may contribute to their current focus in the healthcare sector. The research should be connected to the consulting practice of KPMG in order to add value for KPMG.

3.7.1 General consulting practice

KPMG has formulated the following global vision:

> *Be the best firm to work with, for our clients, our people and our communities.*

From their global vision becomes clear that KPMG puts their effort in the satisfaction of their clients communities and employees. This research focuses on adding value for health insurance companies by facilitating them in fulfilling their steering role in the market. This is in line with the focus of KPMG on client satisfaction. This research may add value for the society by facilitating the role of health insurance companies in order to help them realize their responsibility concerning a more *efficient organization of the healthcare system, the reduction of healthcare cost* and the procurement of *appropriate health services for their clients.*

3.7.2 Healthcare consulting practice

The research is in line with the specific focus of KPMG in healthcare worldwide and may contribute to extent the services delivered by KPMG to clients in the healthcare sector. Healthcare is one of the eight key components of KPMG's global strategy and is recognized as a KPMG global sector (KPMG, 2012). This means that special attention is paid to the healthcare sector and KPMG's position in this sector. KPMG puts its global focus in healthcare on four areas:

- A genuine global footprint in Healthcare Advisory to complement our firms' audit and tax base with national practices working together to deploy people and knowledge in a coordinated way
- Five global propositions: Care System Redesign; Strategy, Transactions and Financing; Quality and Margin Improvement; Health IT; and "Board Grip"
- A virtual Center of Excellence staffed with senior industry experts, supported by regional executives to support and grow our firms' national practices
- Thought leadership studies aligned to the five global propositions

KPMG sees the integration of care as a promising way forward to tackle the challenges of demand, budget constraints, and workforce shortages (Britnell, 2011). KPMG is globally focusing on three types of integration in the healthcare sector namely:

- Clinical integration

- Physician integration
- Functional integration

This research may help to realize the focus of KPMG on the integration of healthcare by providing a method which makes it possible to measure and quantify the performance of integrated care pathways.

Part II

Healthcare Performance Quantification

Chapter 4

Healthcare Performance Indicators

A first step towards the quantification of healthcare performance, according to section 3.4.2, is the definition of KPIs that measure the performance of integrated care pathways on the goals of the healthcare system. This chapter comprises a discussion and examination of the KPIs that need to be quantified in order to enable health insurance companies to properly execute their role.

This chapter is structured with the help of diagram 4.1 in section 4.1. First is defined how KPIs are established. A first step towards the proper definition of KPIs is the definition of the goals of the healthcare system from the point of view of the key actors in healthcare. The goals are defined with the help of what is laid down in the healthcare outline agreement. Section 4.3 discusses the KPIs that should be used to measure the performance of healthcare providers on the right level of detail and on the predefined goals of the healthcare system. The currently available KPIs are evaluated on their quality and applicability to be used for the purpose of this research[1]. Section 4.5 discusses what issues play a role around the interpretation of the KPIs. The interpretation of the performance figures is an important step when it comes to healthcare procurement, where the performance figures of the healthcare providers are the basis for the procurement of health services.

4.1 Approach for establishing KPIs

This section discusses in short how the KPIs are established in healthcare. This is done with the help of diagram 4.1 that gives a graphical representation of how KPIs are established that measure the performance of integrated care pathways. The stakeholders at the right side of the diagram are the key actors in the healthcare sector that are involved in or affected by decision making in the healthcare sector (f.e. the initiatives that are developed in healthcare to reduce the cost and increase the efficiency of health services (see section 1.4). Each actor in the healthcare sector has its own interest and preferences. The interest of the actors determine the goals the actors have in the healthcare system. These goals function as an input for decision makers by the design of policy options that may intervene in the operations of the healthcare system in order to improve its performance according to the goals of the key actors. The decision maker in the healthcare sector is the national government which is the most influential actor in designing policies that intervene in the operations of the system domain[2]. The national government often cooperates with the other key actors in the healthcare sector (f.e. in case of the healthcare outline agreement) to develop effective policies. The outcomes of the integrated care pathways are measured with the help of KPIs. The KPIs should measure the performance of integrated care pathways in an accurate manner on the predefined goals. Policy makers can compare the actual system's performance with the performance goals that where set on beforehand. Policies are adjusted on the basis of information about the gap between the actual and the desired performance of integrated care pathways. This may lead to new initiatives or to the adjustment of running initiatives. The external forces most left in the diagram are the factors that may have impact on the performance of the system domain (read integrated care pathways) and will have a disturbing effect on the comparability of different integrated care pathways. The external factors may

[1] Facilitation of health insurance companies in the execution of their role as defined in the healthcare outline agreement.
[2] The systems domain are in this case the integrated care pathways.

be population specific factors like age, gender and race and geographical factors that determine the healthiness of the population and the performance of the integrated care pathways that treat the population.

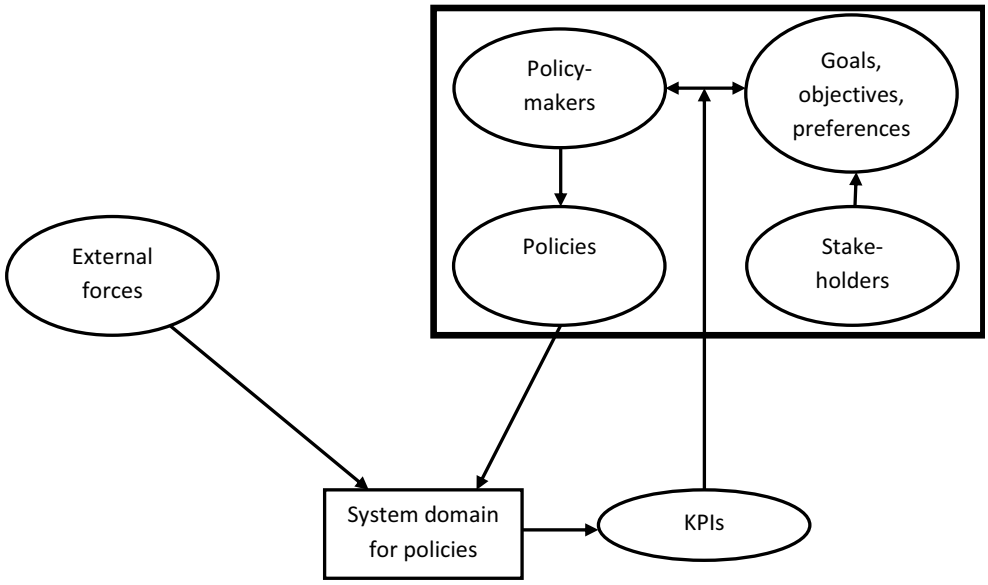


Figure 4.1 – Elements in the policy analysis approach (figure retrieved from (Walker, 2000), p. 13)

In short can be said that KPIs in healthcare are defined with the help of the following steps

1. Definition of key actors
2. Definition of goals and preferences
3. Definition of KPIs that measure the performance on the goals
4. Evaluation of KPIs
5. Interpretation of KPIs
6. Adjustment of KPIs

One should remark that this process is an iterative process, where step six is followed up by step three. The key actors are defined in section 1.1.2. Step two until step five will be discussed in this chapter. Section 9.2.1 discusses what adjustment to the KPIs are required in order to make them appropriate for measuring the performance of healthcare providers on the level of the integrated care pathways.

4.2 Specification of goals

As defined in section 4.1, the first step towards the definition of KPIs is defining the goals and preferences of the key actors in the healthcare sector. Section 1.1.2 comprises a discussion on the key actors in the healthcare sector. Each organization has a set of goals that have to be realized (Shahin and Mahbod, 2007) within a certain time span. KPIs are used to measure the performance of an individual organization on the goals that are set for the organization. KPIs are often used to monitor the developments of the organization's performance towards the prespecified goals periodically. The goals of the key actors are determined by their preferences with respect to the system[3] that is analyzed. For example a patient may have a different interest in the healthcare system than a healthcare provider (Sung et al., 2004). Therefore, first the preferences of each of the key actors needs to be specified. Table A.1 of appendix A summarizes the preferences of the key actors and forms the basis for the formulation of their goals. The goals of each key actor are defined in this section.

[3]The system is in this research defined as the integrated care pathways

Patient The whole population of patients in the Netherlands together form the demand-side of the healthcare system. The demand-side of the healthcare system determines the required capacity and quality of the healthcare system. In case of information transparency[4], healthcare providers have to apply to the preferences of patients in order to realize a high degree of satisfaction among patients. Patient have in that sense a significant position when it comes to innovation in healthcare. Pressure from the side of the patient, due to under performance by healthcare providers or changing preferences, may lead to change in healthcare. Therefore the interests of healthcare consumers become more and more important for the development of policies in healthcare (Sung et al., 2004). This is also visualized by the developments in healthcare towards demand-driven healthcare as discussed in section 1.4.4. The goals of the healthcare system from the point of view of the patient are

- Maximize the availability of healthcare (Smith et al., 2004)
- Minimize the cost of healthcare
- Maximize the experienced quality of healthcare (Omachonu and Einspruch, 2010)
- Maximize the quality of healthcare[5]

Dutch government The national government has a quite different role in healthcare, compared to the position of the patient. The national government has a regulatory role and is in that sense responsible for the overall performance of the healthcare system. This means that the national government is responsible for the implementation of measures that secure the core values of the healthcare system when the system does not perform according to predefined performance goals. The goals of the Dutch government for the healthcare system are specified in the healthcare outline agreement and can be summarized as

- Maximize the quality of healthcare (Long and Masi, 2009; Pereira, 2004)
- Minimize the cost of healthcare
- Minimize the usage of scarce medical resources
- Maximize the accessibility of healthcare
- Maximize the efficiency of healthcare

Healthcare providers Healthcare providers are responsible for the delivery of health services to the patient. They are bound to regulations that are set by the national government. According to the healthcare outline agreement, healthcare providers have to apply to the criteria that health insurance companies use for the procurement of healthcare. The goals of healthcare providers are

- Maximize clinical outcomes (Omachonu and Einspruch, 2010)
- Maximize fit between treatment outcomes and patients needs[6]
- Minimize cost price of healthcare
- Minimize the utilization of scarce medical resources[7]
- Maximize the efficiency of healthcare

[4]Transparency of information leads to increased insight in the performance of integrated care pathways. Patient may not be satisfied when they got a inferior treatment result compared to other healthcare providers.

[5]This is the objective quality of care and not the quality of care from the patient's eyes.

[6]Satisfied patients will increase the demand for health services in a competitive healthcare market.

[7]Health insurance companies face a tight labor market which makes it difficult for them to attract high educated healthcare employees. Reduction of the use of scarce medical resources may reduce the quest for additional labor.

Health insurance companies Health insurance companies are responsible for the procurement of healthcare and have in that way an incentivizing role for the realization of improvements in the performance of integrated care pathways. This role is quite different from the past[8] where health insurance companies were only responsible for the spread of the financial risk for individuals over a larger population (Pauly et al., 2012). The goals of the healthcare system from the point of view of the health insurance companies are

- Minimize billed costs by healthcare providers
- Maximize customer satisfaction about the quality[9]

4.2.1 Conclusions on goals of key actors

Some of the goals that are specified in the previous section are overlapping. Table 4.1 specifies all unique goals for the key actors in healthcare. The goals in this table are input for the KPI definition process which is discussed in section 4.3.

Table 4.1 – Goals of the healthcare system

	Patient	Government	Healthcare provider	Health insurance company
Minimize the cost of healthcare	x	x	x	x
Maximize the experienced quality of healthcare	x		x	x
Maximize the objective quality of healthcare	x	x	x	
Minimize the utilization of scarce medical resources		x	x	
Maximize the accessibility of healthcare	x	x		
Maximize the efficiency of healthcare		x	x	

Table 4.1 shows that all actors agree on lower cost of the healthcare system at a certain general level. However, they still have slightly different objectives at this point. Patients care about the premiums they have to pay, the government cares about the total cost of the healthcare sector as being part of their budget, healthcare providers care about the production cost of health services and health insurance companies care about the cost of care billed by the healthcare providers. Having the same goals does not necessary mean that it is easy for the key actors in the healthcare sector to realize these goals. The goal of decreasing the cost of healthcare may be conflicting with many other goals, like the quality of healthcare, the length of the waiting lists and the accessibility of healthcare. A different prioritization of these goals by the different key actors may lead to a situation where the cost of healthcare do not decrease but still may increase. This may be the case when f.e. the priority for increasing the quality of health services is higher than for decreasing the costs of healthcare.

4.3 KPI definition

This section comprises a discussion on the KPIs that are required for measuring the performance of integrated care pathways on the goals that are defined in section 4.2. Section 4.3.1 defines the approach that is used for

[8] The healthcare outline agreement is valid from January 2012 until December 2015.

[9] Satisfied patients will stay at their health insurance company. Patient will switch easily to a different healthcare insurance company when this company can deliver care that is more appropriate for the patient. This increased patient mobility will be a result of the availability of high quality information in a competitive market.

the definition of accurate KPIs. Section 4.3.2 defines the currently available KPIs that may be used for the quantification of the performance of integrated care pathways.

4.3.1 Approach

First one needs to define the approach that is followed for the definition of KPIs. There are three ways to define the KPIs that health insurance companies need for the proper execution of their tasks. They are called in this research

- Availability approach
- Applicability approach
- Mixed approach

In case of the availability approach there is looked at what performance figures are currently available and how we can measure the performance of integrated care pathways on the relevant goals of the healthcare system with the help of these figures. The applicability approach can be used to specify a set of KPIs that are fully applicable for measuring the performance on the predefined goals. This has the benefit that one can measure the performance of integrated care pathways in an accurate manner. However, this may ask for a full redesign of currently used KPIs. Therefore is chosen to mix these two approaches. First is looked what the goals of the key actors are, and how the KPIs ideally would be defined. Thereafter is determined how currently used KPIs can be adapted in order to be applicable for measuring the performance of integrated care pathways on the predefined goals.

4.3.2 Examination of available KPIs

Table 4.1 in section 4.3 shows the goals actors have in the healthcare sector. This section comprises a discussion on currently used KPIs that may be applicable for measuring the performance of integrated care pathways on these goals. This is done for each goal that is specified in table 4.1. It should be noticed that there exist a broad variety of KPIs in healthcare that can be used for measuring the performance of integrated care pathways on the mentioned goals. However, this research tries to keep the number of KPIs limited. This is required from the point of view that a healthcare procurement model should be transparent and simple in order to be effective (see section 2.4). However, on the same time it is important that the KPIs are accurate in measuring the performance of integrated care pathways. Only those KPIs that roughly fulfill these criteria are discussed in this section. A profound examination of the quality of the currently used KPIs is given in section 4.4.

Cost The performance of integrated care pathways on the cost of healthcare can be split up in different aspects. The *production cost* of healthcare and the *billed cost* of healthcare are both measures that are relevant as performance indicator for the cost of healthcare. Both these indicators can be measured on the level of integrated care pathway. The billed cost of healthcare are the prespecified prices that can be billed by the healthcare providers independent from the actual costs they made for a specific treatment(NVZ, 2011). The premiums that are paid by the patient cannot be measured on the level of the integrated care pathways and are for that reason not applicable to serve as KPI for measuring the performance of integrated care pathways on the cost of healthcare.

Experienced quality A score for the quality of healthcare as it is experienced by the patient is often derived from surveys that are held among a group of patients (Koopman and Rademakers, 2008). There is a composed index based on these surveys which is called the Consumer Quality Index (CQ-index). The CQ-index is a combination of the American CAHPS (Consumer Assessment of Healthcare Providers and Systems) and the Dutch QUOTE (QUality Of care Through the patient's Eyes) instruments (Damman et al., 2009).

Objective quality Several indicators exist that measure the objective quality of healthcare. F.e. the Quality Adjusted Life Years (QALY) give an indication of the number of years in relative held that are added to the patient's life as a result of the treatment the patient got (de Haan et al., 1993; Philips and Thompson, 2009). A second indicator that is often used to measure the quality of healthcare is the mortality rate. This rate gives the number of patients that dies due to a treatment.

There are more indicators that highlight aspects of the objective quality of healthcare like the treatment duration, the chance on complications during or after the treatment and the recidivism risk[10]. The treatment duration is a indicator that is used for a long time. The treatment duration declined significantly for several diseases over the last years (NVZ, 2011). Where the average clinical hospitalization in 1993 was around 10 days, was this decreased to around 6 days in 2009 (CBS, 2010). However, there are many KPIs that measure the objective quality of health services. Not all seem to be applicable for measuring the performance of integrated care pathways because some measure only specific aspects of the objective quality of health services. Where the set of KPIs should ultimately measure the performance of integrated care pathways with a small set of straightforward indicators, may this be conflicting with KPIs that only measure a minor aspect of a health service quality criterion.

Use of scarce medical resources There exist multiple measures for the utilization of scarce medical resources which are often not publicly reported because of the confidentiality of this information. This concerns the number of general practitioners, doctors, nurses, surgery rooms and hospital beds that are occupied by the specific treatments. All these indicators measure a part of the performance of healthcare providers on this specific goal.

Accessibility Currently there is no single performance indicator that can measure the accessibility of an integrated care pathway. The travel time is no applicable indicator because it is more or less an external variable that does not tell anything about the performance of an integrated care pathway nor can be directly influenced by a healthcare provider. A measure that may be applicable is the length of the waiting lists for the polyclinic and surgery. A threshold value is defined for the maximum length of waiting lists which is called the Treek-norm NVZ (2009). Each hospital is obliged to publish his waiting lists monthly since the first of September 2008(RIVM, 2012a). The length of the waiting lists are publicly available for a limited set of treatments in the Netherlands (RIVM, 2012b). A branch report of the NVZ (Dutch Hospitals Association) shows that the Treek-norm still often is exceeded by hospitals (NVZ, 2009).

Efficiency There are different indicators that might be used for the calculation of the efficiency of healthcare providers. The available methods are never applied on integrated care pathways until now. Therefore, a method (see chapter 5 and chapter 6) for efficiency calculation is proposed in this research that is appropriate for the calculation of the efficiency of integrated care pathways in a reliable manner. The efficiency of an integrated care pathway is not a measurable indicator but is calculated with the help of process inputs and outputs in healthcare. The inputs and outputs that will be used for the calculation of the efficiency of integrated care pathways are discussed under section 6.

[10]The recidivism risk is the risk that a patient needs to be treated for the same disease after a first treatment.

Table 4.2 – KPIs linked to goals

Goal	KPI	Unit
Minimize the cost of healthcare	Billed cost of treatment	[€/ treatment]
	Production cost of treatment	[€/ treatment]
Maximize the experienced quality of healthcare	CQ-index	[...]
Maximize the quality of healthcare	QALY	[QALY/ treatment]
	Mortality rate	[%]
	Treatment duration	[day/ treatment]
	Complications risk	[%]
	Recidivism risk	[%]
Minimize the usage of scarce medical resources	Number of doctors	[day/ treatment]
	Number of general practitioners	[day/ treatment]
	Number of nurses	[day/ treatment]
	Number of Surgery rooms	[min/ treatment]
	Number of hospital beds	[day/ treatment]
Maximize the accessibility of healthcare	Length of waiting list	[week]
Maximize the efficiency of healthcare	Efficiency	[%]

4.4 Evaluation of KPIs

This section evaluates the appropriateness of the KPIs that are specified in section 4.3.2 on a set of quality criteria. First is defined which criteria are used for the examination of the quality of the KPIs for the purpose of healthcare procurement on the integrated care pathway level. Furthermore, the KPIs are evaluated on these criteria and the relative importance of the KPIs is determined. The relative importance of the KPIs is important in case of the procurement of health services. This is illustrated by section 4.5.2.

4.4.1 KPI quality criteria

There are several quality criteria that are used for the examination of the quality of KPIs (as defined in section 4.3.2). The quality criteria that are used in this research are based on a set of criteria that is often used in literature. This concerns the following criteria. KPIs should be *specific*, *measurable*, *achievable*, *relevant*, *time bound*, *reliable*, *quantifiable* and *universal*. Each of these criteria are explained in more detail below.

Specific It is important that a KPI measures what it is meant for (del-Río-Ortega et al., 2009). A KPI should not measure a whole set of values but preferably a single value. A KPI should be detailed because that makes it easier to interpret the KPI and the outcomes of the analyses executed in chapter 5. A fuzzy definition or description of a KPI may lead to a situation in which wrong and therefore useless data is gathered. It may be risky to use wrong or useless data as a basis for decision making, as it may have the effect that the focus in the healthcare system will be put on irrelevant goals on the expense of the relevant ones. Subsequently, a KPI is specific when it measures the performance of the healthcare providers on the right level of detail. KPIs should for that reason measure the performance of the integrated care pathways[11].

[11] In section 2.3.2 is argued why the integrated care pathways are the right level of detail for the procurement of health services.

Measurable KPIs should be easy to measure or the calculation of the KPI needs to be based on factors that are easy to measure. Factors that are hard to measure may lead to a delay in the data infrastructure. This may lead to a situation in which data is inaccurate. Analyses that are based on inaccurate data may lead to wrong decisions. Besides this, it is important that the KPI is unambiguously defined. Ambiguity is a major source for miscommunication and may lead to measuring of the wrong factors.

Achievable The KPI should measure a goal that is achievable on one hand and challenging on the other hand. Parties in healthcare may become reluctant to the goals that have to be achieved when they consider a goal that cannot be achieved within a certain time-span. On the other hand, the use of a KPI will never lead to innovations and improvements when a prespecified goal is not challenging at all. This prerequisite tells more about the underlying goal that is measured by a KPI, than about the KPI itself. This criterion will therefore not be taken into account for the determination of the quality of the KPIs.

Relevant The KPIs need to be relevant for measuring the goals of the organization. For example, when the goal of an organization is to produce high quality products, it does not make sense to use a KPI that measures the satisfaction of the employees in the organization. There need to be a good fit between the KPI that is used and the measured goal.

Time bound It is important that KPIs can be measured periodically. This makes it possible to monitor the change in performance realized by the organization continuously. In that way it can be measured whether an organization is on its way to realize a prespecified goal or not.

Reliable KPIs should be reliable. An analyst should be able to trust the performance measured by the KPIs. This can partly lay in the definition of the KPI which should be unambiguous[12]. In addition, KPIs should be based on reliable data sets. KPIs that are based on unreliable data sets may give an unreliable picture of the actual performance on a prespecified goal.

Quantifiable The quantifiability of a KPI is an important prerequisite. Currently, several soft and qualitative KPIs are used in healthcare. Sometimes it may be necessary to use these KPIs (instead of quantitative KPIs) in order to cover all relevant aspects of a quality criterion. Nevertheless, these factors need to be quantified somehow in order to secure the execution of the DEA analysis (the Data Envelopment Analysis (DEA) technique is not developed for handling qualitative information (Ramanathan and Ramanathan, 2009)). It should be remarked that one should use a reliable method for the quantification of qualitative information in order to limit the loss of information and to guarantee the interpretability of the quantified KPIs.

Universal A KPI should be applicable for many different treatment. Otherwise one needs to define a different set of KPIs for each treatment. That limits the usability of the method that is proposed in chapter 5 and may be a barrier for the generalization of the findings in this research to other fields of application. Subsequently, it is important that KPIs can be used for performance measuring of all elements of the integrated care pathway. This has the consequence that KPIs preferably should be defined in such a way that they can be used to measure the performance of healthcare providers in primary, secondary and tertiary care. This criterion may be conflicting to a certain extent with the criterion of specificity. In general can be said that it is often valid that the more universally defined a KPI is, the less specific it becomes.

For the purpose of this research is made use of a limited set of relevant criteria. These criteria are called the SMART criteria and are often used for the examination of the quality of KPIs. SMART stands for Specific, Measurable, Achievable, Relevant and Time bound (de Boer et al., 2001; Shahin and Mahbod, 2007). The

[12]This means that there is only one plausible interpretation of the KPI.

criterion *achievable* is not used for the examination of KPIs in this research because this criterion is more appropriate for measuring the quality of the underlying goal than for the quality KPI itself.

4.4.2 Examination of the quality of KPIs

Table 4.3 gives a summary of the examination of the KPIs on the four criteria. The scores may be a little biased but indicate the applicability, strengths and weaknesses of the several KPIs for the purpose of measuring the performance of integrated care pathways. This table shows which KPIs need to be adjusted or improved in order to measure the performance of integrated care pathways in an appropriate way. The table comprises an additional column which shows whether information is currently available or not in the public or private domain. The following scores are used for the qualification of the quality of the KPIs on the criteria

$--$ = *bad*

$-$ = *insufficient*

0 = *average*

$+$ = *sufficient*

$++$ = *good*

Table 4.3 – Evaluation of KPIs on quality criteria

	Specific	Measu-rable	Relevant	Time bound	Data availability
Billed cost of treatment	++	++	++	++	private
Production cost of treatment	++	–	–	++	unavailable/ private
CQ-index	++	+	++	+	public (for some treatments)
QALY	+	-	+	+	public/ private (for some treatments)
Mortality rate	++	++	0	++	public
Treatment duration	0	++	++	++	private
Complications risk	0	++	+	++	public (for some treatments)
Recidivism risk	0	++	+	++	private
Number of doctors	+	0	–	+	unavailable/ private
Number of general practitioners	+	0	–	+	unavailable/ private
Number of nurses	+	0	–	+	unavailable/ private
Number of Surgery rooms	+	0	–	+	unavailable/ private
Number of hospital beds	+	0	–	+	private
Length of waiting list	+	+	++	++	public (partly available)
Efficiency	++	0	++	++	unavailable

4.4.2.1 Specific

Many of the KPIs are not specific on the right level of detail[13]. This is valid for f.e. the recidivism risk, the complication risk and the duration of the treatment. Especially this last one is important to mention because the treatment duration may have different meanings. This KPI can be used for measuring the duration of the

[13]The right level of detail are the integrated care pathways as argued in section 2.3.2.

hospitalization period, but may also be the time between the start and end data of a DBC (or in the new situation the time between the first and last DOT activity).

4.4.2.2 Measurable

Some of the relevant KPIs may be hard to measure. QALY is a compounded measure for the quality of a treatment. Different institutions use different methods for the calculation of the QALY value (Griebsch et al., 2005). The calculations of a KPI should be uniform in order to be able to present comparable performance figures among different integrated care pathways. In addition the QALY measure includes a lot of estimations which makes it even more difficult to measure this KPI (Conner-Spady and Suarez-Almazor, 2003).

4.4.2.3 Relevant

The relevance of the criteria is probably the most important criterion for the examination of the applicability of the KPIs for the procurement of health services. The use of irrelevant KPIs for the procurement of health services may lead to the wrong focus in the healthcare sector. This may has its drawback on the performance of the healthcare sector on the relevant KPIs because the focus on the performance on specific goals may lead to less focus on the performance on other goals. In general can be stated that the less effort is put in realizing certain goals, the less the performance of an organization is on those goals. This is especially true when relevant and irrelevant goals are conflicting. Whether the KPIs are relevant for the procurement of healthcare is determined by the goals set in the healthcare outline agreement and by the prerequisites for fair competition as defined in section 2.4[14]. In the healthcare outline agreement is specified which criteria are important for the procurement health services. This concerns the following criteria

- Quality
- Affordability
- Efficiency
- Usage of scarce medical resources
- Accessibility

One may see that these criteria overlap with the goals defined in table 4.3. Some important remarks should be made on the relevance of the different criteria for measuring the underlying goals. This is done in the following paragraphs.

Quality The KPIs that measure the quality of integrated care pathways are relevant for the purpose of healthcare procurement. The CQ-index is an ultimate indicator for the appropriateness of health services from the point of view of the patient.

Affordability The production cost of a treatment is not a relevant KPI for measuring the affordability of healthcare. The use of this KPI for the procurement of health services may give health insurance companies an undesirable position in the negotiation process. Because when health insurance companies know the production characteristics, healthcare providers can no longer compete among each other on the prices of health services. Health insurance companies will probably pay them a fixed fee above their production cost in order to let them not make too high profits. Instead of using the production cost of a treatment, health insurance companies may use the billed costs of a treatment. This may put pressure on healthcare providers to decrease their cost in order to become more profitable.

Efficiency An other point of concern is the efficiency. The question here is what efficiency figure to use for monitoring the efficiency of integrated care pathways.

[14]KPIs that seems to be relevant but distort competition should not be used for healthcare procurement.

Use of scarce medical resources The reduction of the use of scarce medical resources is a relevant goal. However, it is not necessary to include these figures as a KPI for the procurement of health services. Performance figures about the use of scarce medical resources are confidential production figures and should for that reason not be shared with health insurance companies. Instead of using figures about the utilization of scarce medical resources, one can use the efficiency scores of an integrated care pathway in which these figures are processed.

4.4.2.4 Time bound

All KPIs can be measured periodically.

4.4.2.5 Data availability

The data availability demonstrates what information currently is available and can be used for the evaluation of the performance of integrated care pathways. In order to realize fair competition, the information of all relevant KPIs should at least be available for the health insurance companies in order to enable them to execute their responsibilities as described in the healthcare outline agreement. According to section 2.3.1, health insurance companies can distribute information among relevant actors by having the responsibility for healthcare procurement on predefined criteria. The KPIs that determine the appropriateness of health services should be public available for patients. Not all KPIs are relevant for the patients. F.e. they do not care about the billed cost of health services (they do care about premiums) nor about the efficiency of integrated care pathways. Most KPIs are currently unavailable for the relevant actors in the healthcare sector. Availability of information needs to be improved in order to enable fair competition among healthcare providers[15].

4.4.3 Conclusions on applicability of KPIs

When we consider the examination of the KPIs on the quality criteria one can see that certain KPIs are not applicable for measuring the performance of integrated care pathways on the goals of the healthcare system. The gray KPIs in table 4.3 are the KPIs that seems to be relevant and appropriate for measuring the performance of integrated care pathways but which are still not sufficiently clear defined and need to be redefined for the purpose of effective procurement. Recommendations for the redefinition of KPIs are done in section 9.2.1.

4.5 Interpretation of KPIs

The interpretation of the scores of the integrated care pathways is an important step towards healthcare procurement. One should be able to interpret the performance figures in a sound way in order to facilitate fair competition. This section discusses the issues that may arise around the interpretation of KPIs. Section 4.5.1 discusses the factors that may have a disruptive effect on the outcomes of integrated care pathways. Section 4.5.2 discusses the relative importance of the KPIs from the point of view of the key actors in the healthcare sector. The relative importance of the KPIs may determine how the overall performance of an integrated care pathway is valued. This information is especially valuable for the procurement of health services, where needs to be decided what integrated care pathways deliver the best health services for the lowest price.

4.5.1 Environmental factors

It is not always possible to compare the performance of almost similar integrated care pathways. Although the end result[16] of different care pathways is equal, they may treat a totally different population of patients which has impact on the performance of the integrated care pathways. This makes it difficult to compare the performance figures of the different pathways. The following factors may have a disturbing impact on the interpretation of the performance figures of integrated care pathways:

[15] Section 2.2.3 argues that sound and relevant information is an essential precondition for fair competition.
[16] The end result is always the treated patient.

- population characteristics like age, gender, race, etc.
- type of care delivered like regular care or follow up care
- the complexity of the disease and risk on complications
- the type of healthcare provider and related characteristics (like additional costs in case of an academic hospital)

It is important to adjust the performance of integrated care pathways for the underlying characteristics before they can be compared. Otherwise there is a risk that the procurement of health services will take place in an unfair manner. An integrated care pathway may for example execute expensive treatments for a specific disease due to the fact that this pathway treats patient with complex complications. Procurement of health services on predefined criteria, without adjusting for the complexity of the disease, may lead to a situation where this healthcare provider is not rewarded with a contract for treating patients because of a lower performance. This may be an undesirable situation according to the goals defined in the healthcare outline agreement where is stated that the procurement of health services not should hurt the accessibility of health services for any of the patients in the Netherlands. Subsequently, diversity within the healthcare system is not taken into account when performance figures of healthcare providers are not adjusted for underlying differences. Diversity, may be reduced to the treatments of those patients that result in the highest performance. This may be an undesirable situation as this means that patients with more complex variants of a disease cannot be treated any longer in the Netherlands when no additional regulations are applied. The above mentioned environmental factors are discussed below in more detail.

Population characteristics The population that is treated by a particular healthcare provider may have a significant impact on the performance of the integrated care pathways (Mant, 2001). The performance of the care pathways needs to be adjusted for characteristics of the population before they can be compared. The average age of a population may for example have a significant impact on the length of a treatment and the recidivism risk. The quality of healthcare when it is measured as QALY (Quality Adjusted Life Years) will also be lower for older people. Besides that, for example the race and gender of a patient may determine the healthcare demand of the population and the relative healthiness of the population (Harper et al., 2007). All these factors may influence the performance figures of integrated care pathways.

Type of health services For the type of care delivered by the healthcare provider, a distinction can be made between regular and follow-up care demand. A patient will receive regular care when he is treated for the first time for a specific disease. It may occur that a patient needs to be treated several times for the same disease. Each time a patient is treated for a disease after the first treatment, is defined as follow-up care. In practice, the performance of an integrated care pathway may be determined by the proportion of follow-up care. It is therefore important to adjust the performance figures for the type of care that is delivered before integrated care pathways are compared.

Complexity of disease The complexity of a disease plays an important role in the comparability of integrated care pathways. For example specialist centers may in general treat patients with a more complex variant of a specific disease. Complex variants may ask for specific knowledge which is expensive. This will affect for example the cost of care. Sometimes the patients with complex diseases are treated at a hospital and are afterwards referred to an academic medical center when certain complications are faced. The treatment at the academic medical centers are in those cases no independent integrated care pathways but are a follow-up of the care pathway at the hospital. The patient is treated there for a different disease (complication) and the treatment is therefore different from the treatment at the hospital. Because of the complexity of the treatment, it is likely that the treatment will be billed under a different and more expensive DBC. The patient may have a lower chance on the same increase in quality adjusted life years as he had for the treatment at the hospital

before he got the complication. This means that a worse performance may be expected for the treatment at the academic medical center, compared to the treatment at the hospital. This example shows the impact of the complexity of a disease on the performance of integrated care pathways.

Type of healthcare provider There are several types of institutions in healthcare. One can distinguish between hospitals, academic hospitals, independent treatment centers, specialist care centers and many more institutions where patients can be treated for a specific disease. These different healthcare institutions may be organized very different. The differences between healthcare providers may lead to different outcomes of integrated care pathways. However, this should not be a problem in this research because the aim of the research is to examine the performance of integrated care pathways, independent of the type of healthcare providers that are involved. However, some of the healthcare providers may have a unique role in the healthcare sector. Academic hospitals for example, have an important role in the education of healthcare employees. Subsequently, the different institutions may treat different populations or diseases with a different degree of complexity. The performance of the pathways need to be adjusted for these characteristics before the integrated care pathways can be compared among different healthcare institutions.

4.5.2 The relative importance of KPIs

Besides the issue of the interpretation of healthcare performance figures there is the issue about how to weight the performance figures of healthcare providers. This may be a relevant question when it comes to the procurement of health services on predefined criteria. When health services are procured on the basis of the actual performance of healthcare providers, the procurement institutions should be able to define what performance indicators are leading during the procurement process. This is especially important in case of comparable performance figures at the higher level, while there are differences at the level of particular KPIs. The definition of a preference relation among criteria gives the possibility to define a preference relation among alternative treatment, even when they have a comparable overall performance. This becomes clear when we look at the following examples.

Example A
Hospital X is a hospital that puts a lot of effort on the experience of the patient. On many places in the hospital is made use of plants and special colored light bulbs, to give the patient the feeling of being at home. Patients are satisfied with the treatment in hospital X, although the quality of care expressed in QALY, lacks behind the quality of hospital Y.

We see that the focus in hospital X is put on the experienced quality of healthcare by the patient rather than on the *hard* quality of clinical outcomes. Hospital Y on the other hand pays more attention to the clinical outcomes.

Example B
Hospital Y is a hospital that is focused on the clinical outcomes of the treatments. The hospital has motivated and performance driven employees, that want to give each patient the best care he needs. Investments in the best equipment led to a superior quality of healthcare, however, the underlying costs for the hospital increased as well.

Suppose that in this simple situation three KPIs are used to measure the performance of the healthcare providers for treating a specific disease. The two hospitals than may have the following performance.

$HOSPITAL_X$
$CQIndex_X = 1$
$QALY_X = 0.5$
$Billed\,cost_X = 0.5$

$HOSPITAL_Y$
$CQIndex_Y = 0.75$
$QALY_Y = 1$
$Billed\,cost_Y = 0.25$

The question arises which healthcare provider has the best performance. This cannot be answered by simply calculating the mean value of the KPIs or the sum of the scores on the KPI; the mean value of the standardized KPIs is equal for both alternatives $SCORE_{HOSPITAL_X} = (1+0.5+0.5)/3 = \frac{2}{3}$; $SCORE_{HOSPITAL_Y} = (0.75+1+0.25)/3 = \frac{2}{3}$. This question, therefore cannot be answered when we do not use the relative importance of the three KPIs. We can answer the question when we give each KPI a simple weight which corresponds with the relative importance of that specific KPI. This weight should be based on the preferences of the involved actors. For example the following weights can be assigned to the KPIs ($W_{CQIndex} = 2; W_{QALY} = 1; W_{Billed\,cost} = 3$). We can now answer the question by calculating the mean value of the KPIs multiplied by their weights $SCORE_{HOSPITAL_X} = (2*1+1*0.5+3*0.5)/3 = \frac{16}{12}$); $SCORE_{HOSPITAL_Y} = (2*0.75+1*1+3*0.25)/3 = \frac{13}{12}$. Hospital X is the most preferable alternative for treating this specific disease, based on this calculation. The most preferred alternative may change for different weights. That directly shows the importance of the careful examination of the relative importance of the different KPIs. This is especially valid in situations where the outcomes of the analyses are sensitive for small changes in the weights of the KPIs.

The relative importance of each KPI is given in table 4.4. The scores may be somehow biased but give a proper indication about the relative importance of the KPIs from the point of view of different actors. The following scores are used for the qualification of the relative importance of the KPIs for each key actor

$--$ = *unimportant*
$-$ = *little unimportant*
0 = *unimportant nor important*
$+$ = *little important*
$++$ = *very important*

Table 4.4 – Relative importance of KPIs

	Patient	Government	Healthcare provider	Health insurance company
Billed cost of treatment	–	+	++	++
CQ-index	++	+	+	+
QALY	+	+	+	+
Mortality rate	+	+	+	+
Treatment duration	0	+	0	-
Complications risk	+	+	+	0
Recidivism risk	+	+	+	0
Length of waiting list	+	+	0	0
Efficiency	–	+	+	0

4.6 Conclusions

Concluding on the discussion in this chapter, the following remarks are made

- The healthcare system has a broad range of goals from the perspective of the key actors

- These goals fully overlap with the goals that are laid down in the healthcare outline agreement
- Many KPIs are used in healthcare for measuring the performance of integrated care pathways on these goals
- There is currently no effective method for the examination of the efficiency of integrated care pathways
- The KPIs often do not meet the quality criteria (specific, measurable, relevant and time bound) for the purpose of measuring the performance on the level of integrated care pathways
- KPIs need to be redefined in order to be meet these criteria. This is required for fair and effective competition among healthcare providers
- The relevance of the KPIs is probably the most important criterion for the examination of the quality of KPIs
- Key actors have a different perception of the relative importance of each KPI
- Several factors may disturb the interpretation of performance figures of a particular care pathway
- Performance figures needs to be adjusted for these factors in order to be able to compare them among each other

Chapter 5

DEA method

The key parties in healthcare defined that increasing the efficiency of health services is an important topic in the healthcare sector for the upcoming years. In this research is proposed to use DEA for the evaluation of the efficiency of the healthcare system at the level of the integrated care pathways. This chapter discusses the characteristics of the DEA method in short and discusses the benefits of DEA as analysis technique for the evaluation of the efficiency of integrated care pathways compared to other efficiency evaluation techniques.

5.1 DEA in short

This section discusses the main elements and characteristics of the DEA method. Section 5.1.1 discusses frequently used terms in DEA in order to increase the readability of the discussion on the basics of DEA and the analyses that are executed in this research. Section 5.1.2, discusses the basic principles of the DEA technique.

5.1.1 Frequently used terms in DEA

This section gives a short description of frequently used terms in DEA that are important for understanding the method and its application.

CRS model CRS stands for Constant Returns to Scale. This term concerns the way how the efficient frontier is established with the help of empirical data. The efficient frontier is characterized by a global linear line through the best performing DMU or a straight surface trough the best performing DMUs (in case of multiple inputs and outputs).

DMU A Decision Making Unit (DMU) is the main subject of analysis in DEA. The DMUs in this research are the integrated care pathways.

Efficiency The efficiency of a DMU is the extent to which a DMU is able to convert its inputs into valuable outputs. The efficiency is determined by the distance of a DMU to the efficient frontier. There are several types of efficiencies. In this research is focused on the productive efficiency of the DMUs which is explained in the introduction of this chapter.

Efficient frontier The efficient frontier is the partly linear line that can be drawn on top of the efficient DMUs. The efficient frontier envelops all inefficient DMUs.

Improvement potential The improvement potential of a DMU can be specified for specific inputs and outputs and demonstrates the performance improvement that can be realized for that specific input or output. The improvement potential can be calculated for both the inputs and outputs by comparing the actual performance of a DMU with the performance of its benchmarks.

Inputs/outputs The inputs and outputs are the factors that are used for the calculation of the efficiency of a DMU.

Input/output-oriented DEA model The orientation of the DEA model determines whether the inputs (input-oriented) are minimized or the outputs (output-oriented) are maximized.

Lambda The lambda scores show which DMUs function as benchmark for the DMU that is under evaluation.

Preference structure model A preference structure model is a DEA model that can work with relative weights for inputs and outputs (in opposite to the non-preference structure model). The efficiency figures will change when one input or output is weighted above another.

Slack values Slack values are the gain in input and output performance that can be realized by a DMU without changing its efficiency score.

Target value The target values are the input and output performance that a DMU can realize when it performs as good as its benchmarks.

VRS model VRS stands for Variable Returns to Scale. The VRS model is opposite to the CRS model. The efficient frontier is piecewise linear in case of the VRS model. Figure and figure point clearly out what the differences of both models are.

5.1.2 Basics of the DEA method

This section shortly describes the main characteristics of the DEA method. Section 5.1.2.1 discusses the basic principles of the DEA method and section 5.1.2.2 discusses the prerequisites that should be fulfilled before the DEA method can be executed.

5.1.2.1 Basic principles of DEA

DEA is a quantitative method for the examination of the efficiency of DMUs with the help of multiple inputs and outputs. Efficiency is in most situations a relative measure. Often there is no objective benchmark (except in case of some physical processes) which determines the maximal theoretical efficiency[1]. The efficiency of a particular DMU is in that case relative to its benchmark. However, efficiency can be measured in different ways. Figure 5.1 and figure 5.2 respectively show a linear efficiency model and a piecewise linear efficiency model. These two models are discussed in more detail in section 5.3.1.

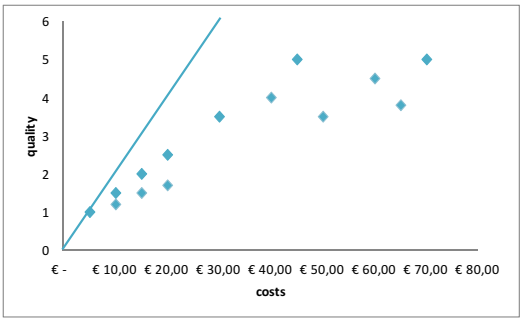


Figure 5.1 – Linear efficiency model (CRS)

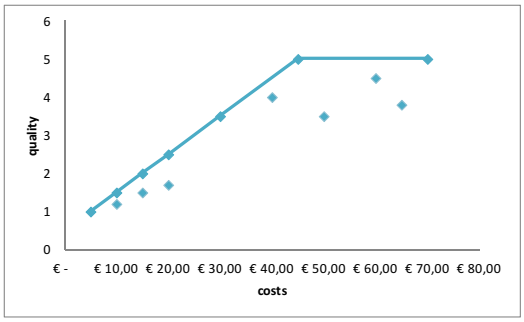


Figure 5.2 – Piecewise linear efficiency model (VRS)

All points that lay on the blue line are efficiently performing care pathways. Where the linear model focuses on the best performing integrated care pathway under assumption of linearity, focuses the DEA efficiency model on the best performing integrated care pathway for each specific input value. This results in an efficient line for the linear efficiency model and a piecewise linear efficient frontier for the DEA model. The points that lay below the efficient frontier are *enveloped* by the frontier. Like other methods, DEA calculates the technical efficiency of a DMU by comparing the inputs and outputs of each DMU among all other DMUs. The inputs

[1] An example of theoretical efficiency can be found in the Carnot efficiency.

and outputs represent performance measures that characterize the analyzed DMUs. The relative distance from a single DMU to the efficient frontier determines the efficiency of that particular DMU.

One can imagine that the efficiencies calculated by a linear efficiency model are quite different from the piecewise linear DEA model. The choice for DEA as efficiency evaluation technique is justified in section 5.4. DEA gives a more conservative indication about what the efficiency of a particular DMU is, and what the improvement potential of that particular DMU is by making use of solely empirical values. DEA solely relies on the interpolation of input and output values. Extrapolation is not applied in DEA.

An important criterion for the selection of an analysis technique is the reliability of the technique. Like other efficiency measuring methods is DEA quite sensitive for the quality of the input and output values. Unnatural fluctuations due to bad data management may negatively affect the quality of the calculated efficiency values. Accurate data management is for that reason a prerequisite for the execution of a proper efficiency analysis whatever method is used.

5.1.2.2 Prerequisites for using DEA

There are some prerequisites that need to be fulfilled for the execution of a proper DEA analysis

- large data sets and many DMUs
- stability and reliability of data
- quantitative inputs and outputs
- unbounded inputs and outputs
- piecewise linearity between inputs and outputs

The size of the data set is an important prerequisite. DEA provides only useful outcomes when the ratio between the number of DMUs and the number of inputs and outputs is reasonably large. The larger the number of inputs and outputs, the more DMUs lay on the efficient frontier. For this reason a big data set is required in order to get valuable outcomes. This is also visualized by figure E.1 in section E.1.1. A third requirement for the use of DEA is the use of quantitative inputs and outputs. DEA is not good in handling qualitative parameters. Fourthly, the inputs and outputs have preferably a ratio scale. Interval variables may be applicable under condition of a large number of DMUs as demonstrated in section 5.4.2. An important requirement is the assumption of piecewise linearity among efficient DMUs. This prerequisite should hold for the ratio between inputs and outputs. This requirement is especially relevant in case of a small data set and a small number of DMUs on the efficient frontier, because the range of interpolation is in that case large. This assumption becomes less relevant in case of a big data set and a large number of DMUs on the efficient frontier, because the range of interpolation is in that situation small. The difference between a long and small range of interpolation is visualized by figure 5.3 and figure 5.4.

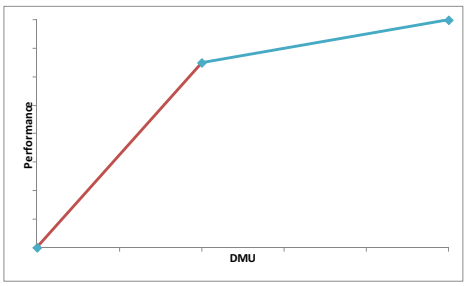


Figure 5.3 – The range of interpolation (in red) for a small data set and a few efficient DMUs.

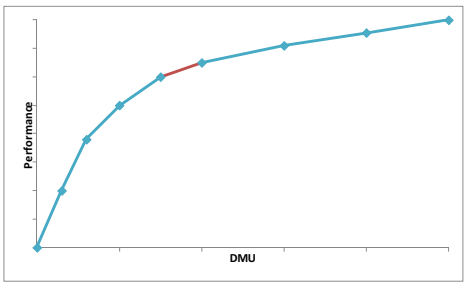


Figure 5.4 – The range of interpolation (in red) for a large data set and many efficient DMUs.

5.2 Steps in DEA analysis

The Data Envelopment Analysis is executed in a structured way in this research. The steps that are distinguished by the author are extensively discussed in this section. The mathematical calculations that need to be executed for each step can be found in appendix D. The author decided to follow a six step approach for the execution of the DEA analysis. This approach is based on an approach that is proposed in literature Golany and Roll (1989).

- Step 0: Definition of analysis objectives and analysis technique
- Step 1: DEA configuration
- Step 2: Determination of DMUs
- Step 3: Determination of inputs/outputs
- Step 4: Quantification of inputs/outputs
- Step 5: Calculation of efficiencies
- Step 6: Interpretation of results

The steps that are mentioned above are a little more extensively discussed below.

Step 0: Definition of analysis objectives and analysis technique Each analysis starts with determining the objectives of the analysis in order to get clear what outputs should be produced. This may determine which analysis approach will be followed and what outcomes of the analysis should be expected. A specific analysis technique should be chosen in order to get the required outcomes.

Step 1: DEA configuration The first step in the DEA analysis is the choice for the type of the DEA model. Each DEA model has its own outcomes and benefits. The choice for a certain DEA model may dependent on the required outcomes of the analyses. The differences between the models are explained in section 5.3.1.

Step 2: Determination of DMUs When there is chosen to execute a DEA analysis, first one needs to determine what will be subject (DMU) to the DEA analysis. The DMUs are the business operations from which the efficiency needs to be calculated. It is important to have a clear definition and boundaries of the DMUs. The inputs and outputs are performance measures of the analyzed DMUs and a vague definition and boundaries may lead to inaccurate performance figures.

Step 3: determination of input/output The third step is the determination of the inputs and outputs. Like other efficiency evaluation methods, DEA calculates the relative efficiency of a DMU with the help of input/output ratios. The selection of inputs and outputs is dependent on the goals the decision maker has with the analysis. Only those performance measures should be included in the analysis, that are important for the evaluation of the efficiency according to the goals of the decision maker. The DEA analysis will deliver less useful outcomes when too much and irrelevant performance measures are included in the analyses. This weakness of the DEA method is discussed in section 5.4.1. One should be careful when defining the inputs and outputs. Measures that have a fixed band with are hard to include in the DEA analysis, because of the abundance of local linearity between DMUs at the frontier of the band with.

Step 4: Quantification of inputs and outputs The fourth step is the quantification of the inputs and outputs. DEA is not good in handling qualitative information. Therefore, one needs to assign a numerical value to each input and output in order to be able to execute the DEA analysis. Quantification of the inputs and outputs deserves for that reason some attention. It is important that as less information as possible is lost in case of the transformation of qualitative information to numerical values. Besides this, the quality and reliability of the input and output values determine the reliability of the efficiency score. Safeguarding the quality of information is therefore important for the use of DEA.

Step 5: Calculation of DEA outcomes The fifth step is the calculation of the outcomes of the DEA analysis for each DMU. DEA can generate a lot of outcomes. The mathematical formulas for the calculation of the outcomes are given in section D.1 of appendix D. The following outcomes are calculated with the help of DEA

- Efficiencies
- Lambdas
- Input/output slack
- Improvement potential

As mentioned in section 5.1.2, the efficiency of a DMU is defined by the relative distance of the DMU to the efficient frontier. There are several ways to calculate the efficient frontier in DEA. The calculation methods for the efficient frontier are discussed in section 5.3. The efficiency can be calculated in a one-stage process when there are no slacks or in a two-stage process when there are weakly efficient DMUs, which means that there are slacks present. The principle of slacks is explained by figure 5.5. From the figure becomes clear that DMU A and DMU X lay on the efficient frontier. Nevertheless the cost of DMU X can be reduced to the level of DMU Y without reducing the output performance and the quality of DMU A can be improved without increasing the costs. The difference in the output between DMU A and DMU B is called output slack and the difference in input values between DMU X and DMU Y is called input slack. The two stage calculation process comprises the calculation of the efficiencies in the first stage and the calculation of the input and output slacks based on the efficiencies in the second stage.

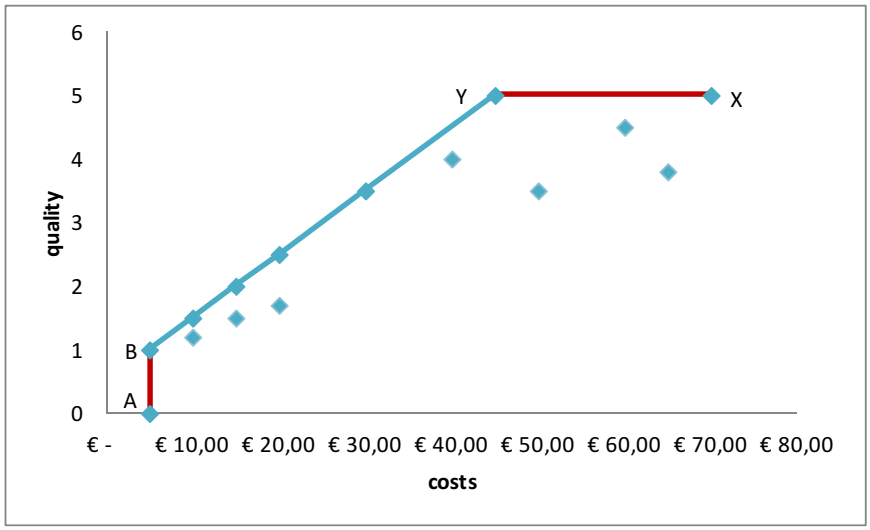


Figure 5.5 – DEA efficiency model with slacks

Step 6: Interpretation of results The last step concerns the interpretation of the analysis outcomes. The interpretation of the results may depend on the type of DEA model that is chosen. The efficiency is a relative measure and shows what performance a DMU can gain at the input side without losing performance

at the output side (in case of input oriented models) or what a DMU can gain at the output side without losing performance at the input side (in case of output oriented models). Furthermore the interpretation of the outcomes may depend on the sensitivity of the outcomes for variations in the underlying data that are defined as inputs and outputs for the DEA analysis. An efficiency value has less meaning when an outcome is sensitive for changes in the input values.

An efficiency value of 100% ($\theta = 1$) means that the DMU under evaluation lays on the efficient frontier. There is no DMU that performs more efficient. An efficiency value of less than 100% ($\theta < 1$) means that a DMU can decrease its inputs (input oriented DEA model) or increase its outputs (output oriented DEA model). The non-zero lambdas are the benchmarks for the DMU under evaluation. The combination of the DMUs with non-zero lambdas form the virtual efficient DMU that serves as benchmark for the DMU under evaluation. point A' in figure 5.6 is the benchmark for DMU A in case of an input oriented DEA model. Point A" is the benchmark for DMU A in case of an output oriented DEA model.

The self developed vba-based excel model comprises a sheet with target values for the inputs and the outputs. The target values indicate the improvement potential that can be realized by moving the DMU under evaluation towards the efficient frontier. The slack values that are calculated by the DEA model determine how sensitive the efficiency figures are for changes in inputs and outputs. The presence of slack values may be problematic when it comes to the interpretation of the efficiency figures and the use of the efficiency figures as incentive for investments in performance improvement.

5.3 DEA models

There are several DEA models that can be used for the calculation of the efficiency of DMUs. It is important that the appropriate model is chosen for the purpose of this research. The characteristics of each model are discussed in this section.

5.3.1 Frequently used models

This section comprises a discussion on the following often used DEA models

- Input oriented vs. output oriented models
- Constant returns to scale vs. variable returns to scale models
- Preference structure vs. non preference structure models

This knowledge is used for the selection of the DEA model (see section 5.3.2) that is most applicable for the purpose of this research.

Input oriented vs. output oriented models A distinction can be made between input and output oriented models. Input oriented DEA models measure the efficiency of DMUs by minimizing the inputs of a specific DMU while keeping its outputs on a constant level. The efficiency of the DMU is defined by the the relative distance of the DMU to the linear part of the frontier that minimizes the inputs. The output oriented DEA model measures the efficiency of a DMU by maximizing the outputs of a specific DMU while keeping it's inputs at least at a constant value. The efficiency of the DMU is defined by the relative distance of the DMU to the linear part of the efficient frontier that maximizes the outputs. The difference between the input and output oriented DEA model is demonstrated in figure 5.6. The distance from A to A' determines the efficiency of DMU A in case of an input oriented DEA model. The input is minimized while keeping the output constant. The distance from A to A" determines the efficiency of DMU A in case of an output oriented DEA model. The output is maximized while keeping the input constant.

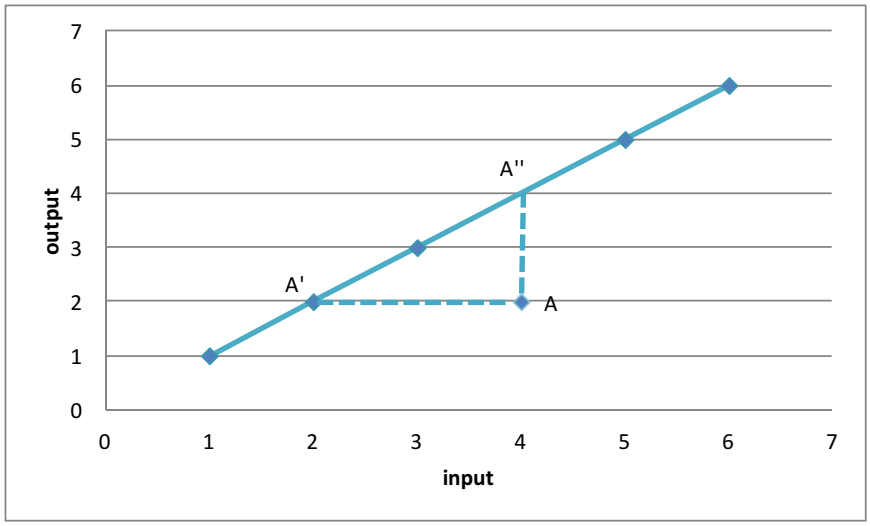


Figure 5.6 – Input versus output oriented DEA model

Constant returns to scale vs. variable returns to scale A distinction is made between variable returns to scale model (VRS) and constant returns to scale models (CRS). The main difference between the VRS and the CRS model is that the direction coefficient of the efficient frontier is constant in case of the CRS model and variable in case of the VRS model. This is visualized by figure 5.1 and figure 5.2. This difference comes forth from an important underlying assumption that outputs are infinitely scalable by changing the inputs in case of a CRS model. The calculation of the efficiency of a DMU can be seen as a linear optimization problem which can be solved with the help of Microsoft Excel and the Solver add-in. The mathematical expression for the calculation of the efficient frontier for the CRS model is a little different from the VRS model as discussed in section 5.2. The sum of lambdas for the CRS model is only constraint by non-negativity. This means that the sum of lambdas can take infinitely large positive values in case of the CRS model where it is constraint to one in case of the VRS model.

Preference structure vs. non preference structure models Preference structure models can be used for proportional optimization of the DMU targets. These models makes it possible to define which inputs or outputs are most important to increase or decrease. Benefits of this model is the fact that it is possible to define efficiency scores for each input and output parameter dependent on whether is made use of an input or output oriented model. In addition, input slacks are removed from the model in case of an input oriented model and output slacks are removed in case of an output oriented model. This means that the model is more effective as explained in section 5.2.

5.3.2 DEA Model choice

The choice for the use of a specific DEA model depends on the purpose of the efficiency analyses and the characteristics of the analyzed system. There should be chosen for an input oriented model when the purpose of the research is to define the best practices in the reduction of inputs by keeping the outputs constant. There should be chosen for an output oriented model when the purpose of the research is to define the best practices for the increase of outputs by keeping the inputs constant. One of the motivation for this research is the agreement between the key parties in healthcare as discussed in section 1.4.3. Here they agreed upon putting effort in the reduction of cost of healthcare by increasing the efficiency of health services. Therefore the input oriented approach is followed in this research.

The choice for the CRS or VRS frontier method depends on the underlying characteristics in healthcare. From the regression analyses as summarized in section 5.4 becomes clear that one cannot assume linear relations between inputs and outputs in healthcare. This is caused by the situation that healthcare is no real production sector and the in and outputs are not simply quantities but also quality measures. An increase in inputs does

not necessary result in a proportional increase in the quality of healthcare. The VRS frontier model is therefore the most applicable model for the purpose of this research.

The choice for the preference structure model depends on whether a decision maker can distinguish between the relative importance of different inputs. This is kept out of scope in this research and there is therefore no reason for the use of the preference structure model. The existence of large input slacks may be an other reason for the choice for the preference structure model. Without knowledge about the preference values one can fix all weights for the inputs at the same level. DEA is now able to optimize the lambdas for the efficiency scores of the individual inputs. Input slacks do in this situation no longer exist. However, whether there are input slacks is only known after the execution of the non preference structure model. For that reason is chosen to use the non preference structure model. The outcomes of the non preference structure model are afterward compared in section 6.3.7 with the outcomes of the preference structure model.

5.4 Justification for the use of the DEA method

There exist multiple methods for efficiency evaluation. Like each efficiency analysis technique the DEA method has strengths and weaknesses. Both the relevant strengths and weaknesses are discussed in this section. Section 5.4.2 gives a conclusion on the strengths and weaknesses of the DEA method and gives a justification for the use of DEA instead of other efficiency evaluation methods.

5.4.1 Strengths and weaknesses

This section discusses the strengths and weaknesses of the DEA method for the purpose of this research.

Strengths The DEA analysis technique has the following strengths. The strengths are discussed in more detail below.

- DEA can work with an infinite number of inputs and outputs simultaneously[2]
- DEA is a realistic method that works with proven efficiency
- DEA is a conservative method (not optimistic like linear efficiency models)
- DEA works even when no statistical relations are proven
- DEA is highly customizable
- DEA presents many valuable figures compared to conventional methods for efficiency evaluation

One of the most important strengths of the DEA method is the fact that it can work with multiple inputs and outputs. This makes it possible to calculate one efficiency figure for a process instead of a bunch of individual efficiency figures. Decision makers can in that sense steer on one figure without loosing insight in the performance on individual inputs and outputs. DEA works with proven efficiency (Zhu, 1996). This is effective when the analyses are executed on a large number of DMUs. The efficient frontier consists in that situation of many DMUs. That means that in many cases there are only a few DMUs on the efficient frontier that function as a benchmark for an inefficient DMU. The benchmark is in that case not a virtual point on the efficient frontier but an existing DMU. This means that there is a DMU that is able to generate better outputs with the same inputs. This directly supports the next point. DEA is a conservative analysis technique. This is a result of the fact that DEA works with local linearity between two points on the efficient frontier instead of global linearity. DEA interpolates the efficiency on a small range in case of many DMUs on the efficient frontier, which gives a more reliable approximation of the efficient frontier than global linear models give. Figure 5.1 and figure 5.2 demonstrate the difference between interpolation over a small range and extrapolation. Subsequently, DEA is a

[2]The number of inputs and outputs that are used is only restricted by the calculation capacity, while the optimization problem becomes more and more difficult when more inputs and outputs are added to the analysis.

handy tool when there are factors included in the efficiency analysis that are equivocally established. This is for example valid for the quality indicators QALY (increase in years in relative health) and the CQ-index (Quality of care from the patients eyes). It is often difficult to determine a relation in case of an equivocally established factor and to determine the meaning of an exact score on these factors. It is for that reason not possible to optimize an efficiency function for this specific factor. DEA is applicable for efficiency analysis, even when no statistical relation between inputs and outputs can be proven or when these relations vary among several cases. This makes the DEA method universally applicable. There is often no significant relation between inputs and outputs of the DEA method and the relation is different for the different care pathways. The abundance of statistical relations between inputs and outputs makes it impossible to use a conventional efficiency analysis method[3]. In addition the prediction model is often not reliable which means that the individual performance of the integrated care pathways lays far from the predicted performance. Due to the fact that DEA does not assume any statistical relations, one is able to define a more accurate efficiency model for the purpose of this research that takes into account all kind of factors that may influence the performance of a care pathway. This may be the composition of the treated population and the capacity of the care pathway. Further more, DEA provide decision makers with more valuable outcomes like the improvement potential of a DMU, and efficiency figures for individual inputs and outputs. This makes it possible to use DEA as an input for performance benchmarking among healthcare providers as proposed in section 9.3.2.

Weaknesses Besides the above mentioned strengths, DEA has the following weaknesses and limitations

- The number of efficient DMUs depends on the number of DMUs that are included in the analysis
- The number of efficient DMUs depends on number of inputs and outputs that are included in the analysis
- Local linearity does not always satisfy
- DEA does not support undesirable measures very well
- DEA does not well support sensitivity analysis
- Non-zero slacks are not handled very well in general DEA models

DEA needs to be executed on a set of relative many DMUs in order to clearly distinguish between efficient and inefficient DMUs. The quality of the efficient frontier is low in case of a few DMUs, which means that there is a low density of efficient points on the frontier. A second point of concern is the fact that the number of efficient DMUs highly depends on the number of inputs and outputs that are included in the DEA analysis.This means that DEA not necessary becomes more accurate when including more inputs and outputs in the analysis. In addition, DEA relies on local linearity between two points on the efficient frontier. However, this assumption may be problematic for some inputs and outputs. For example the quality of healthcare (when expressed in a value between f.e. zero and one) cannot be assumed as a local linear function between two points on the efficient frontier. It may be likely that the function between inputs and outputs expressed as above have a more hyperbolic shape. Another point of concern is the existence of undesirable measures. Undesirable measures are inputs that should be increased and outputs that should be decreased in order to get optimal outcomes. There is no standardized way of treating these measures which makes the outcomes of the DEA analysis hard to interpret. One can handle these measures differently which leads to different outcomes for the same analysis. The efficiency figures in DEA may be quite sensitive for fluctuations in the performance figures of efficient DMUs. DEA does not well support sensitivity analysis on the inputs and outputs, which makes it hard to get insight in the sensitivity of the efficiency of single DMUs. A last problem in DEA is the existence of non-zero slacks. DEA is not able to accurately calculate the efficiency score of a DMU in case of non-zero slacks (Cooper et al., 2011) because a DMU can still improve its performance without changing its efficiency scores in case of the existence of non-zero slacks.

[3]Conventional methods make use of theoretical relations among inputs and outputs.

5.4.2 Treating weaknesses in DEA

There are some important weaknesses in DEA that deserve attention. The more inputs and outputs are used the more efficient DMUs you get. It may be wise to cluster some inputs and outputs[4] while taking care to lose no relevant information in order to decrease the number of inputs and outputs. Also the risk on a low quality frontier is a serious weakness of DEA. However, often there are a large number of DMUs in healthcare that prevent this situation from occurring. The same may be valid for measures where local linearity cannot be assumed. The efficient frontier becomes smoother when a large number of DMUs is subject to the analysis (see figure 5.7 and figure 5.8). This may result in a shape that approaches the actual shape of the efficient frontier. The problem that DEA does not handle data variations well, can be partly solved by the execution of a limited sensitivity analysis by varying the inputs and outputs of only those DMUs that lay on the efficient frontier and that are often a benchmark for inefficient DMUs. By doing so, one can get proper insight in the robustness of the efficiency figures. The fact that DEA is not able to calculate accurate efficiency scores for DMUs with non zero slacks can partly be solved by using the improvement potential as an additional measure for the efficiency of integrated care pathways. An other way to handle slacks is the use of preference structure models. These models makes it possible to calculate the efficiency scores per parameter[5] instead of an overall efficiency score for the DMU. The overall efficiency score is than derived from the weighted parameter efficiency scores.

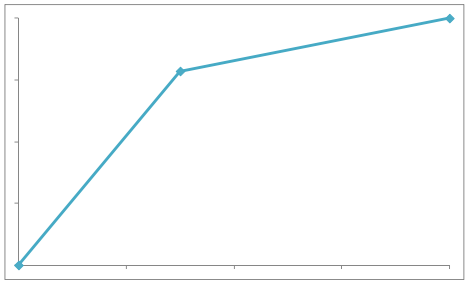


Figure 5.7 – Efficient frontier for few DMUs

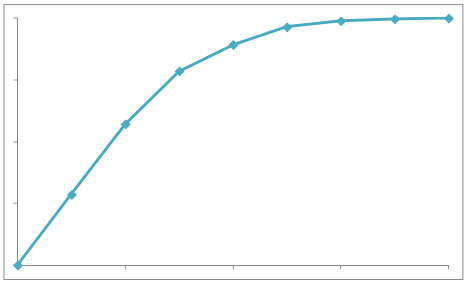


Figure 5.8 – Efficient frontier for many DMUs

5.5 Conclusions on the use of DEA

DEA is a conservative method for efficiency management which works with proven efficiencies instead of theoretical efficiencies. This makes the method valuable for the evaluation of healthcare performance as there are in healthcare often no theoretical efficiencies that can serve as benchmark for the individual care pathways. Even there are often no proven relationships between inputs and outputs which makes it possible to use a regression based globally linear model. From the discussion on the strengths and weaknesses one cannot deduce that DEA is the optimal method for efficiency analysis integrated care pathways. Other efficiency evaluation methods may be applicable as well. However, DEA is likely to deliver interesting outcomes as it is never applied on the integrated care pathway level before. In addition, DEA is a customizable method that can deliver various outputs. This makes it possible to generate outcomes (like the improvement potential) that cannot be calculated with many other efficiency evaluation methods, like simple linear methods. In addition, DEA is a conservative method that works with empirical values, which is consistent with the nature of the healthcare system, where there are often not theoretical efficiencies nor statistical relations between inputs and outputs.

[4] An example may be clustering the inputs # of doctors, # of nurses, etc. as employees. One should be careful with clustering inputs and outputs because it may lead to loss of relevant information.

[5] With the help of preference structure models one can calculate the efficiencies of the input parameter in case of input oriented models and the efficiencies of the output parameters in case of output oriented models.

Chapter 6

DEA Sample Analysis

The previous chapter explains the characteristics of DEA in short and showed which steps are to be taken during the execution of a DEA analysis. This chapter comprises a sample analysis of the DEA method which is executed to demonstrate the benefits and application of DEA for the purpose of performance evaluation in general and particularly the evaluation of the efficiency of integrated care pathways.

There are many types of efficiencies that can be calculated. This research focuses on the examination of the productive efficiency of integrated care pathways. The productive efficiency concerns the optimal combination of input factors that are needed to produce a set of outputs (EconomicsHelp, 2012) at the lowest price. Productive efficiency requires technical efficiency. This means that a firm is able to produce the maximum amount of outputs with a minimal amount of inputs. This is exactly where the four key parties focus on in the healthcare outline agreement. Section 6.2 starts with the selection of an appropriate case on which DEA can be executed in order to demonstrate the benefits of DEA for performance evaluation of integrated care pathways. Section 6.3 comprises the execution of all steps in DEA as discussed in section 5.2 on the selected case. Section 6.4 comprises the findings and conclusions that are experienced during the execution of DEA.

6.1 The use of data

Most information in healthcare should be kept confidential and can for that reason not be published in this research. Performance data of healthcare providers that is available at KPMG is not used in this research because of the confidentiality of this information. For that reason is made use of synthetic data. The synthetic input and output values are generated with the help of random number generators. The algorithms can be found in appendix C. The drawback of using synthetic data is that patterns that exist in real data cannot be imitated by the random number generators. This may have impact on the outcomes of the analysis and is for that reason an important point that will be discussed by the interpretation of the outcomes of the efficiency analysis. In addition, the synthetic data cannot be adjusted for disturbing factors (gender, age, geographical region which are discussed in section 4.5) because of the lack of knowledge about these characteristics.

6.2 Case selection

The benefits of DEA for the purpose of performance evaluation of integrated care pathways will be shown with the help of a sample case in this chapter. This section discusses a case that is applicable for the execution of DEA. The case is selected on the basis of a set selection criteria that are defined in section 6.2.1.

6.2.1 Selection criteria

A set of selection criteria should be fulfilled in order to come up with a case that is appropriate for the demonstration of the benefits and application of DEA for performance evaluation on the level of integrated care pathways. The following case selection criteria are used.

1. The population that is treated for a specific disease is sufficiently large[1]
2. Population characteristics are known[2]
3. The treatment belongs to the physical healthcare system[3]
4. Data about the performance of integrated care pathways is available for a specific disease[4]
5. The treatment comprises multiple steps that are executed by different healthcare providers[5]

There should be remarked that data currently is available but could not be used in this research because of confidentiality. The only relevant criteria for the selection of appropriate cases that remain due to the use of synthetic data are criteria 1, 3 and 5. The other two criteria cannot be checked when synthetic data is used but are relevant in case of proper performance evaluation where the interpretation of performance figures is included.

6.2.2 Selection of specific case

Multiple treatments in healthcare may meet the selection criteria that are mentioned in section 6.2.1. One of the diseases that meets the selection criteria is the treatment of varicose veins. Yearly many people are treated for varicose veins. In addition, the treatment of this disease belongs to the physical healthcare system and there are several treatment options that are executed by multiple healthcare providers. Some of the most often used treatment options for this specific disease are

- Stripping
- Sclerotherapy
- VNUS closure fast procedure
- Endovenous Laser Therapy (EVLT)
- Ambulatory phlebectomy
- Crossectomie

Each treatment can be seen as a separate integrated care pathway that comprises multiple steps. Which treatment is followed by a healthcare provider depends on the capabilities and experiences[6] of the healthcare provider where the treatment is executed and the characteristics of the patient that is treated[7]. In each treatment of varicose veins is the primary healthcare provider involved because the cost of a treatment is in most cases only reimbursed when the patient is referred by a general practitioner (Bergmankliniek, 2012). However, the steps that are taken during the distinct treatment methods are quite different. It may also occur that for the same treatment more tasks are executed by a primary healthcare provider in order to reduce the cost of the treatment[8]. The figures 6.1, 6.2 and 6.3 show three different integrated care pathways that can be used for the treatment of the same patient. The integrated care pathways are different because they are based on local experiences and best practices which may vary among different healthcare providers or different treatment options are chosen (this is more extensively discussed in section 1.4.2).

[1] This is required in order to be able to come up with significant outcomes.
[2] Population characteristics are used for adjusting the performance of the integrated care pathways on the underlying differences.
[3] The mental healthcare system is quite different and it may for that reason not be possible to execute the same analyses on this part of the healthcare system
[4] Quantitative information is required, because DEA is a quantitative method and cannot handle qualitative information very well (see section 5.4.1).
[5] Integrated care pathways that transcend the border of healthcare providers are key in this research.
[6] One may assume that a healthcare provider treats the patient in the way that is most successful according to their experiences.
[7] Under some conditions is one treatment most effective, where under other conditions a different treatment is most effective.
[8] The treatment is often more expensive when it is executed at a secondary healthcare provider.

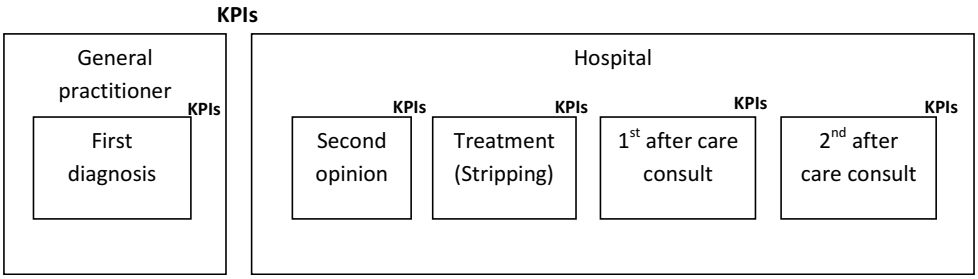


Figure 6.1 – Integrated care pathway A for the treatment of a patient with varicose veins

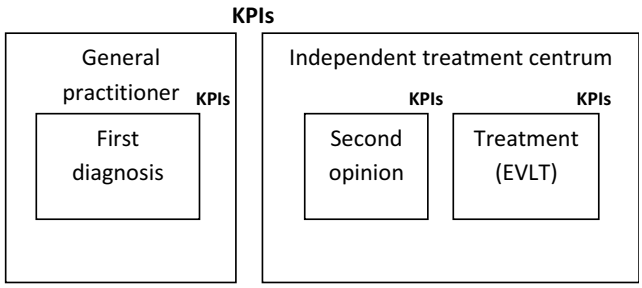


Figure 6.2 – Integrated care pathway B for the treatment of a patient with varicose veins

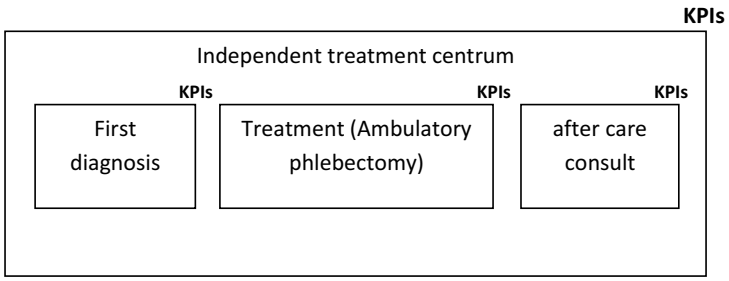


Figure 6.3 – Integrated care pathway C for the treatment of a patient with varicose veins

The following sections discuss the execution of the steps of the DEA analysis on the treatment of varicose vains. The three integrated care pathways that are showed in the figures above are taken as a starting point for the execution of the DEA analysis.

6.3 DEA execution

This section comprises the execution of the DEA analysis on the basis of the steps that are defined in section 5.2. The steps that needs to be executed are demonstrated with the help of the *varicose veins* case. The analysis is based on synthetic data that can be found in appendix C. Figure 6.4 highlights the position of DEA in this research. DEA is used to calculate one of the KPIs that may be used for healthcare procurement, namely the efficiency of integrated care pathways.

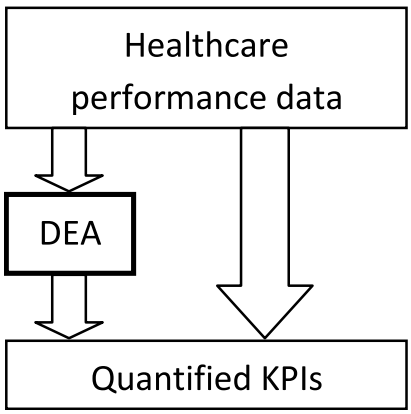


Figure 6.4 – Position of DEA in this research

6.3.1 Step 0: Definition of analysis objectives

The objective of the analysis is the evaluation of the efficiency of the different treatments for varicose veins, where the treatment includes all actions that are executed by any healthcare provider between the time the patient enters the healthcare system until the patient is dismissed from the healthcare system. Subsequently, DEA is used for benchmarking the efficiency figures of the treatments among healthcare providers and for defining the improvement potential of each healthcare provider compared to its benchmark.

6.3.2 Step 1: DEA configuration

The configuration of the DEA model depends on the required outcomes of the analysis. In this analysis is made use of an input-oriented Variable Return to Scale model (VRS) without a preference structure. A justification for this model is given in section 5.3.2. The following parameters are defined

- There is made use of four inputs and four outputs (justified in section 6.3.4)
- All inputs are set to be minimized and all outputs are set to be maximized
- The input and output values are synthetic (a specification of the synthetic data is given in appendix C)
- 100 DMUs where subject to the analyses

6.3.3 Step 2: Determination of DMUs

The decision making units that are subject to the DEA analysis are the integrated care pathways. This becomes more clear when we look at the description of the sample case in section 6.2. The decision making units are all different treatments that are executed on patients with varicose veins as displayed in the figures 6.1, 6.2 and 6.3. A justification for the choice for the integrated care pathways as analysis object is given in section 2.3.2.

6.3.4 Step 3: Determination of Inputs and outputs

A careful consideration of the inputs and outputs that will be used in the DEA analysis is required because of the reasons mentioned in section 5.4.1[9]. It is important that only those inputs and outputs are included that are necessary for measuring the efficiency on the relevant aspects of the healthcare system as mentioned in section 4.2. The inputs and outputs should be clustered where possible[10] in order to reduce the number of inputs and outputs and to increase the effectiveness of the analyses. The relevant inputs and outputs can be distinguished with the help of figure 6.5 and the KPIs that measure the performance of the integrated care pathways on the relevant goals of the healthcare system.

[9]Irrelevant inputs and outputs will result in less effective outcomes of the DEA analysis.
[10]Input and output clustering should only be applied when no information is lost due to the clustering of information

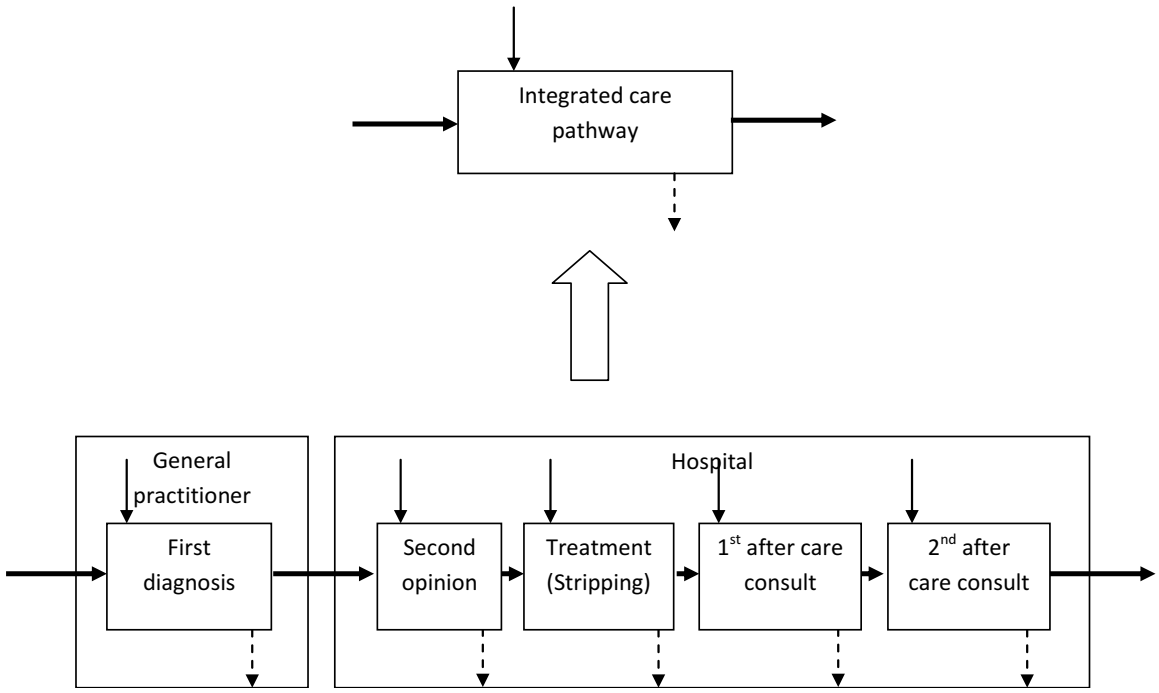


Figure 6.5 – Inputs and outputs of integrated care pathways

As becomes clear from this figure, integrated care pathways consist of several steps. Each of the steps has its own inputs and outputs. All relevant inputs and outputs should be taken into account for the calculation of the efficiency figures of the integrated care pathways. The first diagnosis at the general practitioner has for example the following inputs

- treatment minutes by general practitioner [minutes/ treatment]
- cost price of treatment [€/ treatment]
- treatment duration [minutes/ treatment]

and the following outputs

- patient satisfaction [CQ-score]
- length of waiting list [day/ treatment]

When we have a look on the other steps (see figure 6.5) that are taken during the treatment of the patient for varicose veins we can distinguish the following additional inputs

- treatment minutes by doctors [minutes/ treatment]
- treatment minutes by nurses [minutes/ treatment]
- occupation of surgery room [minutes/ treatment]
- occupation of hospital bed [day/ treatment]

and the following outputs

- number of Quality Adjusted Life Years [QALY]
- complication risk [fraction]
- recidivism risk [fraction]

One should remark that the number of treatments is not included here as an individual output. However, the number of treatments is taken into account when all input and output values are averaged over the number of treatments. The billed cost of a treatment is also not taken into account as this is not a performance measure of an integrated care pathway, but a variable where can be negotiated about.

The current number of inputs is twelve in total. One should look for a possibility to reduce this amount without loosing information and reducing the effectiveness of the DEA analysis. A possible output that can be removed is the *recidivism risk*. The *recidivism risk* can be left out when we define the integrated care pathway transcending the border of healthcare providers. The integrated care pathway comprises all treatments until the patient leaves the healthcare system. This includes the treatment of a relapsed patient. One can also reduce the number of inputs by leaving out the *cost price of a treatment*. The *cost price of a treatment* is determined by factors like the *treatment minutes by general practitioners*, *doctors* and *nurses* and the occupation of capital resources like *surgery rooms* and *hospital beds*. The treatment minutes by doctors and nurses could be reduced to the *treatment minutes by hospital employees* and the occupation of surgery rooms and hospital beds may become the *occupation of healthcare capital resources*. This leaves us up with the following inputs

- treatment minutes by general practitioners [minutes/treatment]
- treatment minutes by hospital employees [minutes/treatment]
- treatment duration [minutes/treatment]
- occupation of healthcare capital resources [minutes/treatment]

and the following outputs

- patient satisfaction [CQ-score]
- length of waiting list [day/treatment]
- number of Quality Adjusted Life Years [QALY]
- complication risk [fraction]

6.3.5 Step 4: Quantification of inputs and outputs

The quantification of the inputs and outputs of integrated care pathways may be one of the most challenging tasks in the execution of the DEA analysis and is quite different from other situations as the integrated care pathways transcend the borders of healthcare providers. This adds a lot of complexity to the quantification step. Input parameters may be valid for multiple steps at different healthcare providers which means that the information at the level of the individual steps needs to be aggregated to the integrated care pathway level in order to get single values for the inputs and outputs. This may become clear when we look at the *treatment duration*. This parameter is measured at each step of the integrated care pathway. This means that one needs to add up all individual *treatment duration* values in order to get this measure at the level of the integrated care pathway. One should remark that reliable figures at the level of the integrated care pathway requires a reliable information infrastructure at each specific step.

Most of the inputs and outputs that are required for the calculation of the productive efficiency cannot be quantified with the help of currently available information[11]. This section will discuss what issues may arise around the quantification of input and output values.

[11]This concerns both publicly and privately available information like databases of healthcare providers, health insurance companies, the NVZ and the national government.

Inputs The input parameters that are used for the calculation of the productive efficiency of integrated care pathways are given in section 6.3.4. The treatment minutes by general practitioners and hospital employees are currently not publicly available because this is confidential information of the healthcare providers. However, there exist a central database for healthcare providers in which this knowledge is stored. The same is valid for the treatment duration and the occupation of healthcare capital resources.

Outputs The output parameters that are used for the calculation of the productive efficiency of integrated care pathways can also be found in section 6.3.4. The output parameters seem to be much harder to quantify than the input parameters as the output parameters often are no single measurable parameters. Most of these parameters are currently not measured and for that reason not available for all integrated care pathways. This is valid for all output parameters that are mentioned in section 6.3.4. The length of the waiting lists is only available for a few treatments. The same is valid for the CQ-index, for the QALY indicator and the complications risk. The conclusions in chapter 9 comprises a discussion on required improvements at the side of data quality for the purpose of the proper quantification of healthcare performance.

6.3.6 Step 5: Calculation of DEA outcomes

The calculation of the relevant outcomes of the DEA analysis is done with the help of a vba based Microsoft Excel model. As mentioned before, the calculations are executed on synthetic input and output data. There is made use of four inputs and four outputs. Section D.2.2 of Appendix D comprises a description of the model and presents the vba-code. The model is able to calculate for an unlimited number of DMUs, inputs and outputs, the efficiencies, lambdas, input/output slacks, target values and improvement potential of the integrated care pathways. The mathematical model that is used for the calculation of these figures is discussed in section D.1 of appendix D.

6.3.7 Step 6: Interpretation of results

Due to the use of synthetic data, the efficiency figures cannot be interpreted as real performance figures for any integrated care pathway. However, we can come up with useful conclusions and recommendations when we take the results of the DEA analysis as real outcomes. The consequences of the use of synthetic data for generalization of outcomes and the validity of the conclusions are also discussed in this section

Efficiency The efficiency of the integrated care pathways is only one of the performance indicators and should for that reason not be seen as the overall performance of a healthcare provider. One should remark that the efficiency figures do not necessary tell whether the individual steps are efficient, but only give the efficiency of the whole sequence of steps that are executed during the treatment of a patient. The efficiency figure solely tells the decision maker whether a DMU is able to produce its outputs with a minimal amount of inputs and does not tell which DMU has the best overall performance. This becomes clear when we compare the following efficient DMUs[12]. We see that the performance of each DMU is quite different. DMU-8 and DMU-16 serve only one time, where DMU-47 serves two times and DMU-83 four times as a benchmark for the other DMUs. The decision for one of the alternatives is not only determined by their efficiency score but also by the performance on other KPIs and the relative importance of these KPIs (see section 4.5.2).

[12]The data is extracted from table C.1 in appendix C

DMU	Input1 Cost price of treatment [€/ treatment]	Input2 Employee occupation [day/ treatment]	Input3 Capacity utilization [day/ treatment]	Input4 Treatment duration [day/ treatment]	Output1 Length of waiting lists [week]	Output2 QOL score [..]	Output3 QALY [QALY/ treatment]	Output4 Complication risk [%]
X1-8	469,00	2,39	163,33	4,38	0,18	6,24	23,71	30,28
X1-16	217,00	10,54	103,62	4,54	0,08	14,24	26,33	19,71
X1-47	198,00	4,48	113,54	2,21	0,00	12,58	12,91	12,41
X1-83	415,00	2,71	108,26	3,31	0,19	15,62	30,45	49,70

Table 6.1 – Performance of efficient DMUs

The second column in table E.13 comprises the efficiency scores for the DMUs under evaluation. A relatively large number of DMUs appears efficient from the analysis. The analyses in appendix E show that the number of inputs and outputs have a major impact on the number of efficient DMUs. Another reason may be the lack of data patterns due to the use of synthetic data. A graphical presentation of the efficiency scores in case of the non preference DEA model is given in figure 6.6. Almost forty percent of all DMUs is efficient based on this figure. This comes also forth from the statistical analyses presented in section E.1.2.

All the efficient DMUs together form the efficient frontier. The inefficient points are the healthcare providers that can improve their performance by reducing their inputs or by increasing their outputs until the target levels. This means that they can reduce the use of inputs without reducing any of the outputs. The improvement potential of the DMUs is discussed under section 6.3.7. The ratio between the number of dimensions (inputs and outputs) and the number of efficient DMUs, as discovered in section E.1.2 of appendix E is an indicator for the quality of the efficient frontier as it determines the density of DMUs on the efficient frontier.

For the interpretation of the efficiency figures it is important to remark that the use of random input and output values may have impact on the number of efficient DMU. Because of the lack of data patterns, it is likely that there are more efficient DMUs in case of random inputs and outputs than in case of original data.

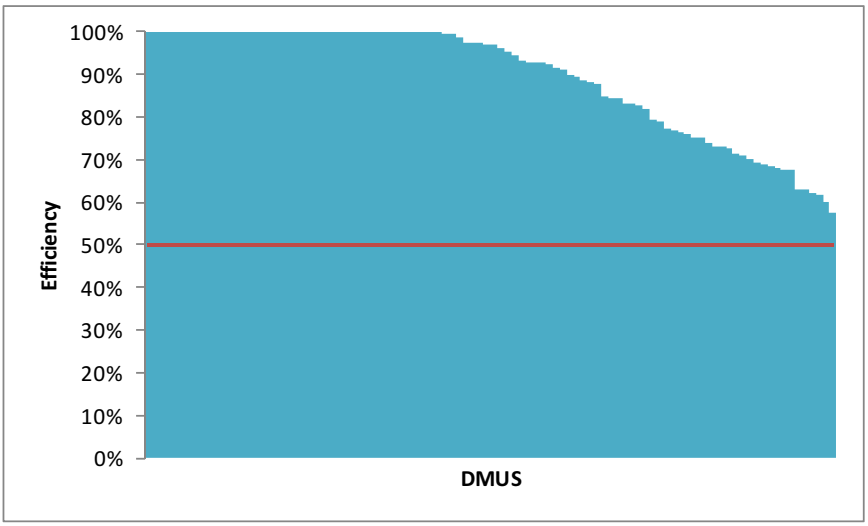


Figure 6.6 – The efficiency scores of the analyzed DMUs for the non preference DEA model

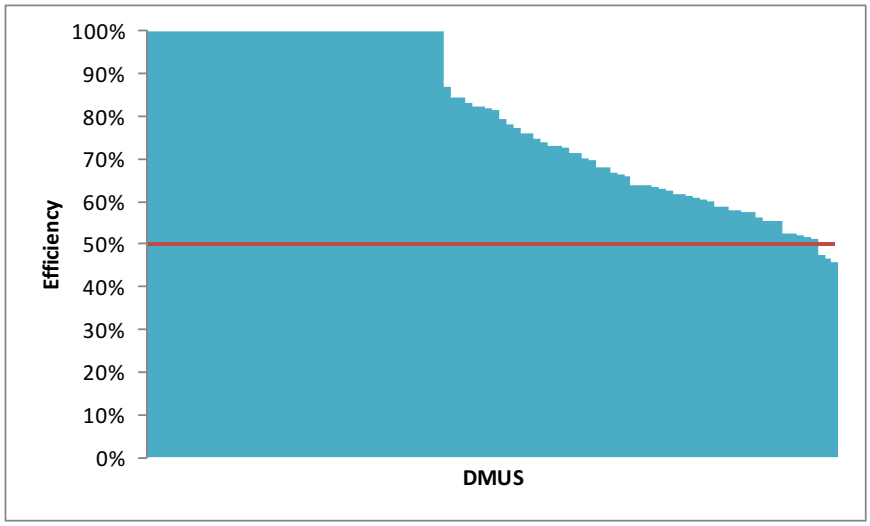


Figure 6.7 – The efficiency scores of the analyzed DMUs for the preference DEA model

Lambdas One of the outcomes of the DEA analysis are the lambda scores. The lambda scores show which DMUs[13] serve as benchmark for the DMU under evaluation. The benchmarks are always efficient DMUs. The virtual point on the efficient frontier that is created by the combination of the benchmark DMUs is the target point for the DMU under evaluation.

Table E.13 of appendix E comprises the benchmark DMUs for each integrated care pathway. The number of benchmarks vary from one to six. All efficient DMUs have only one benchmark (these DMUs are their own benchmark). The inefficient DMUs have generally more than one benchmark. The benchmarks are important for establishing the target values of the inputs and outputs of each DMU. An indication can be given about the potential for the reduction of inputs in healthcare based on the improvement potential for each DMU.

Input and output slacks Table E.17 in appendix E comprises the input and output slacks of the DEA analysis. The input and output slacks are a technical output of the DEA analysis and do not have a special meaning for decision makers. Nevertheless, the presence of slack values may negatively affect the effectiveness and accuracy of the efficiency scores. From this table becomes clear that in general many DMUs are confronted with large input and output slacks. The presence of large slack values is an unwanted situation as the outcomes of the DEA analysis may become surrealistic. There should be remarked that the presence of large input and output slacks may be caused by the use of synthetic data. This leads to the abundance of data patterns that may exist in real data. There is a solution present in DEA that can solve this problem. When we use a preference structure model in case of a non preference structure model we can calculate efficiency scores for the individual input and output parameters. There are no longer slack values present when we minimize the overall efficiency for the individual efficiencies per input or output parameter. The efficiency scores for the individual inputs can than function as a measure for the improvement potential per parameter and give clear insight in the potential for performance improvement for each healthcare provider on specific parameters. The efficiency figures for the individual inputs are given in table E.14 of appendix E. One can see in figure 6.7 that the efficient DMUs stay efficient, but that the efficiency scores of the inefficient DMUs is adjusted due to the reduction of the slack values. This makes the preference model more effective than the non preference model.

Target values and improvement potential The target values are the input and output values of the virtual benchmark point on the efficient frontier. The target values are the best values that can be achieved for a DMU based on the analyzed empirical data set. The improvement potential is the difference between the actual input and output values and the target values. This values tells what improvements can be realized by a particular DMU based on the performance of comparable DMUs.

[13]The DMUs are the integrated care pathways.

Table E.18 in appendix E.2.3 presents the target values for the different inputs and outputs. There should be remarked that the improvement potential may be relatively large due to the lack of data patterns in the synthetic data. This becomes clear from figure 6.8 and figure 6.9.

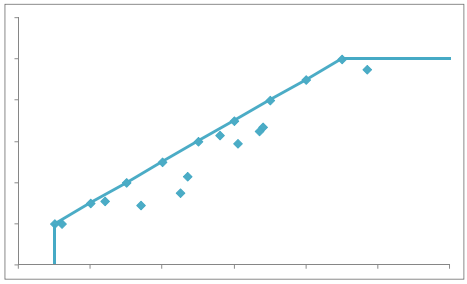


Figure 6.8 – improvement potential in case of real data

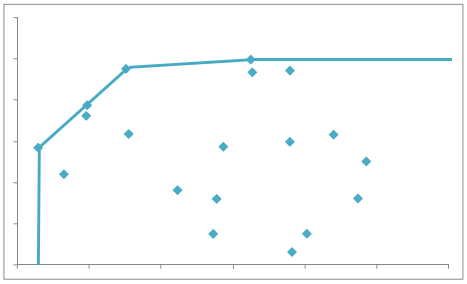


Figure 6.9 – improvement potential in case of random data

6.4 Conclusions

Some important conclusions can be derived from the DEA analysis in this chapter. The conclusions are based on the experience gained during the execution of the DEA method.

- The execution of DEA on integrated care pathways adds a lot of complexity to the analyses by the execution of several steps
  - Relevant inputs and outputs should be defined for each step that is taken during the treatment of a patient
  - The quantification of the inputs and outputs becomes more difficult as the same input/output parameter may be valid for different steps. This asks for the aggregation of the individual parameters to the single level of the integrated care pathway.
  - One cannot disaggregate the outcomes (efficiency figures, improvement potential, etc.) of the DEA analysis from the integrated care pathway level to the level of the individual steps. The efficiency figures can for that reason only be interpreted as the efficiency of the whole sequence of steps that are taken during the treatment of a patient. One cannot distinguish here between separate healthcare providers that are part of the integrated care pathway.
- The DEA analysis provides valuable information for decision makers about the efficiency and improvement potential of integrated care pathways. DEA makes it possible to demonstrate which treatment method in general is most efficient compared to other treatment methods.
- DEA does not provide insight in the overall performance of integrated care pathways, as the efficiency is only one aspect of the performance of integrated care pathways.
- DEA is effective when a decision maker can clearly distinguish between efficient and inefficient DMUs with the help of the outcomes of the DEA analysis.
- The effectiveness of the outcomes of the DEA analysis depends on some factors
  - The number of efficient DMUs increases with the number of inputs and outputs used in the analysis. This makes DEA less effective because it makes it harder to distinguish between efficient and inefficient DMUs. It is for that reason important to include no more than the strictly necessary inputs and outputs for the calculation of the productive efficiency.

    * It is important to adjust the input and output figures of integrated care pathways for environmental factors (see section 4.5.1) in order to get comparable performance figures. It may be wise to adjust the input and output values on beforehand when possible because adding them as inputs or outputs to the analyses may lead to a significant increase of efficient DMUs. This makes DEA less effective.

  - The ratio of inefficient DMUs increases with the number of DMUs that are included in the research. It is for that reason important to include as many DMUs as possible in the analysis. DEA should for that reason preferably be executed on all integrated care pathways in the Netherlands that exist for a certain disease.
  - The slack ratio may increase by an increasing number of DMUs. It may be wise to choose for a preference structure model in case of an increasing slack ratio. A preference structure model reduces the amount of slacks, gives more specific and accurate figures for the overall efficiency of an integrated care pathways and can also provide efficiency figures for specific inputs and outputs. This gives insight in the strengths and weaknesses in the management of inputs and outputs in healthcare processes.

- It may be better to use a preference structure DEA model in stead of a conventional DEA model for the calculation of the efficiencies in case of the presence of much input slack. The input efficiencies are calculated more accurately by a preference structure model than by a non preference structure model in case of the presence of much input slack.

Chapter 7

Design and Implementation of the HPQ-method

The design objective for this research is defined in section 3.4.1 as a method for the quantification of healthcare performance on the integrated care pathway level. This chapter presents the Healthcare Performance Quantification method[1] as a first step towards a healthcare procurement model and a performance benchmarking method for health services on the level of specific treatments. The method consists of different steps that are described in section 7. Section 7.2 discusses for each step the issues that may arise around the execution of these steps.

7.1 Method definition

Figure 7.1 gives a graphical representation of the HPQ-method as it is proposed in this research. The method consists of eight steps that are executed in the previous chapters of this research. The important findings for the distinct steps are presented in this section. The following distinct steps can be distinguished for the HPQ-method

1. actor definition
2. actor preference identification
3. actor goal definition
4. definition of KPIs
5. definition of disruptive factors
6. definition of relative importance of KPIs
7. KPI quantification
8. performance interpretation

[1] This method is called the HPQ-method in this research.

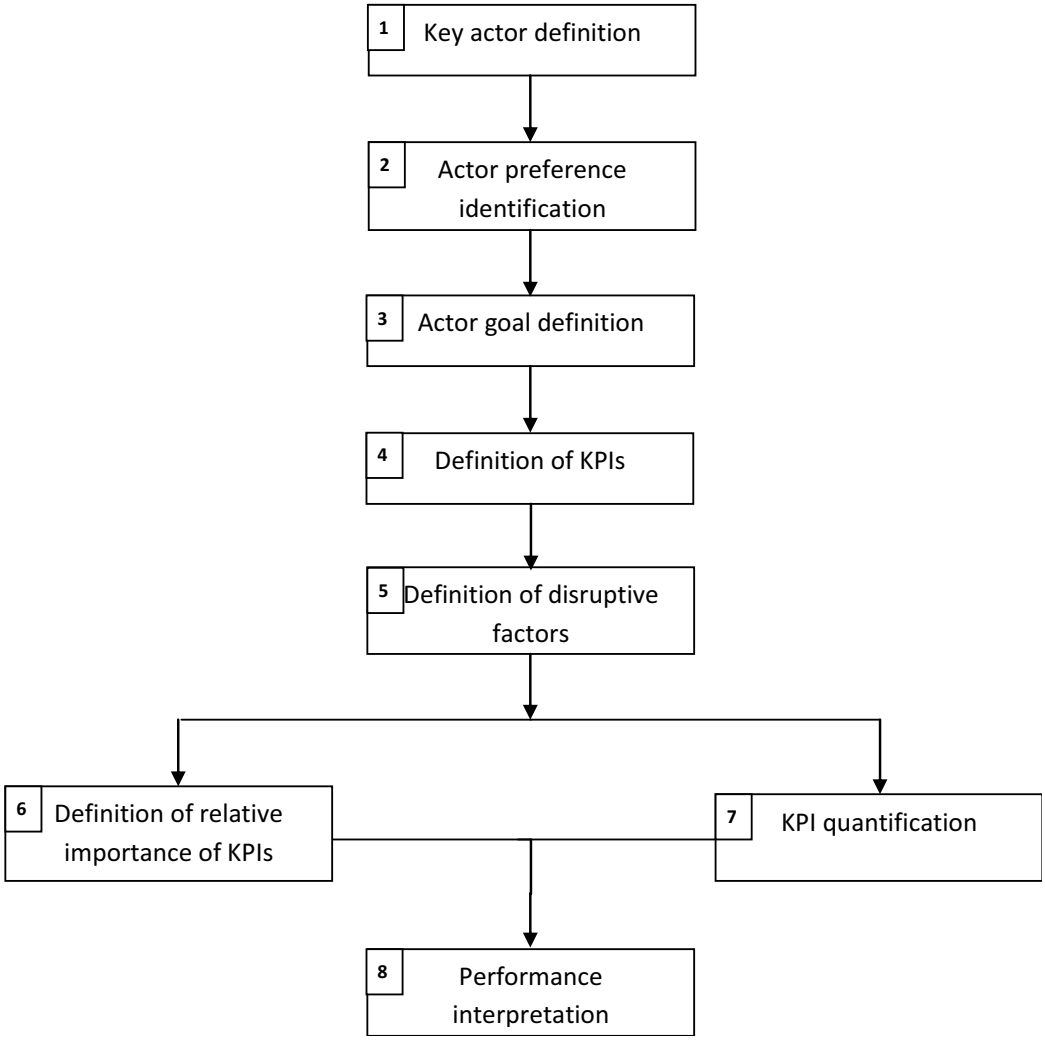


Figure 7.1 – Graphical representation of the HPQ-method

The above mentioned steps are discussed in more detail below. One should remark that there are only a few important differences between the quantification of the performance of the healthcare system at the institutional level and the integrated care pathway level. These most important differences are experienced at the first, fifth, seventh and eight step of the method.

Actor definition The first step towards the quantification of the performance of healthcare providers on the level of the integrated care pathways is the definition of the different actors in the healthcare sector that play a dominant role. These actors determine which goals are important for the healthcare system and often have the power to help these goals being realized. The number of actors that may play a relevant role increases when there is looked at the level of the integrated care pathways as many healthcare providers and individual healthcare employees are involved in the treatment of patients. These actors stay out of scope in case of the quantification of healthcare performance at the institutional level as they play a far less important role in the establishment of the performance figures of an institution compared to the integrated care pathways.

Actor preference identification The second step concerns the identification of the preferences of actors. Each actor has its own interest in the healthcare sector. Patients will be treated best for the disease they have, the national government wants to realize a high quality healthcare system for the patients that delivers affordable health services, healthcare providers will realize continuity and health insurance companies will realize a high degree of client satisfaction by the deliverance of appropriate health services. The preferences of the different actors determine which goals are relevant for them to be realized by the healthcare system.

Actor goal definition As mentioned under the previous steps, the actors and their preferences are the input for the definition of the goals of the different actors. The definition of the goals of the key actors in healthcare is an important step, because the goals of the healthcare sector determine the KPIs on which the performance of healthcare providers is measured. Actors can formulate their goals with the help of their preferences. The goals of the actors help them to realize a desirable situation in healthcare from their point of view. It is for that reason important that only the relevant goals are taken into account. Steering on irrelevant goals may come at the expense of achieving the relevant goals.

Definition of KPIs Key Performance Indicators are formulated in order to measure the performance of healthcare providers at the integrated care pathway level on the relevant goals of the key actors. The KPIs should be of high quality[2] in order to measure the performance of integrated care pathways in an accurate way.

Definition of environmental factors A next step is the definition of environmental factors. During this step, environmental factors are identified that have an impact on the performance of the integrated care pathways. It is necessary to adjust the performance of integrated care pathways for these factors in order to be able to steer accurately on the performance of integrated care pathways. Statistical information about the relationships between the external factors and the performance figures is required in order to be able to calculate accurate performance figures. One should remark that it makes a difference whether to adjust the performance figures of the healthcare providers at the institutional level or on the integrated care pathway level. More environmental factors may have a significant impact on the performance figures of the integrated care pathways than on the performance figures of a specialism or a healthcare institution as the population characteristics and the complexity of a disease may be averaged when we look at the performance of a healthcare provider at a higher level. This will not be the case for an integrated care pathway when it treats a specific population in a specific gegraphic region.

Definition of relative importance of KPIs Information about the relative weights of KPIs is required in order to be able to define a preference relation among different alternative treatments of a specific disease. The relative importance of the KPIs can be determined with the help of the preference of the key actors and the relative importance of the different actors for the success of the decision making process. An alternative way of determining the relative importance of KPIs is to make use of the desires of the patient. This may be required in order to deliver health services that fit with demand driven healthcare. This may result in a different weight for the KPIs for different diseases. Patients for example may value the cost of health services as being less important in case of a complicated treatment and more important in case of a routine treatment.

KPI quantification The quantification of the KPIs is based on many of the previous steps and can be executed in parallel with the definition of the relative importance of KPIs. Actually, this step consist of three smaller steps namely the *gathering of information*, *information validation* and the *processing of information*. Processing of information may be quite complex for some KPIs where it is quite easy for other KPIs. The calculation of the efficiency scores of the integrated care pathways is a more complex step that is documented and executed in chapter 5 and chapter 6 of this research. Calculations are less complex when for some KPIs only the average value over the analyzed period needs to be calculated. The complexity of the quantification of the KPIs is also affected by the distinct steps that exist within an integrated care pathway. Some KPIs (like the length of the waiting list) may be measured at different steps and need for that reason be aggregated to the integrated care pathway to enable the unambiguous interpretation of the performance figures.

Performance interpretation The last step of the HPQ-method is the interpretation of the performance of healthcare providers on the level of the integrated care pathway. This step actually consists of multiple sub-steps namely the *adjustment of the performance figures for environmental factors* and the *interpretation*

[2] A KPI has a high quality when it meets the quality criteria that are defined in section 4.4.2.

of the adjusted figures with the help of the relative importance of KPIs. This step is required in order to define a preference relation among multiple alternative integrated care pathways on the basis of their overall performance. One should remark that the interpretation of the performance of the integrated care pathways may be different from the performance interpretation of healthcare providers at the institutional level as it is much easier to account individual persons for the performance of an integrated care pathway[3].

In conclusion One can see that the HPQ-method comprises many sequential steps. This means that the execution of one step depends on the progress of the previous step. This may delay the overall execution of the method seriously. However, the whole process may be speed up when we take the healthcare outline agreement as a starting point for the execution of this method. In this agreement is established that these parties not only will take care for their own benefits but also for the desires of the patients. This means that already a decision is made about which parties are critical in this process[4]. The criteria which should be guaranteed by the execution of this agreement represent the goals of the healthcare system from the point of view of the key actors in healthcare. Therefore, the starting point for the execution of this method in the Dutch healthcare sector may be the definition of the Key Performance Indicators (step 4). Starting at the fourth step may speed up the process to a larger extent as long as the first three steps are executed in a sound way.

7.2 Method implementation

Chapter 2 presents a set of prerequisites[5] that should be fulfilled by the HPQ-method[6] in order to facilitate fair competition among healthcare providers. The method presented in this research should comply with these prerequisites. However, a lot of issues may arise around the implementation of this method that may threaten the prerequisites. This section discusses the issues that may arise around the implementation of this method and give some solutions for dealing with this issues in order to safeguard the prerequisites for the deliverance of sound and relevant information for the purpose of fair competition. The issues are recognized with the help of the information input and output streams of the different steps that are executed under the HPQ-method. A graphical representation of the information input and output streams is given in figure 7.2. The solid lines are the internal information streams. The information that flows through these lines are outcomes of previous steps. The dashed lines are external information streams. This information is not a result of one of the previous steps but comes from external information sources. The issues around the input and output information streams are discussed for the several steps. One should remark that each step converts certain input information streams in output information streams.

[3]The actions of an individual person may have much more impact on the performance of an integrated care pathway than on the performance of a whole healthcare provider.

[4]Namely, the three parties that enclosed this agreement, supplemented with the patients.

[5]These prerequisites concern the provision of information on the healthcare market and are laid down in section 2.4.

[6]And for that reason also by the healthcare quantification method (as presented in section 7) that serves as the basis for a healthcare procurement method.

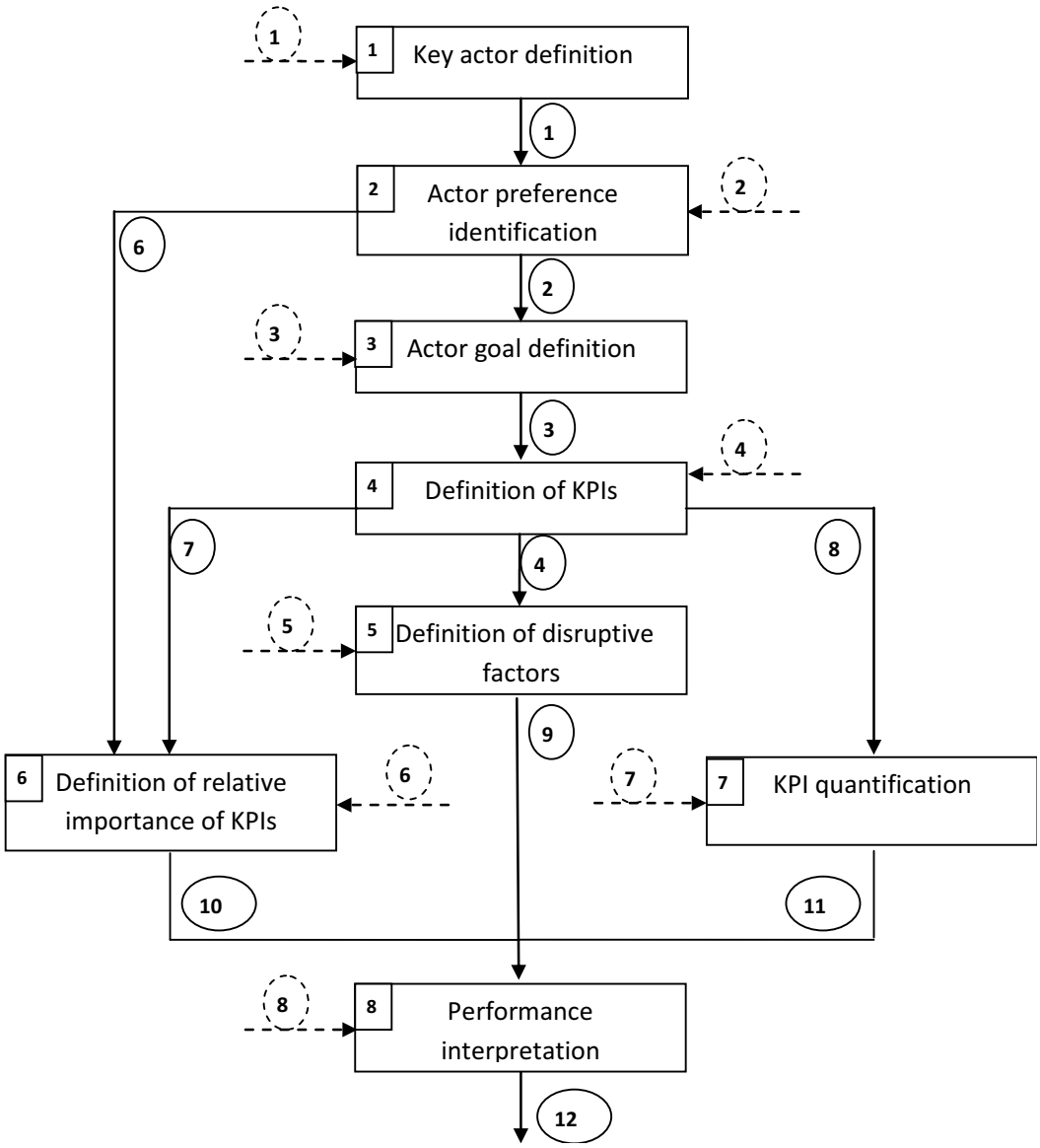


Figure 7.2 – Information streams in the HPQ-method

7.2.1 Actor definition

The incoming information stream [External 1] represents information about what actors are present in the healthcare sector and what actors play a dominant role in the treatment of a patient alongside the integrated care pathways. An issue may be how to determine which actors to involve in the execution of the HPQ-method. Another issue that may play a role by the execution of this step is how to involve the relevant actors in the execution of the method and how to create commitment among these actors for the quantification of healthcare performance. The issues are summarized as follows

- Which actors to involve in the execution of the method
- How to realize commitment among actors for the design and implementation of the HPQ-method

Actor selection Some difficulties may be faced around the selection of actors that should be invited for the process concerning the design and implementation of a method for the procurement of health services on predefined KPIs. A wrong decision at this point may lead to less support (or even resistance against) for the healthcare procurement method. According to section 2.4, broad support for a healthcare procurement method is crucial for the success of the implementation of the method. Currently is determined[7] that medical

[7]This becomes clear from the healthcare outline agreement, where the medical specialists are not taken as a separate actor.

specialists are not taken as a critical actor in the decision making process. This may be a major risk later on in the process. The changed role of the health insurance companies may significantly affect the activities of the medical specialists. Leaving them out of the decision making process may result in high resistance during the contracting process of health services as discussed in section 8.5. The medical specialists have a strong position in healthcare as the quality of health services is directly influenced by them (see section 8.3.2). Whether or not to take into account a certain actor may be a tough dilemma. It is important that the right actors are taken into account here because adding critical actors may slow down the process but depress resistance during the execution of the method. There are different options to increase the support of actors

- Invite all actors that are directly or indirectly affected by the operations of an integrated care pathways
- Invite actors that represent the goals of a broader group of actors (this is done in the healthcare outline agreement where the patients are somehow represented by the other actors)

Inviting all actors that are affected by the operations of the integrated care pathways may result in a broad support among the actors in the healthcare system. A drawback may be that it increases the time that is spend on the design and execution of the HPQ-method. the increase in time may be very serious when many actors are involved in the process. This makes the process more expensive and may reduce the effectiveness of competition as competition relies on accurate and up to date information. For that reason may be chosen to speed up the process by only inviting a set of key actors that represent a larger set of relevant actors for decision making processes in the healthcare sector. There may for example be chosen to involve only those healthcare providers that have the main responsibility for the treatment of patients (these are in may cases the hospitals). The same can be done for the patients and the national government. This may significantly decrease the process duration and process cost.

Actor involvement Another crucial issue for realizing commitment and avoiding resistance in the healthcare sector is the involvement of the relevant actors during the implementation of the HPQ-method. Commitment can be realized by giving permits to the parties that are invited for the process. There are several means to get parties involved in the execution of the method. First it is important to make a distinction in the degree of involvement. Some parties may have the responsibility to execute any of the steps of the HPQ-method, where others only may deliver content to the discussion about the lay-out of the method. Ways to involve actors in the design and execution of the HPQ-method are

- Giving actors room to deliver content to the agenda
- Granting actors the responsibility for the execution of tasks (see section 7.2.9 for options for the allocation of responsibilities for the execution of the steps of the HPQ-method)
- The definition of clear rules for behavior during the discussion sessions that safeguard the core values of the actors that are involved in the design and execution process.

According to the first point, one may give the key actors room to deliver content to the agenda by giving them the possibility to determine their own preferences and goals. Behavioral rules for the design and execution process of the HPQ-method may be rules that guarantee the actors that are involved in the process that they can freely make their point without interruption by other actors.

7.2.2 Actor preference identification

No serious issues are identified around the information streams that play an important role for the execution of this step that may threaten one of the prerequisites for the HPQ-method. The preferences of the actors are defined with the help of external information [External 2] about what their role and desired situation is. There may arise an issue around the definition of the preferences which should be as sharp as possible in order to be able to define clear and proper goals for the healthcare system. It may be a challenging task to convert a bunch of information in sharp and relevant preferences for the different actors.

7.2.3 Actor goal definition

The goals of actors in the healthcare sector depend on their preferences [Internal 2]. It may be challenging to define the goals of actors in such a way that they are clearly formulated and can be measured with simple KPIs. Fuzzy goals may lead to fuzzy KPIs which are hard to quantify and interpret. This will provide parties in the healthcare sector with information that does not meet the requirements as described in section 2.2.3. Low quality information may in the end lead to less effective competition among healthcare providers, because figures that are incomplete or unknown cannot be taken into account in the decision making process.

7.2.4 Definition of KPIs

The KPIs are defined with the help of information about the goals that actors have in the healthcare sector supplemented with information about currently available KPIs that can be used for measuring the performance of healthcare providers on the predefined goals. The following issues can be recognized for this step

- How many KPIs should be used for the evaluation of healthcare performance?
- Which KPIs should be used for the evaluation of healthcare performance?
- How to secure the applicability of the KPIs for all treatments?

The number of KPIs A first issue that arises is the number of KPIs that should be included in the analysis. There is an important consideration between the simplicity and the appropriateness of the proposed HPQ-method. According to section 2.4, it is important that the HPQ-method improves the transparency of healthcare performance. This asks for the use of a limited number of KPIs. The use of a limited number of KPIs at the same time keeps the method and all processes around the gathering of information at a low level of complexity. On the other hand, it is for two reasons important that the HPQ-method fully covers the performance of the integrated care pathways on the goals set in section 4.2. First, it increases the commitment by the relevant actors when they are convinced that their goals are covered by the set of KPIs. Second, it is important for the purpose of competition that procurement of health services is based on the right performance aspects because the procurement criteria determine the focus on improvement in the healthcare sector.

Taking into account the argumentation above some maxims can be used for the determination of the number of KPIs

- All relevant performance aspects should be covered by the KPIs
- No KPIs should be used that (partly) measure the same performance aspects[8]
- Each unique goal is preferable measured by one KPI

Selection of KPIs Besides the number of KPIs is it important that the KPIs have the right quality for measuring the performance of the integrated care pathways. There are lots of criteria that can be used for the evaluation of the quality of KPIs. From a broad set of criteria, the following criteria seems to be most relevant for the examination of the quality of KPIs

- specific
- measurable
- relevant
- time bound

[8]This leads to redundancy of KPIs and give the overlapping performance aspects a higher weight in the procurement process.

With the help of these criteria can be determined which KPIs are most suitable to measure the performance of healthcare providers on the relevant goals. However, there is a trade off between the quality of the KPIs on one hand and the usability and cost for implementation on the other hand. There are two ways for the selection of KPIs

- Define new KPIs that fulfill the four criteria
- Make use of applicable existing KPIs and slightly adjust them to make them fit for the purpose of performance evaluation on the level of integrated care pathways

Using the KPIs with the highest quality means that new KPIs should be defined for the purpose of performance evaluation on the level of integrated care pathways. A drawback may be the cost and duration of the implementation of a new set of KPIs. Healthcare providers have to become familiar with a new set of KPIs that are never used before. In addition, the definition of a whole new set of KPIs may cost a lot of time. A second option is the use of existing KPIs for performance evaluation. This is done in this research. A drawback of this choice is that the existing KPIs need to be redefined. Section 9.2.1 comprises recommendations for the redefinition of the KPIs for the purpose of performance evaluation on the level of integrated care pathways.

Applicability of KPIs for different treatments A though issue is the definition of KPIs in such a way that they can be used for the evaluation of a broad set of treatments. At this point it is important to make the distinction between the treatment of patients and the healthcare end result (see section 2.1.2). The treatments in healthcare are diverse, but the end products for a specific diagnosis can be seen as a homogenous product. The KPIs are assigned to the end product (which is an outcome of the treatments) and not to separate treatment steps. This makes it possible to evaluate the performance of integrated care pathways on a simple set of KPIs. However, there still remains the issue about the evaluation of the performance of different healthcare products[9] with the same set of KPIs. This research has the purpose to evaluate the performance of integrated care pathways on general goals from the point of view of the key actors. These goals can be realized for all specific treatments. The KPIs can be made applicable for multiple health services by specifying KPIs that measure the performance on these general goals. It is for that reason important that the goals of the healthcare system are formulated in such a way that they are applicable for each specific integrated care pathway.

7.2.5 Definition of environmental factors

Environmental factors are factors that cannot be influenced by any of the key actors in the healthcare sector but may have a disruptive effect on the performance figures of integrated care pathways. Major issues may arise around the definition and quantification of factors that have a significant impact on the comparability of performance figures.

- How to detect the environmental factors that have a significant impact on the performance of integrated care pathways
- How to quantify the factors that have a significant impact on the performance of integrated care pathways

Determination of significant factors It may be hard to determine which factors may have a significant disruptive effect on the performance figures of integrated care pathways. A set of obvious factors are discussed in section 9.1.4. However, this set of disruptive factors may be incomplete. Nevertheless it is important to have a complete picture of the environmental factors in order to be able to adjust the performance figures for these factors. There exist some methods for the detection of significant environmental factors

- Literature research
- Statistical analysis

[9] A distinction can f.e. be made between a patient that is treated for lung cancer and a patient that is treated for burns.

Literature research may help to find the relevant factors that may have impact on the performance figures of healthcare providers. Statistical analyses can be used to determine both the significance and the quantitative impact of the factors that are found in literature. In the end, only those factors should be taken into account that have a significant effect on the performance figures. This method may cost a lot of time, because the impact of an environmental factor on the performance of an integrated care pathway may be different for different diseases.

Quantification of significant factors For the adjustment of performance figures one also needs to quantify the impact of the significant disruptive factors on the performance figures of healthcare providers. This may be costly and difficult under certain conditions. First, the impact of the factors may be very different for different diseases. Therefore, one needs to quantify the impact for all different diseases. This may cost a lot of time and money. Secondly, the impact of the disruptive factors can only be determined when the analyzed population is big enough. Otherwise no significant outcomes can be produced by a statistical method. This may be problematic for rare diseases. A solution can be found in the use of figures over a longer period of time or taking together the performance figures of multiple integrated care pathways. These analyses requires a load of data which may not be available at this moment.

7.2.6 Definition of relative importance of KPIs

The relative importance of KPIs from the point of view of different actors is determined by their specific preferences and goals. In order to evaluate the relative importance of KPIs among different actors, additional information is required about the relative importance of the different actors that are involved in the implementation process. At this point one may expect some issues. The question may arise what the relative impact of each actor is on the decision making process. This is an issue that needs to be solved in order to be able to give the different KPIs a weight.

It may be difficult to determine the relative importance of KPIs when it comes to the weight of each actor that is involved in this step. The question may arise whether all actors should have the same impact. Should the judgment of the patient, healthcare providers, health insurance companies and government be equally weighted? An agreement on this issue is important for the commitment of the actors to the health procurement method. There may be several methods to get an agreement about the relative importance of the different actors. A solution may be to give all actors an equal weight in this process. This will give all actors an equal influence and may reduce the resistance by the creation of solidarity. However, it may occur that not all actor can agree with an equal distribution of influence. The determination of the relative importance of actors may in that situation require a process in which openly is discussed what the position of each actor is and what the influence of each actor should be. This can be done with the help of information about the extent to which each actor is affected by the new situation in healthcare[10].

Another option for the definition of the relative importance of KPIs may be a result of demand-driven healthcare. One can determine the weights of the KPIs with the help of the opinion of the patients. A problem here may be that patient value the KPIs different for different diseases. This can be solved by taking an average weight for all KPIs.

Some state that it is not necessary to explicitly weight the KPIs on beforehand when it comes to the procurement of health services. One may argue that the market is an adequate mechanism for the indirect weighting of KPIs. The demand side of the healthcare market are treated at those integrated care pathways that meet the requirements of the patient as long as the patient is free to move to whatever healthcare provider and health insurance company they want. The patient is in that sense the mechanism that forces healthcare providers to deliver the health services that meet the performance of the patient. This becomes clear from figure 7.3 where one can see that the overall performance of all integrated care pathways is equal (a sum of

[10]The new situation in healthcare is described in the healthcare outline agreement and comprises increased competition among healthcare providers and an important role for health insurance companies in the procurement of health services.

1), however, the patient may be preferably treated at an integrated care pathway with a specific performance. Health insurance companies and healthcare providers are expected to adjust their behavior[11] according to the preferences of the patient. However, the healthcare market is quite differently organized from many other market organizations as the demand side does not directly procure health services at the healthcare providers. This is done (as discussed before) by the health insurance companies as an intermediate party. It may for that reason occur that healthcare providers do not accurately adjust their behavior according to the preferences of the patient because of the information delay that may exist due to the position of the health insurance companies in between the healthcare providers and the patients. In addition, health insurance companies clustered themselves in the past which led to an enormous reduction of health insurance companies. This may be a threat for fair competition (see section 8.1) and may threaten the freedom of choice for patients as well.

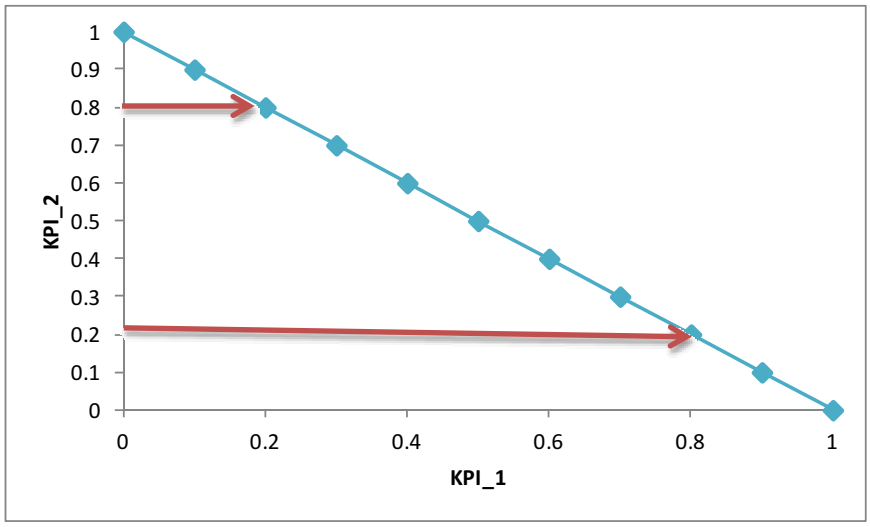


Figure 7.3 – Preference order determined by the demand side of the healthcare market

7.2.7 KPI quantification

The KPI quantification step requires a lot of input information. A clearly defined set of KPIs [Internal 8] is the first prerequisite that should be fulfilled. Another important information input are the performance figures of the several healthcare providers [External 7] that together make up the integrated care pathways. A lot of issues may arise around information management at the healthcare providers and the reporting of performance figures to a central database system. A third information stream is related to the calculation of the efficiency figures. This requires the proper communication of the efficiency evaluation method. In summary the following issues can be distinguished.

- Efficiency calculation
- Transparency of quantification methods
- How to secure the quality of performance figures among multiple healthcare providers
- Quantification of the performance of low volume treatments

Transparency of quantification methods A high degree of transparency of the performance quantification methods is required in order to provide broad-based information to the market. Performance figures that are calculated in a fuzzy way will not be perceived as reliable. It is for that reason important that there is transparency among all relevant actors about how performance figures are derived and calculated. Two means for increasing the transparency of information are

[11] Health insurance companies are likely to procure health services that fit with the preferences of the patient and healthcare providers are likely to deliver health services that are most likely of being contracted by the health insurance companies.

- The use of simple quantification methods
- Clear communication about the used methods

For the provision of credible figures, the use of simple methods for the calculation of healthcare performance are required. The methods should provide clear insight in how the figures are calculated and what inputs are required for the calculation of the performance figures. However, the transparency of the method may not come to the expense of the accuracy of the methods. This is taken into consideration by the decision for a method for the quantification of the efficiency of integrated care pathways. There becomes clear that conventional methods may be less accurate for the calculation of the efficiency figures of the integrated care pathways (see section 5.4). Clear communication about the methods that are used for the quantification of performance figures is always required. Parties will probably not agree with the figures (especially not when they are highly affected by the figures like healthcare providers are) when they do not understand how they are calculated or established.

Quality assurance of performance figures among multiple healthcare providers High quality[12] performance figures are required in order to be able to guarantee the reliability of the performance figures of integrated care pathways. This is also true for the calculation of the efficiency figures of integrated care pathways which are based on input and output figures that are provided by healthcare providers. A lot of complexity will be faced at this point because many of the KPIs are measured at different steps of the treatment and should be aggregated to the integrated care pathway level in order to get a single performance value. There is a lot of risk on inferior data as the quality of the single value is determined by all performance figures at the level of the particular treatment steps (see section 6.3.5). There are some options that may help to improve the quality of the performance figures of integrated care pathways

- Unambiguously defined KPIs that are applicable among different steps of the integrated care pathways
- Clear and simple protocols for data measuring, storage and reporting
- Independent institution for the assurance of the quality of performance figures

A first important step is the clear definition of KPIs as discussed in section 7.2.4. This may prevent misinterpretation of the KPIs and increases the reliability of the information that is gathered. Furthermore, protocols that are valid throughout the whole healthcare sector may increase the quality of information that is provided by healthcare providers. Information may be easily processed when it is stored according to standard protocols. Protocols may be used to realize uniformity of information. This is especially important in case of integrated care pathways as KPIs are measured at different treatment steps within the integrated care pathways and need to be aggregated to a single level of interpretation. It is impossible to get reliable performance figures of the integrated care pathways when information is reported differently at different steps. An independent institution may be asked to monitor the compliance with the protocols for data storage and reporting. The protocols should be clear and simple in order to prevent additional bureaucratic measures that may increase the cost of the healthcare system furthermore.

Quantification of the performance of low volume integrated care pathways Another important issue concerns the quantification of the performance figures of integrated care pathways that yearly treat a small population of patients. It is hard to get reliable performance figures from a small population as these figures are sensitive for outliers and results may not be significant. This is due to the fact that the band with is relatively big for a small population, where it becomes smaller when the population increases. This is demonstrated by the formula for the estimation of the variance of a student-t distribution with the population size n, the sample x_i and the sample's average $\bar{x}$

$$s_n^2 = (\frac{1}{n-1}) * \sum_{i=1}^{n} (x_i - \bar{x})^2$$

[12]The quality of information is examined on the criteria specific, measurable, reliable and time bound.

The bandwidth can be reduced by using the treatment performance figures over a longer period of time. However, this may lead to an undesirable situation as performance figures become more stable when they are calculated over a longer period of time. This suppresses the attractiveness of innovation because performance improvements that are realized in a certain year are average with the performance figures of the previous years. Healthcare providers are in that situation not rewarded for the effort they did on innovation and performance improvements. An alternative may be to leave the smaller specialisms out of the new procurement system. However, this may lead to fragmentation of the healthcare sector instead of the desired specialization[13]. The consequences of healthcare procurement on the basis of the actual performance of integrated care pathways for low volume pathways is discussed in more detail in section **??**.

7.2.8 Performance interpretation

The interpretation of the performance figures of integrated care pathways requires information about the actual performance of integrated care pathways [Internal 11] supplemented with information about [External 8] environmental factors that may affect their performance. There may arise some issues around the determination of environmental factors that may have a serious impact on the performance figures of the integrated care pathways. The following issues are distinguished.

- How to define norms, standards and thresholds for performance
- How to adjust performance figures for underlying differences

Definition of norms and standards Norms and standards are required in healthcare in order to guarantee a minimum performance of integrated care pathways on certain critical KPIs. One can for that reason not work with a minimum overall performance as an integrated care pathway can have a sufficient overall performance but under performs at certain crucial KPIs. The *Treeknorm* is an example of a norm that is currently used to guarantee a maximal length of the waiting lists. There may arise some issues around the definition of norms and standards in healthcare. Currently, the *Treeknorm* is different for different treatments. This demonstrates that it may be impossible to define norms and standards that are generally applicable[14] among the treatments of all diagnoses. The definition of norms and standards may for that reason require a careful consideration of the characteristics of each specific treatment. This will raise the bureaucracy in healthcare significantly, because when norms and standards are established, one also needs to check that health insurance companies comply with the norms and standards. This may be difficult in a situation where multiple healthcare providers are responsible for the performance of an integrated care pathway. Norms and standards ask for maintenance with the help of rewards and punishments. It may be difficult to determine which healthcare provider is responsible for exceeding certain norms and standards and how to allocate rewards and punishments in case of shared responsibilities. A solution may be to add the norms and standards to the terms and conditions of the contract and define at that point the responsibility for the performance of the integrated care pathways (this is proposed in section 8.5).

Adjusting performance figures In section 7.2.7 is mentioned that it is difficult to calculate reliable performance figures for smaller integrated care pathways. It may be even more difficult to adjust the performance figures for underlying differences as discussed in section 7.2.5. There is probably insufficient information available to calculate the relation between environmental factors and the performance of integrated care pathways. This problem may be solved by taking information about these relationships over a longer term. Many of the relationships can be calculated with the help of information that is available in the databases of health insurance companies. It may be impossible to adjust the performance of a whole integrated care pathway for environmental factors as the integrated care pathways consist of several steps. It may be necessary to adjust

[13] See the healthcare outline agreement.

[14] One can use the same norms and standards with different values. The Treeknorm for example may be four weeks for urgent diseases and for example 6 weeks for non urgent diseases.

the performance of each individual step for the environmental factors and aggregate the performance figures to the level of the integrated care pathways.

7.2.9 Overall issues

Besides the issues that play a role around the execution of the specific steps of the HPQ-method, there are some overall issues that have to be taken into account during the implementation of the HPQ-method. This concerns

- Information quality management
- Responsibility allocation for the execution of the HPQ-method

Information quality management One should distinguish between internal and external information streams that play a role during the implementation of the HPQ-method. The source of internal information streams can be controlled where the information source of external information streams lies out of control for the key actors in the healthcare sector. The quality of information streams is essential for the effectiveness of the proposed method. Unreliable input information can never lead to reliable outcomes. The risk of bad outcomes is even higher in case of many sequential steps where the outcomes of each step, depends on its inputs. Errors that are once made are hard to remove and will accumulate during the execution of the sequential steps of the HPQ-method. The quality of the outcomes is important as it has impact on the performance of the healthcare system. The use of low quality information may lead to the procurement of low quality health services. Although there are many options that can help to secure the quality of information streams, one should be careful to adopt all kinds of protocols and regulations that may increase the administrative load in healthcare. This makes the administration in healthcare more expensive and time consuming. The following four aspects(Eppler, 2006) that affect information quality can be distinguished

- information should be relevant[15]
- the information should be sound[16]
- information delivering processes should be optimized[17]
- information infrastructure should be reliable[18]

There are some solutions that may help to secure the quality of information by solving issues around the four aspects of information quality that are mentioned above. The relevance of information can be improved by a clear definition of the required information at each step in the HPQ-method. Only those information should be gathered that is required for the execution of each specific step. The quality of information can be examined with the help of the criteria that are mentioned in section 4.4.1. When it appears that information does not have the right quality, one needs to redefine the required information with the help of the information quality criteria. Adequate processing of information can be realized by defining sound methods and protocols for the processing of information[19] and by defining clear responsibilities for the execution of the different tasks. This is discussed in more detail in section 7.2.9. Protocols may help to standardize the processes concerning the processing of information but may also increase the administrative load in the healthcare system[20]. An independent institution may help to safeguard compliance with the protocols by the responsible parties. The reliability of the information infrastructure may be a more technical issue that needs to be solved. Information

[15] Only those pieces of information should be gathered that are required for the realization of the goals of the method (i.e. provision of relevant information to the market).

[16] The relevant information should be of high quality (specific, measurable and time bound)

[17] Information should be stored and processed in a timely manner and in such a way that it fits for the end user of the information.

[18] The information infrastructure should guarantee the reliable supply of information.

[19] For example for the calculation of the efficiency figures of the integrated care pathways, one should use a method that is transparent and appropriate for the calculation of adequate figures.

[20] Parties should not only have these protocols but also comply with the protocols which means that compliance with the protocols is ensured by an institution.

storage and processing devices should be aligned[21] with each other in order to provide sound information to the healthcare market. Subsequently, confidential information should not be accessible for irrelevant actors. When information is unprotected, parties may change information in the system or damage the system so that it can no longer deliver sound information to the relevant actors. Several checks can be implemented during the execution of the method that verify whether the outcomes of each step are as expected on the basis of the inputs. In addition, source data can be checked on credibility by comparing it to data from other time periods. One should remark that this is only possible for internal information sources, and not for external information sources that are out of control of the key actors in the healthcare sector.

Allocation of responsibilities The accurate allocation of responsibilities may help to improve the execution of the HPQ-method. Responsibility allocation does not only concern the supply of information but all kind of activities that are executed during each step of the method. A distinction should be made between the overall responsibility for the execution of the method and the execution of each distinct step. The responsibility for the execution of the method should ultimately lay by the national government. According to section 1, they are responsible for safeguarding the core values of the healthcare system. However, this does not mean that they have the responsibility for the execution of each step. Responsibility allocation for the individual steps of the method can be based on the following information

- affinity and capabilities of actors with the tasks that are executed under each step
- focus of the actors
- the use and processing of confidential information
- the interest of actors in the tasks that are executed

The affinity of actors with the tasks that are executed may be a reason to assign the execution of a step to this actor. It is important for the proper execution of tasks that the institution that execute the task is experienced with similar activities[22]. A second point concerns the focus of the actors. It may be unwise to assign the execution of a task to a party that has a focus in the healthcare sector that does not match with the task that has to be executed. This may lead to the lose of focus on the core activities of the actor. The use and processing of confidential information may be a determinant for which party should get the responsibility for the execution of certain tasks. For the calculation of f.e. the efficiency of integrated care pathways is made use of confidential production figures of healthcare providers. For that reason, one cannot assign the calculation of the efficiency figures to health insurance companies, because that may give them a serious advantage in the health service contracting and negotiation processes. A similar concern may arise around the interests actors have in the execution of a certain task. A huge interest in a specific task may be a reason to not assign the quantification of the performance figures of healthcare providers to a healthcare provider related actor. It is important that the independency of the responsible party can be guaranteed as this may determine the quality of the outcomes or at least the confidence in the outcomes.

[21] Alignment of technical utilities may mean that the processing capacity is adequate and that storage of information is done in a safe and uniform manner.

[22] Actors that are familiar with the execution of the tasks are likely to perform better than inexperienced actors.

Chapter 8

Discussion on Implications of the Research

The initiatives that are mentioned in section 1.4 are aimed at safeguarding the core values of the healthcare system by introducting more competition on the healthcare market. The quantification of healthcare performance is an important step that is required for the facilitation of these initiatives. The introduction of healthcare performance quantification and performance based procurement of health services at the level of integrated care pathways may have some significant side effects. This chapter discusses the most important consequences of the introduction of the performance based procurement of health services for the performance of the healthcare system.

Diagram 4.1 in chapter 4 is used for the determination of appropriate KPIs and may also be used for the detection of the consequences of performance based health service procurement, however, in an extended form. The old diagram is not sufficient to explain all the consequences that come forth from the introduction of healthcare procurement on predefined criteria as it sees actors in the healthcare system as static objects that do not interact with eachother nor behave strategically. For that reason an extended diagram is used that is much more dynamic (see figure 8.1).

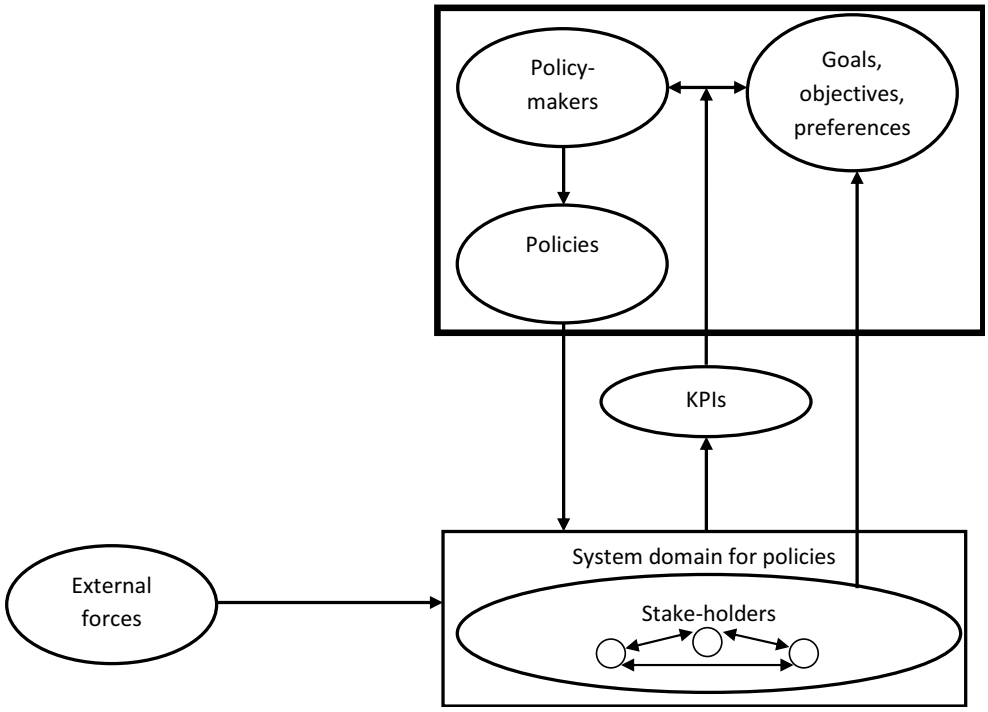


Figure 8.1 – Extended framework for the policy analysis approach (based on (Walker, 2000), p. 13)

This diagram sees the key actors in the healthcare system no longer as static objects that do not change their behavior but as interdependent actors that continuously adapt their behavior to the environment. This is consistent with the situation in healthcare where the relationship between parties continuously change. This is for example the case for the healthcare providers that together treat a patient along an integrated care pathway. The integrated care pathways are often no static cooperation among healthcare providers but may change at each moment in time. The environment of the healthcare system consists of external forces and policy measures that intervene in the performance of the system domain. The behavior of stakeholders is furthermore influenced by the behavior of competitors and other actors that are active in the healthcare system[1]. Each time is looked how issues that occur at certain points in the diagram affect the performance of the system's domain for policies.

8.1 Clustering of health insurance companies

One of the stakeholders in the healthcare system are the health insurance companies who play a central role in this research. The number of health insurance companies decreased significantly in the past due to the fact that many of the health insurance companies merged. This results in the situation that a few large health insurance companies remain. These companties have a strong position on the health insurance market, which makes them somehow immune for the signals of the patients because patients have a limited freedom of choice to insure themselves at an alternative health insurance company. This situation seems to be undesirable as it may have some negative consequences on the performance of the healthcare system as patients will stay at their current health insurance company due to the limited freedom of choice. This may be a disincentive for the health insurance companies to deliver services that are appropriate for their insured population.

8.1.1 Impact of clustered health insurance companies on the performance of the healthcare system

The low degree of competition among health insurance companies and the immunity for signals at the demand side of the healthcare market may result in a lower performance for the healthcare system when it is observed from the point of view of the goals of the healthcare system (as defined in section 4.2). Health insurance companies are likely to procure not the health services that fit best by the preferences of the patient but those who deliver the highest margins to them (as one of their goals is profit maximization). There is no urgency for them to adjust their behavior according to the preferences of the patients as the patient do not have the possibility to go elsewhere. Appointments between health insurance companies about the services they deliver to their customers may hurt the position of the patient and strength the position of health insurance companies even more. There are several measures that might be taken in order to increase competition on the health insurance companies and reduce the position of health insurance companies.

- Strict supervision on illegal agreements and cartels among health insurance companies
- Usage of customer satisfaction indicators that measure the fit between the patients preferences and the services delivered by health insurance companies
- Punishments and rewards based on the customer satisfaction indicators

These policy measures may help to safeguard the goals of the healthcare system like the reduction of cost and the improvement of efficiency of health services. Strict supervision on illegal agreements among health insurance companies is important in order to prevent cartels from being established. Cartels may be a significant threat for the healthcare system as it may reduce competition even further. Measuring of the relative customer satisfaction is a measure that may help to improve the focus of health insurance companies at the desires of the demand side of the healthcare market. One could rewards the health insurance companies that deliver the most accurate

[1] The actors that are active in the healthcare sector are described in section 1.1.2.

health services and punish the ones that deliver the worst health services according to the needs and preferences of the patient. This system of rewards and punishments should in that way be cost neutral.

8.2 Imperfect information

In section 2.5 is mentioned that it is impossible to provide perfect information to the healthcare market with the help of healthcare procurement based on the HPQ-method. The information infrastructure in healthcare is complex as there are many parties that store information and many individual actions are executed during the gathering and processing of information. These issues accumulate the risk on imperfect information being delivered to the healthcare market. The existence of imperfect information on the healthcare market may have several drawbacks on the performance of the healthcare system. Imperfect information is present on all sub markets of the healthcare market that are discussed in section 2.1.1. Imperfect information may be wrong information but can also be information that is known by only one party (private information (Vives, 2002)) which strengthens the position of a particular party. Imperfect information may in that sense have its drawbacks on competition on the sub markets as it gives certain parties a stronger position, which distorts fair competition.

8.2.1 Impact of imperfect information on the performance of the healthcare system

This section discusses the presence of imperfect information on the *care market*, the *healthcare procurement market* and the *health insurance market* and the consequences of imperfect information for the performance of the healthcare system. The relevant information topics for competition on the healthcare market are discussed in section 2.2.3.3.

Imperfect information may be present on the healthcare procurement market in the form of unreliable performance figures of integrated care pathways or inaccurate KPIs that measure the performance of healthcare providers on the wrong goals or wrong level of detail. Unreliable performance figures may be a result of the fact that performance figures of integrated care pathways are measured for different steps at the same time. A small deviation in one of the performance figures of the particular steps of the integrated care pathway will affect the performance figures on the more aggregate level of interpretation. This may result in strategic behavior by both the healthcare providers and the health insurance companies. Health insurance companies may use incomplete performance figures during the contracting phase with the healthcare providers to reduce the reimbursed cost of health services. Healthcare providers on the other hand may deliberately adjust their performance figures in order to improve their position during the contracting and negotiation phase.

Imperfect information may have negative consequences on the health insurance market when there is no perfect insight in the performance of services that are delivered by the health insurance companies to the patients. Patients may take a wrong decision about where they should be insured in order to get the treatment they want. At the same time, imperfect information about the patients needs may have negative consequences for the health insurance companies. Health insurance companies cannot adjust their contracts with healthcare providers accurately when they rely on wrong figures about the preferences of the patients. This may distort competition when there are health insurance companies that do have reliable information about the patients needs. Those companies may be able to enclose contracts with healthcare providers that deliver health services that fit better to the needs of their insured population. Imperfect information on the care market may be present in the same form as on the health insurance market as competition on this sub market is based on the same information.

In general should be remarked that imperfect information especially endangers the outcomes of the healthcare market when processes rely on information that is an outcome of previous steps. Information that is used in an early stage may in that sense change information that is used later on. This is the accumulated effect of imperfect information in a sequential information processing and transformation process. The impact of imperfect information on the performance of the healthcare system depends for a larger part on the sensitivity

of the sub markets for changes in the information. Fragile market mechanisms may deserve special attention when it comes to safeguarding the quality of the information flows and the information infrastructure. Means for improving the information storage mechanism are discussed in section 9.2.2. One may also focus on the prevention of strategic behavior instead of delivering perfect information to the healthcare market. Strategic behaviour may be reduced or prevented by

- Defining clear rules of conduct for honest behaviour among actors
- Highlight the interdependencies among the actors
- Create long term en repeated agreements

Clear rules of conduct that prohibit taking advantage of other actors by the means of asymetric information may help to reduce strategic behaviour as long as adequate sanctions are in place. Another measure may be to highlight the interdependencies among the different actors in the healthcare system. Actors may change their behaviour when they feel themselves dependent on others. Long term and repeated agreements may force actors to behave themselves according to the rules of conduct as they have to cooperate with eachother more often on the longer term.

8.3 Factor mobility

The existence of mobility barriers for customers may impede competition to a significant extent (Defeuilley, 2009). One of the major barriers for customer mobility is the lack of information. This demonstrates the quest for transparency about the performance of healthcare providers towards health insurance companies and the patient. The insight in the performance of healthcare providers on the level of integrated care pathways may therefore lead to a significant increase in the mobility of patients and healthcare employees[2]. The mobility of patients and healthcare employees on their turn may affect the performance of the healthcare system that is measured with the help of criteria that are described in the healthcare outline agreement.

8.3.1 Customer mobility

The mobility of patients may increase significantly when the non-confidential[3] performance figures of healthcare providers become publicly available. One may assume that patients become more mobile in case of free competition and transparency of information. Patients are likely to go to the healthcare provider that delivers the highest quality of care for the lowest price as long as the better performance adds more value than the value destruction that is realized by an increased travel time and other factors like the relation with a specific healthcare provider etc. Immobility of patients may be a sign that there is lack of competition among healthcare providers, that information is not available in the right quality or that the patient is satisfied by the health services delivered by its current healthcare provider. The mobility of patients will not increase when information is not available in the right quality. Performance figures of healthcare providers at the institutional level are not likely to result in a higher customer mobility as patients may not care about the performance of a healthcare provider in general but only about the performance on the level of specific treatments. Performance figures on the integrated care pathway level are for that reason likely to increase the customer mobility and the degree of competition among healthcare providers and health insurance companies.

When a certain healthcare provider has a better performance than its competitors, one may expect an increased demand for health services[4] at that specific healthcare provider. As a consequence, healthcare demand is likely to become more concentrated in a competitive market. This will lead to an increased required capacity at the healthcare providers that have a high level of health service quality. The concentration of supply and

[2] Doctors and nurses.

[3] The confidential performance figures should not be made publicly available in order to prevent competition among healthcare providers from being disrupted (see section 4.4.2).

[4] Under assumption that there is transparency about the performance of the healthcare providers.

demand asks for more medical resources like healthcare employees, hospital beds, surgery rooms etc at specific points in the healthcare system. The quest for labor and capital is discussed in section 8.3.2 and section 8.3.3.

8.3.2 Labor mobility

One can split the quality of health services in technical quality and service quality. Where the technical quality is determined by the quality of the facilities is the service quality determined by the quality of the healthcare employees (Kenagy et al., 1999). It is mainly the service quality that determine the experienced quality by the patient. Healthcare providers are likely to put more focus on the quality of employees, under the situation that healthcare providers are accounted for the performance of health services they deliver. This may lead to a high demand for well educated healthcare employees by the good performing healthcare providers. Subsequently, these healthcare providers will face an increased demand for their services, because of the high quality of care they deliver. Competition can only withstand when healthcare providers are able to attract the employees they need for the deliverance of high quality health services. This is especially important in a tight labor market. The market will not function as supposed when there are significant barriers for labor mobility, because these barriers may prevent healthcare providers from improving their performance.Fair competition will therefore require information transparency and a high degree of labor mobility.

8.3.3 Capital mobility

As mentioned in section 8.3.1, healthcare providers that are able to create a higher demand for the services they deliver, need to purchase additional scarce medical resources like surgery rooms, hospital beds and other capital goods. This is required in order to be able to deliver the required quantity of services. In order to enable fair competition, one needs a high mobility of these capital goods on the healthcare market. Capital mobility will lead to the reallocation of a surplus of capital goods at some point in the healthcare system to points in the healthcare system where there is a shortage of capital goods. A lack of capital mobility will prevent healthcare providers from delivering the required quantity of services which will force patients to get their care at other healthcare providers which is a distortion of competition.

8.3.4 Impact of increased factor mobility on the performance of the healthcare system

The increased customer, labor and capital mobility may have significant impact on the performance of the healthcare system. There is already mentioned that this may result in the concentration of supply and demand of specific health services. However, more consequences of the increased customer and labor mobility may be mentioned that seriously affect the performance of the healthcare system as measured on the criteria that are described in the healthcare outline agreement.

Concentration of supply and demand may lead to improved quality and reduced cost[5] of health services over the mid-long term. Patients will not longer go to under-performing healthcare providers but get their care at healthcare providers that deliver high quality health services. There is a risk that the quality of health services on the longer term decrease as a consequence of reduced variety among healthcare providers. Supply and demand may become concentrated for specific diseases which leads to a reduction in the number of healthcare providers. Reduced variety may lead to a lower innovative pressure which may result in a lower quality of health services over the long term.

Another consequence of the concentration of supply and demand may be that smaller healthcare providers can no longer make profit and vanish from the healthcare market. This may have serious impact on the accessibility of care in case of rare diseases in sparsely populated areas. One should remark that this may be a desirable outcome of the competitive process because it will probably lead to a more efficient healthcare system. However, one can also conclude that certain types of care should be easily accessible for everyone. These

[5]Cost reduction may be realized by economies of scale and standardization of processes within an integrated care pathway.

consequences may result in the initiation of additional requirements for the healthcare system by the national government that have the purpose to guarantee the core values of the healthcare system under competition.

There is mentioned that factor mobility is an important precondition for fair competition. One should remark that factor mobility never will be perfect. The reallocation of goods and services is a process that may cost a lot of time. Healthcare employees for example cannot switch immediately from job and the movement of capital goods involve money and time. This has the consequence that competition among healthcare providers always will be hindered by the lack of factor mobility because the lack of factor mobility will prevent healthcare providers from delivering the desired quality and quantity of health services at the right point in time.

8.4 Sub-optimality in healthcare

In this research is argued that the procurement of health services should take place at the level of the integrated care pathways transcending the borders of individual healthcare providers because procurement on the level of integrated care pathways

- is the best way to procure health services that are appropriate for the patient
- increases competition among healthcare providers on the level that is most beneficial for the performance of the healthcare system[6]

An important remark needs to be made at the second argument because one can also argue that the opposite is true. Careful consideration of the healthcare system shows that processes within the physical border of healthcare providers are interdependent. Different integrated care pathways make often use of the same resources. Surgeons for example may treat patients with quite different diseases. The same is true for general practitioners, which are part of the integrated care pathways and help patients with a broad variety of diseases. The performance at one treatment may therefore affect the performance that is acquired for the treatment of another disease. It is for that reason not obvious that steering on performance improvement at the level of the integrated care pathways leads to a better performance of the overall healthcare system. The situation may be compared with the Dutch banking sector where was focused at the performance of individual divisions without keeping in mind the overall performance of the banking institutions (Boselie et al., 2012). This led to the so called silo-mentality in the banking sector. People were only focused on improving the performance of the division they worked for. It is for that reason important that besides the focus on the performance of integrated care pathways, also attention is paid to the performance of healthcare institutions and the healthcare sector as a whole.

A second issue concerns the risk of using the current performance of the integrated care pathways as a benchmark for their future performance. The current situation may be incomparable with the future situation. Interdependencies among integrated care pathways within the borders of a healthcare provider may lead to excellent performance on one treatment where the performance on other treatments lacks behind compared to competitors. The excellent performance may be realized by the unequal allocation of resources. The focus on the performance of integrated care pathways may prevent the unequal allocation of resources in a market with a high factor mobility (see section 8.3). Subsequently, the composition of integrated care pathways may change continuously. This may affects the performance of the integrated care pathways to a larger extent[7]. These issues may result in a situation where it is not possible to acquire the same performance in the future. Accounting healthcare providers on their past performance may for that reason be a disincentive for innovation as the goals and standards cannot be reached.

Policy makers should realize that it is possible that the future performance of certain integrated care pathways will be worse than the current performance, although the overall healthcare system's performance probably will

[6] Healthcare providers are forced to deliver health services that meet high standards instead of acquire a good overall performance at the institutional level.

[7] Long term cooperation is more likely to result in high performance than short term cooperation, although long term cooperation also may be a disincentive for innovation as it makes organizations *lazy*.

increase. They should ask themselves the question whether it is desired that some treatments perform better at the expense of the performance of other treatments. This may be the case for the treatment of some diseases. A way to realize this may be the exclusion of certain treatments from competition.

8.5 Health service contracting

This section discusses what the impact of the changed situation in healthcare is on contracting of health services on the healthcare market. First an introduction is given to health service contracting. Section 8.5.2 discusses the principles of contracting in healthcare in short. Section 8.5.3 defines some options for the design of the contracting process in the new situation. This section rounds up with a discussion on the impact of the new contracting situation on the performance of the healthcare system.

8.5.1 Introduction

Chapter 2 discusses the current and future healthcare market organization. There is stated that the current healthcare market is fully regulated where the future healthcare market will be a more free but still regulated market (managed competition). In that chapter is stated that a free market is no real option as organizational form for the healthcare market, because of the lack of capabilities to reduce externalities and to cope with allocation issues around the cost of health services and the quest for long term planning in healthcare. Long term planning may be a significant obstacle for patient mobility as health insurance companies are bound by long term obligations and cannot easily deviate from that. These characteristics has major consequences for contracting of healthcare providers on the healthcare market. Where actors in a regulated market are *obliged* to enclose contracts with others, are they *free* in an open market to enclose contracts with whatever party and at whatever time they want. Another way to distinguish economic organization forms is based on the type of communication via contracting. The following classifications are made

- a hierarchy
- a network
- a market

The hierarchy corresponds somehow with a fully regulated market where contracts are unilaterally enclosed between parties. The old regulated healthcare market can be seen as a hierarchy. This is visualized by figure 8.2 where the arrows are the relations (contracts) between the actors that are active on the healthcare market. Contracting in healthcare in the old situation is driven by the task of the health insurance companies that is assigned to them by the national government and regulatory bodies.

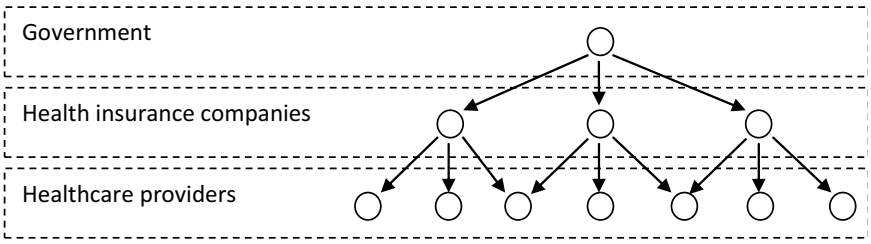


Figure 8.2 – The hierarchical healthcare market

The market type of organization corresponds with the open healthcare market (see chapter 2) where contracts are multilaterally enclosed by actors on the marketplace. The network classification is a tricky one. Some see a network as an intermediate state between a market and a hierarchy where others see it as a distinct type of a market organization (Powell, 1990). The future healthcare market corresponds at certain levels to the network type of markets. This is demonstrated in section 8.5.3.

This section will figure out how contracting will take place in healthcare in case of procurement on the basis of healthcare performance that is measured at the integrated care pathway level. This is done with the help of the contracting theory. There are several options for how contracting in healthcare can take place. The procurement of health services on the performance of integrated care pathways has the benefit that there can be steered towards a healthcare system that delivers appropriate health services. The fact that procurement is based on the performance of healthcare provider transcending integrated care pathways means that there are multiple parties involved in the healthcare service delivering process. This may have direct consequences for the negotiation and contracting process between healthcare providers and health insurance companies. Health insurance companies have to procure services that are delivered by multiple healthcare providers. The involvement of multiple parties adds complexity to the contracting and negotiation process. This section discusses the differences in contracts as a consequence of the introduction of more competition on predefined performance figures. Subsequently is discussed what options there are for the design of a contracting situation and how these options correspond with available theory.

8.5.2 Contracting in short

Contracting has a broad definition. In literature it is defined as making up an agreement between at least two parties, that is enforceable by law. Contracting is a broad field of research which makes it impossible to cover all elements of contracting in this research. The most important topics that will change in the healthcare sector as a consequence of the new position of health insurance companies are

- The parties that are involved in contracting
- The content of the contract
- The contracting process
- The types of contracts that are enclosed

Parties involved in contracting There are always at least two parties involved in the contracting process. In the old situation always one healthcare provider enclosed a contract with one health insurance company. This may change when it comes to contracting that is based on the performance of healthcare providers at the level of integrated care pathways. The services that are procured by a health insurance company are in that situation no longer delivered by one party but by multiple healthcare providers. The healthcare providers may be active in different parts of the healthcare system (primary, secondary and tertiary health care).

Content of the contract A contract can comprise all kinds of content and is enforceable by law as long as the content is in line with the law. This has serious implications for the parties who agreed on the document. They are bound by the contract and have to comply with its content after the contract is signed. The content of the contract may comprise more elements in the future. Contracting in healthcare is no longer solely based on the quantity of health services but also on the quality. Therefore, future health service contracts are likely to comprise specifications about the price, quantity and quality of services that are delivered by the healthcare providers and reimbursed by health insurance companies. In addition, there is specified in the terms and conditions for what period the contract lasts. No changes should be expected at this point as there exist serious economies of scale in healthcare. The plannability of health services is for that reason important as it delivers the possibility to allocate scarce and expensive medical resources effectively over time. For that reason there can be expected that the contracting term remains the same.

Subsequently, due to their task to steer towards a more efficient healthcare system, health insurance companies may want to add appointments to the contract about the improvement of the performance of the health services that are delivered by the integrated care pathways. An additional change that can be expected is the number of parties that are involved in the contracting process and will be bound to the terms and conditions of a single contract in the future. This number is likely to increase as mentioned above.

Contracting process Contracting in the old situation was somehow a uni directed process, where healthcare providers did not have a significant position in the negotiation process. This may change when contracting will be based on the performance of healthcare providers on the level of integrated care pathways. The market power of healthcare providers may become dependent on their performance. This has the consequence that healthcare providers will get market power to determine the prices of their services. Healthcare providers had a weak position and could not prove the performance of health services that they delivered, because of the lack of transparency about their performance on the level of particular treatments. The increased transparency in healthcare which may be a result of healthcare procurement based on the actual performance of the integrated care pathways, may have the consequence that the healthcare contracting process becomes a negotiation process in which the healthcare providers and health insurance company have an equal position in terms of market power. However, the equal distribution of market power cannot be guaranteed on the healthcare market as the degree of competition is an important determinant for the power position of healthcare providers and health insurance companies. The competitive pressure seems to be much lower for the health insurance companies compared to the healthcare providers as demonstrated in section 8.1.

Types of contracts Also the types of contracts may change under the future conditions. It is possible that in the new situation multiple parties are bound to the same contract, where in the past most of the contracts where single-party contracts. Health insurance companies may decide to make up one contract with all parties (primary, secondary and tertiary health care providers) that are involved in the treatment of a specific disease (integrated care pathway) or to enclose different contracts with all different parties. This variety may add complexity to the contracting process and the content of the contract because the contracting party (which are the health insurance companies) has in that situation to deal with the preferences and desires of multiple parties. The different options for the design of a contract between health insurance companies and the healthcare providers are discussed in section 8.5.3.

8.5.3 Contracting design options in healthcare

There are multiple options for the design of the contracting situation on the healthcare market. Some important points should be mentioned that may have impact on the design of the contracting situation in healthcare

- There is a quest for plannable healthcare
- There is a quest for supervision in order to decrease the impact of market failure[8]
- There is a quest for more appropriate (seen from the point of view of the patient) health services[9]
- There is a quest for the provision of more efficient health services (see footnote 9)

The here mentioned points has the consequence that contracting in healthcare will never be free of regulations. All actors on the healthcare market have to comply with the points above. The following consequences for contracting on the healthcare market can be distinguished

- Contracts are enclosed for a longer term
- Contracts are enclosed on the basis of criteria for appropriate healthcare
- Contracts are a means to realize the provision of efficient health services

These three rules of the game limit the design space for the contracting situation as it does not allow a market in which contracts are enclosed and disclosed at each moment in time. Secondly, it asks for an intermediate party[10] that will distribute the cost of healthcare fairly among all patients. Lastly, the intermediate party is

[8] Market failure can be the imperfect allocation of cost, or the specialization of healthcare providers to an undesirable extent.
[9] This is laid down in the healthcare outline agreement.
[10] The health insurance company is the intermediate party in healthcare.

not free in contracting healthcare providers but has to act in the interest of the patient. The intermediate party is expected to enclose contracts with the healthcare providers on behalf of the patient. This means that contracts are enclosed on the level of the integrated care pathways, as appropriate health services are delivered by integrated care pathways and not by institutions[11].

When we look at the requirements and limitations for contracting, we see that it cannot be classified as a pure hierarchy nor as a pure market. Contracts will no longer be uni directed (which is a characteristic of a hierarchy) but health insurance companies become more flexible in contracting healthcare providers because of the knowledge they have about the performance on the integrated care pathway level. On the other hand, patients are not free to get their treatment at a healthcare provider they want, but are bound to the healthcare providers that are contracted by their health insurance companies. The same is true for the health insurance companies who are bound to a set of criteria for the procurement of health services. In addition contracts persist over a longer period of time[12]. This hinders the mobility of patients and is a major barrier for competition. The following economical organization forms for the design of a market are distinguished in general

- Exclusive single party contracting
- Exclusive multiple parties contracting
- Hierarchical contracting

The design options for the future contracting situation in healthcare are related to the classification that is made above. Three contracting situations are discussed in more detail below. There should be remarked that the future healthcare contracting situation is not necessary the most efficient one in terms of contracting cost. This is due to the fact that the design for a future contracting situation is partly limited by its current design. One cannot change the role and responsibilities of all actors at once but has to admit to the characteristics of the current healthcare market organization. This is taken into account by defining the different alternatives in the following sections.

8.5.3.1 Exclusive single party multiple stage contracting

Contracting in healthcare is in all situations exclusive. This means that patients only can get health services at healthcare providers that are contracted by their health insurance companies. Patients can get their health services everywhere in case of non-exclusive contracting. However, the quest for appropriate health services does not allow non-exclusive contracting[13]. Some alternative designs can be chosen at this point. Figure 8.3 demonstrates the contracting situation in case of exclusive *single party* contracting. Health insurance companies can choose to contract only a single healthcare provider that has a dominant position in the establishment of an integrated care pathway. By doing so, health insurance companies lay the responsibility for the delivered service quantity and quality at a single party. This can be seen as the first stage of the contracting process. Healthcare providers that are contracted by the health insurance companies have the role to make appointments with other healthcare providers in primary and tertiary care that are involved in the treatment of patients within an integrated care pathway. These appointments have a multilateral and dynamic character and are much more flexible[14] than the contracts between health insurance companies and healthcare providers. This can be seen as the second stage of the contracting process

The economical organization form is not just one of the three types that are discussed in short in section 8.5.1 but seems to be a mixture of a hierarchy and a network. The relations between the government and governmental bodies, the health insurance companies and the contracted healthcare providers in the first stage is quite hierarchical and uni directed. However, the healthcare providers together form a network of actors which are

[11] A more extensive discussion on this is given in section 2.3.2.
[12] Because of the required plannability of health services as discussed above.
[13] Health insurance companies should only contract those parties that deliver health services that meet the requirements of their insured population.
[14] These appointments may cover a shorter time period and may even not be a contract that is enforceable by law.

highly interdependent and have complementary skills that are required for the execution of the treatment of a patient.

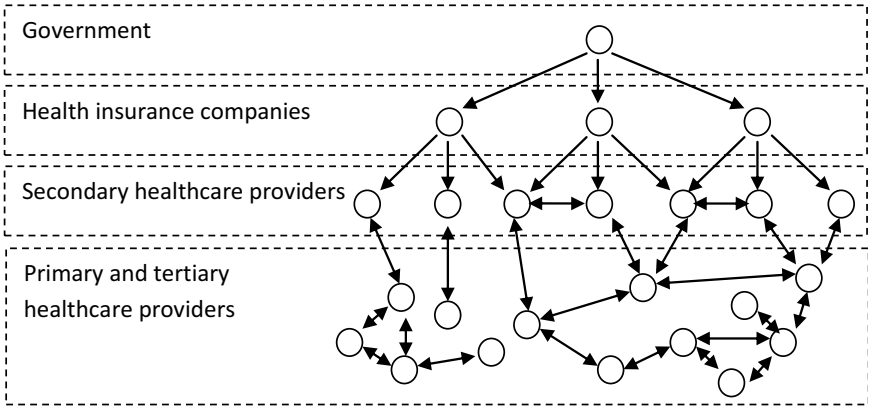


Figure 8.3 – Single-party contracting situation

8.5.3.2 Exclusive multiple parties single stage contracting

The exclusive multiple parties contracting situation, as demonstrated in figure .8.4, resembles the single parties contracting situation. However, this situation may be quite different concerning the contractual relations among the healthcare providers and the health insurance companies. The multiple parties contracting setting means that health insurance companies contract all parties that are involved in the treatment of one patient[15] in one stage. There may be faced some difficulties here. Not all parties have the same impact on the performance of the integrated care pathway. This may lead to less stable contracts as parties that do not agree with the terms and conditions of a contract will group up with other healthcare providers in order to deliver the same health service in a different composition of healthcare providers. Secondly, parties do not always operate in the same composition. General practitioners may refer to different hospitals and hospitals may refer to different day care clinics. This has the consequence that a healthcare provider has to sign multiple contracts for the execution of the same treatment. This may increase the complexity and cost of the contracting process and have undesirable side effects as the terms and conditions of the different contracts may be different. This may lead to the situation that general practitioners will always refer the patients to the hospital which yields them the highest profits. This may make the other contracts worthless as long as there are no obligations for the different healthcare providers to deliver a certain quantity of health services.

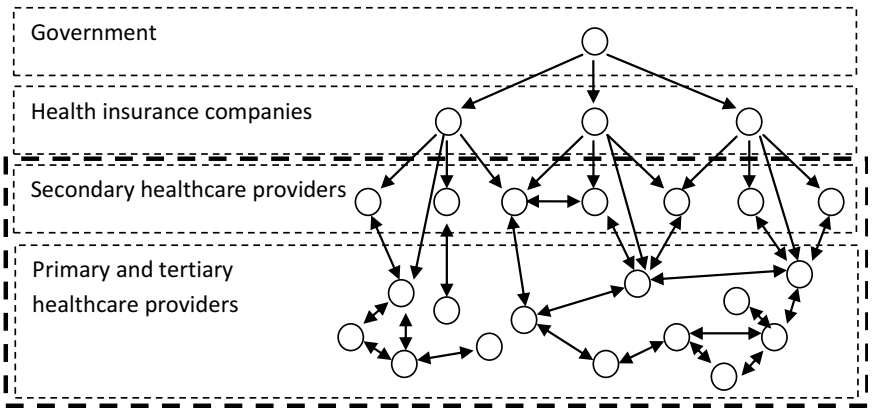


Figure 8.4 – Multiple-parties contracting situation

[15] In other words can be said that health insurance companies contract all parties that are related to an integrated care pathway.

8.5.3.3 Hierarchical two stage contracting

The hierarchical contracting situation is demonstrated by figure 8.5. This form of contracting is very rigid and uni directed and takes place in two sequential stages. Health insurance companies will enclose contracts with secondary healthcare providers which give these parties the responsibility for the performance of the health services that are delivered by the integrated care pathways they are part of. Following from their responsibility, secondary healthcare providers may decide to reduce their risk by contracting primary and tertiary healthcare providers. Hierarchical contracting may in that way lead to a stable situation as all relations between actors are fixed in a contract which is enforceable by law. However, contracts are less flexible than other kinds of agreements which will make the contracting process sluggish and expensive[16]. Subsequently, the contracts at the lower level between secondary healthcare providers and primary and tertiary healthcare providers may be a disincentive for innovation when they are enclosed over a longer period of time.

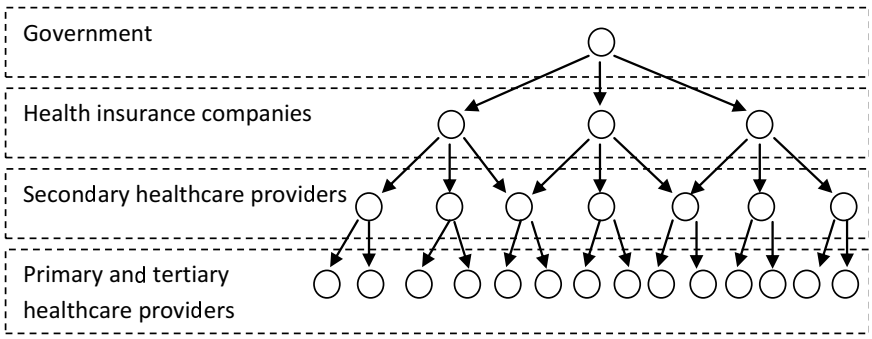


Figure 8.5 – Hierarchical contracting situation

8.5.4 Impact of the changed contracting situation on the performance of the healthcare system

The different contracting situations may have some negative side effects on the performance of the healthcare system. This section will discuss in short some serious implications of the new contracting situation on the performance of the healthcare system as a whole

1. Reduction of healthcare providers in case of exclusive contracting
2. Resistance by responsible healthcare providers in case of single party contracting
3. Geographical not ideal integrated care pathways
4. Improved performance due to customizable contracting terms and conditions
5. More effective contracting due to single treatment contracts
6. Faster and less expensive contracting process due to standardization of terms and conditions
7. Resistance by medical specialists as long as they are not involved in the contracting process

Some state that exclusive contracting may be beneficial for the performance of the healthcare system as long as there is no healthcare provider that is excluded by all health insurance companies (Bijlsma et al., 2010). However, exclusive contracting may also be beneficial when healthcare providers do not get a contract as this is a signal to the market that there is too much capacity and that healthcare providers have to improve their performance in order to be awarded with a contract[17]. However, the risk of being not awarded with a contract may increase the

[16] When an actor signs the document, he is tied by the contract which is a reason to ensure a good position in the contract. This may result in a long and sluggish process when different actors have opposite interests.

[17] A contract gives healthcare providers the right to exist as they are fully dependent on the health insurance companies that reimburse the cost of health services made by a patient. Patients will not go to a healthcare provider that is not contracted because in that situation they have to pay themselves for the treatment.

volatility of the healthcare system. Healthcare providers may invest less in product innovation when they are not sure to be awarded with a contract that help them to pay back their investments. Figure 8.6 demonstrates the consequences of exclusive contracting for healthcare providers in case of single-party contracting. One may see that exclusive contracting becomes problematic for an individual healthcare provider as long as this provider does not have a network of in which is healthcare provider is important. This may press healthcare providers to improve their network, which has the positive effect of improved cooperation in the healthcare system.

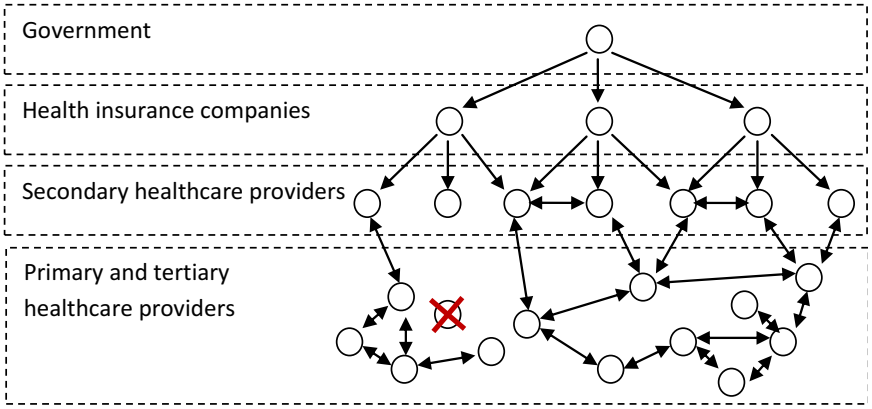


Figure 8.6 – Consequences of exclusive contracting

Single party contracting may lead to resistance by the healthcare providers that contracted by the health insurance companies and in that way responsible for the performance of the integrated care pathway. This may pop up when healthcare providers are kept responsible for activities that lay out of their range[18].

A third effect of contracting on the basis of the performance of healthcare providers may lead to the formation of geographical non-optimal integrated care pathways as good performing healthcare providers are likely to group up with the best performing ones. This may be caused by the fact that travel time is not included as a performance parameter for integrated care pathways and by the fact that the performance of a healthcare provider that is part of an integrated care pathway is averaged with the other healthcare providers. This makes it attractive for a healthcare provider to group up with other healthcare providers that have a better performance.

A positive effect of contracting on the level of integrated care pathways is that it may lead to a better performance of integrated care pathways due to the focus on this level of detail. Where healthcare providers in the past where pressed to improve their overall performance are they now pressed to focus on specific treatments. Subsequently, contracting on the level of integrated care pathways makes it possible to add terms and conditions to the contract about investments in product and process innovation. This may in the end result in a better performing healthcare system as the system can be seen as the sum of its parts.

The contracting process in healthcare is very costly at the moment. Healthcare procurement on the basis of the performance figures of integrated care pathways may facilitate the standardization of the terms and conditions of the contracts as one can base the terms and conditions directly on the actual performance of a healthcare provider. The contracting terms and conditions should be based on the norms and standards that are laid down in the health service procurement model. Standardization of the terms and conditions may result in a much simpler and less costly contracting process than the current situation (Ashton et al., 2004) where contracts often comprise specific terms and conditions (Steven Goldberg, 2008).

It is important to get all parties committed to the procurement model in order to enable a smooth contracting process. The contracting process is the ultimate moment for actors to resist when they do not agree with healthcare procurement on the performance at the integrated care pathway level because resistance at that moment in time may have the highest results. Health insurance companies are pressed to enclose contracts and healthcare providers have a more powerful position than after the contract closure. Currently the medical

[18]For example activities that are executed by primary and tertiary healthcare providers, while the contracted healthcare provider is a secondary healthcare provider.

specialists are left out from the healthcare outline agreement. Although this speeds up the decision making process in first instance, it may result in high resistance during the contracting process which is dangerous for the overall process as medical specialists are a key party in the healthcare sector when it comes to the quality of health services[19].

8.5.5 Final remarks

Two final remarks should be made on which additional research is required. This concerns in the first place the number of contracts that should be enclosed with one healthcare provider. There are several options here.

- Enclosing single appropriate contracts for the treatment of each disease
- Enclosing a bunch of *close to* appropriate contracts for the treatment of a set of related treatments

Health insurance companies may choose to enclose single contracts with healthcare providers that deliver the most appropriate health services for specific diseases. This may increase the appropriateness of health services, but may also lead to a more expensive and long lasting contracting process. A second option is to look for healthcare providers that can deliver a set of treatments that have a good fit with the preferences of the insured population. This speeds up the contracting process and makes it less expensive. However, contracting may in this form lead to less competitive pressure among healthcare providers as it still is sufficient when they have an overall good performance while lacking behind for several treatments. This may be a major concern because healthcare procurement on the performance of integrated care pathways may in that sense not deviate a lot from the current situation on the healthcare market. Figure 8.7 demonstrates the trade-off for health insurance companies for the number of contracts that should be enclosed.

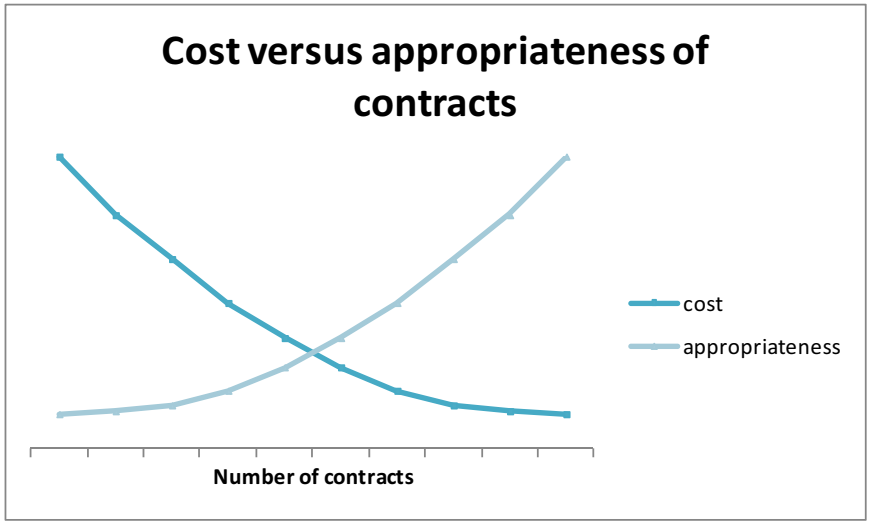


Figure 8.7 – Trade-off between the cost and the appropriateness of contracts.

A second point concerns the design of the contracting situation. The question may be whether the contracting situation (see for several design options section 8.5.3) should be defined by the government or by the market. Both options have some drawbacks. The design of the contracting situation by the government may prevent the healthcare sector from negative external effects as discussed in section 8.5.4. However, the government may be less efficient in designing a contracting situation than the market. Subsequently, the contracting situation may become quite rigid, where there is no room for customization of the process. This may limit the flexibility of contracting in healthcare seriously. This may have significant impact on the performance of the healthcare system as each treatment is different and asks for customized terms and conditions. When we make use of the market to design the contracting process, one may expect a more efficient and customizable lay-out that

[19] According to section 8.3.2 where is stated that the quality of healthcare employees are an important determinant for the quality of health services.

is applicable in multiple situations. In addition, learning may be improved when the contracting process is regulated by the market. The drawback of this situation is that the market is not good in managing negative external effects. At least additional legislation is required in order to prevent the market from setting up contracts that are a threat for the core values of the healthcare system.

8.6 Specialization and fragmentation of healthcare providers

One of the expected desirable effects of healthcare procurement on the basis of actual performance of the integrated care pathways is the specialization of healthcare providers. The idea is that insight in the performance on the level of the integrated care pathways will lead to more focus by the healthcare providers on the good performing treatments. Health services are expected to become more efficient when healthcare providers focus on a limited set of treatments. However, one may also argue that healthcare procurement on the level of the integrated care pathways under certain conditions may result in a fragmented healthcare sector.

8.6.1 Specialization

The procurement on the basis of the actual performance figures of the integrated care pathways may have significant consequences for the operations of healthcare providers as healthcare providers can only continue the operations that are rewarded with a contract. Other treatments will not be reimbursed by health insurance companies. This will be a reason for the insured population to go to other healthcare providers. The uninsured population in the Netherlands may be far too small to keep an not reimbursed integrated care pathway running. Healthcare providers are therefore forced to remove the non reimbursed activities and will become more specialist.

Healthcare procurement on the basis of performance figures is at the same time an incentive for a focused strategy[20]. This is caused by how the healthcare sector is organized along long term contracts. As mentioned before, a healthcare provider will not get a contract when their performance is insufficient. This may cost them a lot of money[21]. Healthcare providers have for that reason to be sure that they will be awarded with a contract and may therefore invest a lot of money in a particular set of treatments.

8.6.2 Fragmentation

As mentioned in the introduction of this section, healthcare procurement on the basis of performance figures may under certain conditions also lead to the fragmentation of the healthcare sector. This is an unwanted situation (according to the healthcare outline agreement) because low volume integrated care pathways are expected to be less efficient and effective than high volume pathways because of existing economies of scale. Fragmentation may be a consequence of the inability to quantify the performance of low volume integrated care pathways. The quantification of the performance of low-volume integrated care pathways is problematic because of the lack of information. Performance figures of healthcare providers may vary quite a lot, dependent on the types of patients that are treated. In order to come up with reliable average performance figures with an acceptable standard deviation, one needs a bigger data set[22]. The procurement of health services cannot be based on unreliable performance figures as the performance figures are used as a input for healthcare procurement. Healthcare providers may steer towards low-volume integrated care pathways in the abundance of adequate regulation. This may lead to the fragmentation of the healthcare sector.

[20] This is quite different from a general market where many different effective strategies coexist.
[21] They have the employees and all capital present which needs to be paid.
[22] The size of the data set depends on the required confidence interval and the variation in the performance figures.

8.6.3 Impact of specialization and fragmentation of healthcare providers on the performance of the healthcare system

Both specialization of healthcare providers as the fragmentation of the healthcare sector may have serious consequences for the performance of the healthcare system. More specialist healthcare providers may mean that the treatment for certain scarce diseases become less accessible for people that live in sparsely populated areas. In addition, the healthcare system may become more volatile due to the current contracting system. It may occur that healthcare providers have to dispose a lot of activities within a short period of time. This will increase the dynamics of the healthcare system seriously. An increased volatility will be no problem as long as healthcare providers are flexible and have sufficient capacity. However, the healthcare system has to secure important core values[23], health services cannot easily be imported[24] and the healthcare system is currently not flexible. A fast disposal of integrated care pathways may for that reason lead to lack of capacity of the healthcare sector on the short term. Lack of capacity may decrease the quality of healthcare services on the mid-long term because health insurance companies still have to procure the required treatments for their clients. This means that they have to procure low quality health services in case of the lack of high quality healthcare capacity. Shortages at the supply side of the healthcare sector will be a disincentive for performance improvements[25]. One may argue that the market will solve this problem. A precondition for good functioning of the market is that there should be no entry barriers for new entrants to the market. This may be a difficult point because of the existence of many norms and standards for minimal performance. These norms and standards may be hard to reach by new healthcare providers but can be reached by experienced healthcare providers that extend their capacity.

Fragmentation may also be a threat for the goals of the healthcare system that are formulated in the healthcare outline agreement. Fragmentation of health services may lead to a less efficient healthcare system because of the lack of economies of scale. Subsequently, quality management may become difficult for both healthcare providers as health insurance companies. As mentioned before, it is not possible to quantify the performance figures of low-volume integrated care pathways in a reliable way. Procurement cannot be based on unreliable performance figures. A solution may be to use the performance figures over a longer period of time. However, a problem with that may be that it is a disincentive for innovation because the increased performance of a healthcare provider over a certain time period is averaged with the performance figures of multiple previous periods. Healthcare providers are in that situation not rewarded for their effort and actual performance.

8.7 Conclusions

The use of a healthcare procurement method may have some a serious impact on the performance of the healthcare system. The following implications of the use of such a method can be distinguished

- Changed position of the patient and healthcare employees
- Risk on sub-optimality of the healthcare system
- Increased complexity of the contracting process
- Changed focus of healthcare providers
- Reduced innovation due to the reduction of product variety
- Reduced competition due to the clustering of health insurance companies

As discussed in the previous sections of this chapter, these implications may affect the performance of the healthcare system to a larger extent. In many cases additional legislation and incentives should be in place to guarantee the core values of the healthcare sector in the future.

[23] One can for that reason not afford big mistakes.
[24] It is not easy to get the health services from other countries
[25] Healthcare providers are sure that they get a contract independent of their performance.

Part III

Conclusions and Recommendations

Chapter 9

Conclusions and Recommendations

This chapter summarizes the conclusions on the research questions that are defined in section 3.4.2. Subsequently, Section 9.2 comprises recommendations that are based on experiences from this research and steps for further research are formulated in section 9.3.

9.1 Conclusions on research questions

This section comprises a summary of the conclusions on the research questions that are presented in section 3.4.2. The conclusions on the research questions will be discussed separately.

9.1.1 Conclusions on research question one

Research question one is formulated as follows

> *What are the relevant goals of the healthcare system from the point of view of the key actors in the healthcare sector?*

The relevant goals of the healthcare system from the point of view of the key actors in the healthcare sector are discussed in section 4.2. First four different key actors are distinguished in the healthcare sector, namely the patients, healthcare providers, health insurance companies and the national government. The goals of the healthcare system are summarized for each key actor respectively. The goals of the key actors are occasionally overlapping. The shortlist of main goals of the key actors after the removal of redundant goals is given in table 9.1. The crosses indicate whether the goals belong to an actor.

Table 9.1 – Goals of the healthcare system

	Patient	Government	Healthcare provider	Health insurance company
Minimize the cost of healthcare	x	x	x	x
Maximize the experienced quality of healthcare	x		x	x
Maximize the objective quality of healthcare	x	x	x	
Minimize the utilization of scarce medical resources		x	x	
Maximize the accessibility of healthcare	x	x		
Maximize the efficiency of healthcare		x	x	

9.1.2 Conclusions on research question two

Research question two is formulated as follows

> *Which Key Performance Indicators are currently used to examine the performance of integrated care pathways on these goals?*

The KPIs that are currently used in the healthcare sector for measuring the performance of integrated care pathways on the predefined goals are discussed in section 4.3.2. Not all these KPIs are applicable for measuring the performance of integrated care pathways. Whether a KPI is applicable depends on how they are formulated and how well the KPIs can be measured. The quality of KPIs is examined on the criteria *specific*, *reliable*, *relevant* and *time-bound*[1]. The KPIs in table 9.2 can be used for measuring the performance of integrated care pathways. However, these KPIs still are not perfect and need to be adjusted in order to fit for the purpose of healthcare performance quantification on the level of the integrated care pathways. The following scores are used for the qualification of the quality of the KPIs on the criteria

$--$ = *bad*
$-$ = *insufficient*
0 = *average*
$+$ = *sufficient*
$++$ = *good*

Table 9.2 – Examination of currently used KPIs

Goal	KPI	Unit	Specific	Measurable	Relevant	Time bound
Minimize the cost of healthcare	Billed cost of treatment	[€/ treatment]	++	++	++	++
Maximize the experienced quality of healthcare	CQ-index	[...]	++	+	++	+
Maximize the quality of healthcare	QALY	[QALY/ treatment]	+	-	+	+
	Mortality rate	[%]	++	++	0	++
	Treatment duration	[day/ treatment]	0	++	++	++
	Complications risk	[%]	0	++	+	++
	Recidivism risk	[%]	0	++	+	++
Maximize the accessibility of healthcare	Length of waiting list	[week]	+	+	++	++
Maximize the efficiency of healthcare	Efficiency	[%]	++	0	++	++

9.1.3 Conclusions on research question three

Research question three is formulated as follows

> *What is the relative importance of the goals for different actors?*

[1] The quality of currently used KPIs on these four criteria is extensively examined in section 4.4.2.

The relative importance of the different goals, that actors have in healthcare are discussed in section 4.5.2. The relative importance of the goals is determined with the help of the needs and preferences of the key actors as described in table A.1 of appendix A. A summary of the relative importance of the different KPIs is given in table 9.3. An aggregate importance level can be assigned to each KPI with the help of the relative importance of the individual KPIs from the point of view of the key actors. The following scores are used for the qualification of the relative importance of the KPIs for each key actor

$--$ = *unimportant*

$-$ = *little unimportant*

0 = *unimportant nor important*

$+$ = *little important*

$++$ = *very important*

Table 9.3 – Relative importance of KPIs

	Patient	Government	Healthcare provider	Health insurance company
Billed cost of treatment	−	+	++	++
CQ-index	++	+	+	+
QALY	+	+	+	+
Mortality rate	+	+	+	+
Treatment duration	0	+	0	-
Complications risk	+	+	+	0
Recidivism risk	+	+	+	0
Length of waiting list	+	+	0	0
Efficiency	−	+	+	0

9.1.4 Conclusions on research question four

Research question four is formulated as follows

> *Which factors may have a disruptive impact on the comparability of the performance figures of integrated care pathways?*

There are several environmental factors that may have a disruptive impact on the performance figures of integrated care pathways. The performance figures need to be adjusted for the impact of these factors in order to enable the unambiguous interpretation of the performance figures. The factors that may have a disruptive impact on the comparability of the performance of integrated care pathways are extensively discussed in section 4.5.1. The following factors are distinguished

- population characteristics like age, gender, race, etc.
- type of care delivered like regular care or follow up care
- the complexity of the disease and risk on complications
- the type of healthcare provider and related characteristics (like additional costs in case of an academic hospital)

The outcomes of a medical treatment may be quite different when one of the factor above changes. This may result in different performance figures for the same treatment on a different population. The average age of the

population for example may have serious impact on the recidivism risk or the number of quality adjusted life years (QALY).

9.1.5 Conclusions on research question five

Research question five is formulated as follows

> *Which general method can be defined for the quantification of the performance of healthcare providers on the right level of detail?*

A method for the quantification of the performance of healthcare providers on the level of integrated care pathways is presented in chapter 7. The method consists of the following eight sequential steps[2]

1. actor definition
2. actor preference identification
3. actor goal definition
4. definition of KPIs
5. definition of disruptive factors
6. definition of relative importance of KPIs
7. KPI quantification
8. performance interpretation

One should remark that some serious issues may arise around the execution of the several steps of the HPQ-method. Two important issues that affect *all* steps of the method are information quality management and the allocation of responsibilities for the execution of the steps of the method. These two issues are important for the success of the method as they directly determine the quality of the outcomes of each step. The outcomes of each step has impact on the overall outcomes of the method.

9.1.6 Conclusions on research question six

Research question six is formulated as follows

> *What may be the impact of implementation of the proposed method on the performance of the healthcare system?*

Chapter 8 discusses some important consequences of the introduction of healthcare procurement on predefined KPIs for the performance of the healthcare system. Some serious impacts on the performance of the healthcare system are

- Changed position of the patient and healthcare employees
- Risk on sub-optimality of the healthcare system
- Increased complexity of the contracting process
- Changed focus of healthcare providers
- Reduced innovation due to the reduction of product variety
- Reduced competition due to the clustering of health insurance companies

[2]Only step 6 and step 7 can be executed in parallel. The other steps are for the larger part dependent on the input that is delivered by the previous step(s).

In the first place, more competition may result in a higher customer, labor and healthcare capital mobility[3]. This may lead to an increased concentration of supply and demand of health services at specific points in the healthcare system. A second point that is mentioned concerns the unilateral focus on increasing the performance of integrated care pathways. Section 8.4 discusses the risks and consequences of this policy for the performance of the healthcare system. There is a substantial risk that the healthcare system will not perform as expected under the conditions of more competition when the required prerequisites are not in place. The government should for that reason facilitate a shift towards more specialist healthcare providers as proposed in the healthcare outline agreement. This may help to guarantee the quality of the healthcare system as this may improve the focus of healthcare providers to deliver high quality health services for a limited number of treatments.

Furthermore the introduction of performance based procurement may result in a different healthcare contracting process than before. Health services are no longer enclosed on the basis of quantitative aspects but much more on the quality of health services. This changes the position of both healthcare providers as health insurance companies.

A negative side effect of performance based health service procurement may be the reduction of variety and as a result the reduction of the innovative pressure. In addition, health insurance companies are likely to merge in order to reduce competition on the health insurance and healthcare procurement market. This may negatively affect the expected outcomes of the introduction of competition on the healthcare market.

Additional incentives and regulations may be required to safeguard the core values of the healthcare system over the longer term by the elimination or reduction of the negative side effects of the introduction of performance based health service procurement.

9.2 Recommendations

This section comprises recommendations for change in the healthcare sector that are required in order to enable the introduction of effective competition on the level of integrated care pathways.

9.2.1 Redefinition of KPIs

From section 4.4.3 becomes clear that the KPIs that are currently used for the evaluation of the performance of healthcare providers do not fully fit for the purpose of performance quantification on the level of the integrated care pathways. Most of the KPIs need to be redefined in order to enable the appropriate evaluation of healthcare performance on the right level of detail. This section discusses for each KPI what adaptions needs to be made in order to make them fit for purpose.

Billed cost of treatment No adjustments need to be made to the billed cost of a treatment. However, this KPI can currently not be calculated at the level of the integrated care pathways. It is not possible to aggregate the billed cost at the different healthcare providers to a higher level, because of the lack of couplings between the treatment of a patient at different healthcare providers. This is a more general issue that plays an important role by the calculation of each KPI and is discussed in section 9.2.2.

CQ-index The CQ-index is currently measured for only a few diseases. The CQ-index can only be used for healthcare procurement when it is available for all healthcare providers and integrated care pathways. The following improvements are suggested

- Measure the CQ-index for all steps of the treatments
- Define an overall CQ-index that covers the whole treatment

Measuring the CQ-index for all steps of the treatments makes it possible to include the CQ-index as a KPI for the procurement of health services[4]. Subsequently, it should be possible to aggregate the CQ-index to the

[3] When no barriers are raised that damage the mobility of patients and healthcare employees.
[4] It can then be used among all integrated care pathways and is for that reason universally applicable.

level of the integrated care pathways as shown in figure 9.1. This is not only beneficial for the health insurance companies that have the task to procure health services based on this KPI but also for healthcare providers that can improve their services with the help of this information.

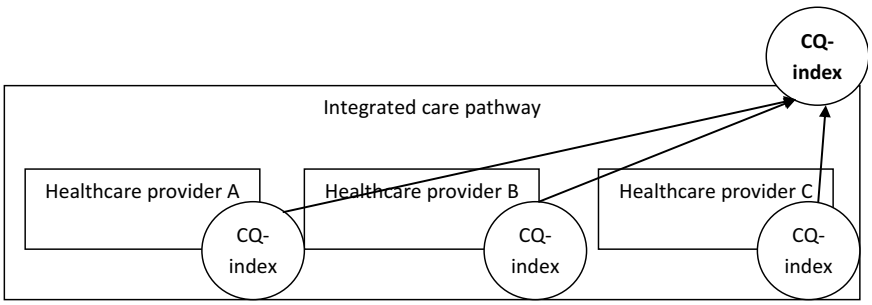


Figure 9.1 – Determination of high level CQ-score

QALY There are currently some issues with the calculation of the QALY values. The QALY value is calculated with the help of different methods in the healthcare sector. The different methods calculate the QALY value in a different way. To avoid this, one general method should be defined for the calculation of the QALY value. The QALY value should be calculated on the basis of a full treatment among multiple healthcare providers instead of the treatment by one healthcare provider. This gives a more accurate impression of the quality of a treatment for the patient.

Mortality rate The mortality rate is currently defined in an accurate manner.

Treatment duration There are some issues with the definition of the treatment duration. The treatment duration is currently often based on the start and end date of a DBC instead of the duration of the exact duration of each individual step. This is due to the fact that the databases of health insurance companies only comprise the start and end date of the DBCs but do not comprise the duration of for example the hospitalization for individual patients. This is a more relevant value than the total DBC duration as the actual treatment duration may be an important determinant for the choice for a certain healthcare provider.

Complications and recidivism risk The complication and recidivism risk should be measured at the level of individual steps of the integrated care pathway instead of the healthcare provider level[5]. This issue is discussed in detail in section 9.2.2.

Length of waiting list It may be difficult to define which waiting lists are relevant when we talk about the performance of integrated care pathways. The parameter *Length of waiting list* becomes *waiting time between treatments* in case of integrated care pathways where the whole treatment can be seen as sequential series of steps. It may be wise to redefine the length of the waiting lists by the total expected waiting time between treatments, in order to give an accurate impression of the effectiveness of the alignment of the sequential steps that are executed for the treatment of a patient.

Efficiency Currently, the efficiency of integrated care pathways is not used as a performance indicator in healthcare. In this research is proposed to define the efficiency with the help of the DEA method which allows a conservative and accurate calculation of the efficiency of integrated care pathways. Subsequently this method can be used to calculate the efficiency of individual inputs and outputs.

[5]The healthcare provider is only part of the integrated care pathway. Figures at this level do not provide the full picture.

9.2.2 Improve information management

This research demonstrates that information management in healthcare currently does not meet the requirements for the deliverance of sound and relevant information for the procurement of health services on the integrated care pathway level. Powerful and effective information management seems to be a major challenge. This section will give some clear recommendations for improving information management in health care on the following aspects[6]

- information should be relevant
- information should be sound
- information delivering processes should be optimized
- information infrastructure should be reliable

A general recommendation for improving the quality of information that is delivered to the healthcare market is done in section 7 where a method for the quantification of healthcare performance is proposed. This method mainly focuses on delivering sound and relevant information to the healthcare market, but it does not improve all information deliverance processes and the information infrastructure in healthcare. Some recommendations are done in this section that may help to improve the information delivering processes and the information infrastructure.

9.2.2.1 Information delivering processes

Some important improvement are required for the information delivering processes in order to make them fit for the quantification of healthcare performance on the level of the integrated care pathways. There is mentioned that it is currently not possible to follow the patient throughout the healthcare system. In databases there is no coupling between the information about the treatment of at one step step of the treatment and at a following step at different healthcare providers. This makes it impossible to aggregate the performance of the individual steps to the level of the integrated care pathways.

Solutions There is a simple solution for this problem. One can assign a unique code to each patient when a treatment is started at f.e. the general practitioner. The patient keeps this code until he is dismissed from the healthcare system. By doing so, it is possible to assign the performance of a healthcare provider to one code. With the help of this information, one can aggregate the performance to the level of the integrated care pathways.

9.2.2.2 Information infrastructure

The information infrastructure in healthcare is currently quite complex. There are different parties that own a part of the relevant information that is present in the healthcare system. This may give rise to some problems that directly affect the quality of information. Information may be lost when certain attributes are stored at a single location and do not have shared information with attributes in another database. This makes it impossible to assign the different attributes to one treatment. Problems may also occur when information is processed in a different way at different locations. This may lead to asymmetry of information. Information asymmetry is undesirable from the point of view of fair competition as it means that it may occur that health insurance companies in the future procure health services on the basis of incomplete information.

[6] These aspects are mentioned in section 7.2.9.

Solutions There are some solutions available to solve the issues that are mentioned above. One can store all relevant performance figures[7] in one central place. This prevents the above situations from occurring. However, some of the KPIs that are used for the calculation of the efficiency figures of integrated care pathways are confidential and should for that reason not be available for all parties. This can be solved by giving each actor special permission rights to access specific parts of the database. A central database makes the whole process of performance evaluation more transparent as everyone has insight in the source data that is used for the evaluation of healthcare performance. Additionally, the presentation of the performance figures for public purposes[8] may become easier when all information is stored in a central place.

Centrally stored information requires adequate data security mechanisms that guarantee the quality of the information that is stored in the database. Different parties should no longer be kept responsible for the quality of information but information quality management would ideally be laid down by one independent party. Because of the fact that this database comprises high confidential information it may be wise to keep the management of this database under responsibility and supervision of the national government. Subsequently, all information should be strictly protected order to prevent the misuse of information by malicious parties.

9.3 Next steps

This research can be seen as a first step towards towards fair competition on the healthcare market as it has the purpose to deliver the relevant information to the healthcare market. However, more research is required on some important topics. This section discusses some next steps that should be taken in order to take advantage from the insights (as discussed in section 9.1) that are gained by this research. Section 9.3.1 discusses the position of this research as an input for a healthcare procurement method. Section 9.3.2 discusses the use of this research for a healthcare performance benchmarking study.

9.3.1 Healthcare procurement model

This section discusses the research that is required in order to be able to come up with a model for the procurement of health services. Section 9.3.1.1 highlights the connection between the HPQ-method and the health service procurement model. The content of the proposed research is discussed in section 9.3.1.2.

9.3.1.1 position of this research

Figure 9.2 demonstrates how the research that is presented in this report can function as input for a healthcare procurement model. The HPQ-method has the purpose to enable the quantification of the relevant healthcare performance figures for fair competition. These KPIs will serve as an input for a healthcare procurement model, supplemented with information about the relative weights of the KPIs which can be defined with the help of the information in section 4.5.2.

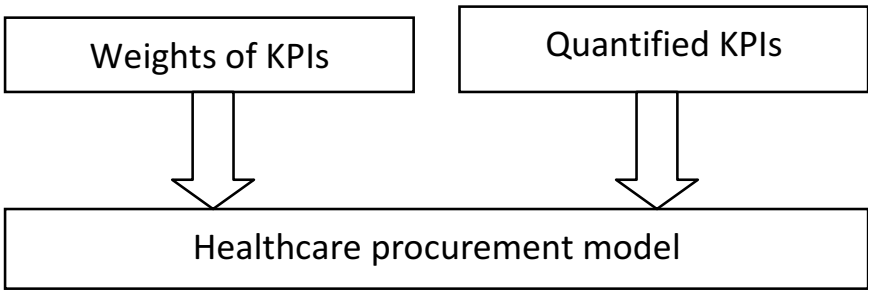


Figure 9.2 – Application of the research for a healthcare procurement model

[7] Performance figures that are relevant for the procurement of health services. Section 9.1.2 summarizes which performance figures are relevant.

[8] For example to make the performance figures of integrated care pathways available for the Dutch population.

9.3.1.2 Content of the research

The healthcare procurement model will add value by providing a clear method for the evaluation of the performance of integrated care pathways and the definition of a preference order among healthcare providers.

The healthcare procurement model should comply with the information requirements as described in section 2.4. Subsequently it should provide the possibility to

- execute a weighted evaluation of the performance of integrated care pathways on a complete set of KPIs
- define a preference order among different integrated care pathways on a complete set of KPIs
- provide information to the healthcare market about the performance of integrated care pathways
- base healthcare procurement on minimal performance standards for integrated care pathways

One may think that DEA can be used for the procurement of health services. However, DEA does not provide enough information for healthcare procurement as DEA is aimed at the evaluation of the relative efficiency figures. The efficiency figures are only one of the KPIs on which the performance of integrated care pathways is evaluated and can therefore not be used to determine a preference relation between integrated care pathways on the full set of relevant KPIs. Subsequently, DEA cannot work with weighted KPIs and is for that reason not applicable for weighted healthcare performance evaluation. The quest for a weighted evaluation of the performance of integrated care pathways is explained in section 4.5.2.

The healthcare procurement model should be able to assign a preference order to a set of alternative integrated care pathways on the basis of a complete set of KPIs. This may serve for both the health insurance companies as the patients as a basis for healthcare procurement. The billed cost of healthcare may play a central role because the preference for a certain healthcare provider (from the point of view of the health insurance companies) will depend on the ratio between the billed cost and the quality of the integrated care pathways[9]. The quality factors cannot be changed on the short term[10], so the only variable in the negotiation process is the billed cost of a treatment.

The question may arise about whether it is necessary to include all KPIs that measure the performance of the healthcare system on the predefined goals. There may be argued that patients can get the information themselves[11] if they need it for determining which healthcare provider delivers the most appropriate health service to them. However, research shows that patients cannot get the information they need for their decisions as long as it is not provided to the market. Currently there are a lot of information barriers present. Information on the internet is often unreliable or prices are incomparable (Vaartjes, 2012; Purcell et al., 2002). This may disturb competition, because a patient may be guide to the healthcare provider who presents the best figures, and in the end be confronted with additional costs etc. The quality of the healthcare system cannot be guaranteed when there is no adequate management of information. The patient would then be better of in a fully regulated market where central supervision is applied to the quality of the healthcare system.

9.3.2 Performance benchmarking study

This section discusses the research that is required in order to be able to benchmark the performance of healthcare providers. This may help healthcare providers to improve their performance on the KPIs that are used as input for the procurement model by improving their focus for improvements on the right parameters. The position of the HPQ-method as input for this research is highlighted in section 9.3.2.1. Section 9.3.2.2 discusses the content of the research in more detail.

[9] A worse performing pathway may be as preferable as a better performing one, when it can deliver health services for a lower price.

[10] The quality is somehow a given, while investments in the improvement of health services in general will pay back on the longer term.

[11] By going to the internet or calling healthcare providers about their performance figures.

9.3.2.1 position of this research

Figure 9.3 demonstrates how the HPQ-method and the DEA method that are presented in this report function as input for a healthcare performance benchmarking method. The quantified KPIs are an output of the HPQ-method. DEA is used to calculated one of the KPIs and can also be used for the calculation of the efficiency of each input and output that is used in healthcare processes. In addition, DEA can be used to define the improvement potential of an integrated care pathway as discussed in section 5.2.

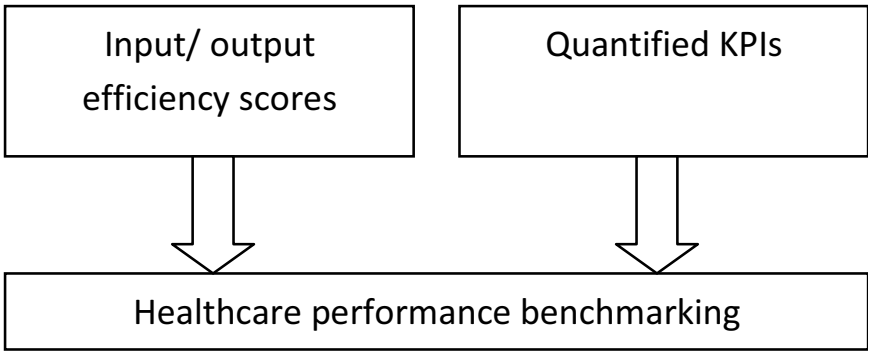


Figure 9.3 – Application of the research for a healthcare performance benchmarking method

9.3.2.2 Content of the research

The outcomes of the HPQ-method may serve as input for a performance benchmarking research in healthcare. This method may be beneficial for healthcare providers when it is aligned with the procurement model for health services that is proposed in section 9.3.1. A healthcare benchmarking method may provide healthcare providers insight in their actual performance on the KPIs that are used for the procurement of health services. Healthcare providers can apply their focus on the performance figures that lack behind compared to competitors.

It is important that the performance benchmarking study complies with the prerequisites for a good quality of information as described in section 2.4. This may guarantee the proper provision of information to the healthcare market, which is required for fair competition among healthcare providers. Subsequently the performance benchmarking method should provide the possibility to

- compare the performance of healthcare providers on the goals of the healthcare system
- provide insight in the improvement potential of healthcare providers, compared to direct competitors[12]
- formulate the best practices in order to enable performance improvements on the relevant goals

The outcomes of the DEA method can ultimately be used for the detection of sources for improvement. DEA can be used to find out where major improvements can be realized. This is done with the help of the efficiency figures for inputs and outputs and the figures about the improvement potentials. These figures indicate what improvements can be realized without the deterioration of other parameters. Efficient DMUs in DEA cannot change one of their inputs without negatively affecting their output performance where inefficient DMUs can improve their outcomes. However, this does not mean that efficient DMUs perform *optimal*. The efficiency of the integrated care pathways is only based on empirical. An efficient DMU might be able to improve its performance in the future with the help of f.e. innovation.

Lastly, the benchmarking study should provide the possibility to formulate best practices that help healthcare providers to realize ultimate performance. Sharing the best practices on a *national* level may help to realize serious improvements in the healthcare sector compared to the current situation where improvements most of the time are based on *local* experiences and best practices (see section 1.4.2).

[12] Competitors that are active in the same market segment.

9.3.3 Research after the consequences of the research

The introduction of more competition by assigning performance based procurement of health services to the health insurance companies may have serious negative side effects on the performance of the healthcare system. Additional research is required after the consequences of the research for the performance of the healthcare system. The most important consequences are extensively discussed in chapter 8. It is important that the consequences of healthcare procurement on predefined KPIs are clear in order to be able to define accurate policy measures that intervene in the operations in the healthcare sector. Research should at least provide an answer on the following questions

- What is the likelihood of occurrence of the several consequences mentioned in chapter 8?
- What is the likelihood of the impact of these consequences on the performance of the healthcare system?
- What prerequisites should be guaranteed in order to prevent unnecessary negative side effects?
- What policy measures are available that can be used to cope with the negative side effects of healthcare procurement?
- What policy measures are effective in coping with the negative side effects?
- How feasible is the implementation of the policy measures?

An answer on these questions may help to detect and eliminate or reduce the negative side effects of competition on the healthcare market.

Chapter 10

Discussion and Limitations

This chapter comprises a discussion on the application of the HPQ-method. Section 10.2 discusses the possibilities for the generalization of the proposed method to other parts of the healthcare system. Subsequently, the limitations of the research and challenges for improvements are discussed in section 10.3 of this chapter. This chapter rounds up with a realistic view on the actual value and acceptance of the HPQ-method by the key actors in the healthcare sector.

10.1 Application of the HPQ-method

The HPQ-method can be used as an input for a healthcare procurement method and a healthcare performance benchmarking study (see section 9.3.1 and section 9.3.2). This may facilitate health insurance companies in the execution of their role in healthcare. However, this method may have additional benefits and applications which are discussed in this section.

10.1.1 Instrument for change

Besides the fact that the design of this method has the purpose to facilitate health insurance companies to execute their new role in healthcare, the HPQ-method may be used as an instrument to realize change in the healthcare market structure. Section 1.4.4 mentions that health service delivery should change from supply driven towards demand driven healthcare. This method may be used to facilitate this change by

- delivering insight in the needs of the supply side of the healthcare market
- procurement of health services on the basis of the needs of the supply side[1]
- offering transparency in the performance of healthcare providers
- providing a basis for governmental intervention

Insight in the needs and wishes of the patient may give healthcare providers a powerful instrument to put effort in the deliverance of health services that are consistent with the needs of the patients. However, when there is no mechanism that enforces healthcare providers to adjust their operations, they are not likely to change their behavior as long as this is not beneficial for them[2]. The focus on the patients needs can be enforced by the position of health insurance companies. They will procure healthcare on the basis of predefined KPIs. These KPIs correspond with the goals of the key actors in the healthcare sector (see section 4.2); including the desires of the patient. By offering transparency of information to the patient, one may expect the concentration of demand for health services at the healthcare providers that deliver healthcare that meets the desires of the patients best[3].

[1] Formulated as criteria for the procurement of health services.
[2] This concerns both their financial position as the image they have.
[3] This will only occur when there are no mobility barriers for the patient (see section 8.3)

In section 2.1.2 is mentioned that the healthcare market is not expected to match supply and demand perfectly, due to the characteristics of the market and the services that are delivered on the market[4]. Governmental interventions may be required to maintain the core values of the healthcare system. The transparency of the performance figures of healthcare providers may be used by the national government as a basis for intervention on the healthcare market when the performance of the healthcare system deviates from the desired performance from the point of view of the key actors in the healthcare sector.

10.1.2 Instrument for improving clinical outcomes

The HPQ-method may be used as an instrument for the improvement of clinical outcomes. Improvements in clinical outcomes can be realized both voluntary as forced. There exist several mechanisms that use the information from the HPQ-method as a basis to improve clinical outcomes

1. Voluntary improvement by healthcare providers
2. Forced improvement by
    2.1 the market
    2.2 coupling of performance figures with the terms and conditions of the health service contracts

Healthcare providers in general and medical specialists in particular are focused on delivering health services to the best of their capabilities (Ablij, 2012). Transparency about the performance of healthcare providers may in that sense be an incentive for voluntary improvement of the performance of healthcare providers. Transparency of the relative performance of healthcare providers on the level of integrated care pathways can be given with the help of a healthcare performance benchmarking study (see section 9.3.2).

Some additional mechanisms can be used to force improvements in clinical outcomes. The first mechanism is the discipline of the market. Healthcare providers that do not meet the requirements of the demand side of the healthcare market have to improve their performance under fair competition. Otherwise they will experience a decrease in healthcare demand which may result in losses and the elimination of an integrated care pathway over the longer term. The HPQ-method may also be beneficial for improving clinical outcomes by coupling the performance of healthcare providers at the integrated care pathway level with the terms and conditions of the contracts that are enclosed between the health insurance companies and the healthcare providers. This is also proposed in section 8.5.

10.1.3 Simple integrated care pathways

This research focuses at the quantification of complex integrated care pathways that are executed transcending the border of the healthcare providers. Performance quantification is most challenging for those pathways, but the proposed HPQ-method may also be applicable for simple pathways that are executed by only one healthcare provider. However, the execution of the HPQ-method may be much simpler and faster than in case of complex pathways. In addition, performance quantification will probably add less value for the reduction of cost and the increase of efficiency as simple pathways are easier to optimize when they consist of a few steps that are executed by one healthcare provider. Subsequently, contracting of simple treatments will possibly not be subject to a interactive contracting and negotiation process but terms and conditions of contracts for simple specialisms are likely to be standardized among all healthcare providers. Insight in the performance may for that reason not have a big impact on the contracting setting, but may be relevant for healthcare providers to realize minor improvements in efficiency. The national government may benefit from the performance figures from a monitoring perspective where they can use the knowledge as a basis for intervention when performance figures suddenly changes or deteriorate over time.

[4]Perfect competition is not possible on the healthcare market as the requirements for perfect competition cannot be fulfilled.

10.2 Generalization of HPQ-method

This section discovers whether the HPQ-method can be generalized to other parts of the healthcare sector. Section 10.2.1 discusses whether the HPQ-method can be used in the mental healthcare system and section 10.2.2 discusses the possibility to use the method in other countries.

10.2.1 Mental healthcare

The national government, health insurance companies and mental healthcare providers in the Netherlands are close to a healthcare outline agreement for the *mental* healthcare sector.The goals and responsibilities of the parties in the mental healthcare system will be laid down in this agreement. It may occur that health insurance companies again will get a prominent role[5] in the procurement of appropriate health services and steering towards a more efficient mental healthcare system. However, the details may be slightly different. F.e. they may agree on a different gradient for cost increase than in the healthcare outline agreement for the physical healthcare system. The minor differences in the healthcare outline agreement for the mental healthcare system will probably not have a huge impact on the applicability of the proposed method. However, the mental healthcare system has a lot of characteristics that makes it different from the physical healthcare system. These characteristics may affect the usability of the HPQ-method in the mental healthcare system. The following differences are distinguished

- information may be structured different
- the quality of outcomes are difficult to measure
- some criteria do not apply for the treatment of mental diseases
- treatment conditions are different for mental diseases
- less significant performance results can be expected because of lower treatment volumes
- there is an abundance of integrated care pathways for many mental diseases

Information in the mental healthcare system may be structured different from the physical healthcare system. This will not be a problem for the use of the HPQ-method but may affect the complexity of the implementation of the method and will in that sense be a limitation for the generalization of the method to the mental healthcare system. Major issues may arise around the quantification of treatment outcomes in mental healthcare. It is for example difficult to determine the impact of a treatment on the mental health of a patient.

Next, it may be hard to define a set of KPIs that can measure the performance of mental health service accurately on the goals of the mental healthcare system. When the HPQ-method would be used in mental healthcare, one needs to redefine, add or remove some of the KPIs (like the mortality rate). In physical healthcare, the treatment conditions (age, gender, race, etc.) are already often different per patient. This is even more the case in mental healthcare[6]. Each patient that is treated for a mental disease may have different conditions compared to other patients. This does not only mean that performance parameters needs to be adjusted for these differences but also that knowledge is required about the impact of all kinds of factors that determine the success of a treatment. A solution may be to do not adjust the performance figures but compare the patients that have the same characteristics. However, this may result in small sub groups of patients. It is in that situation no longer possible to determine significant performance figures. Another important difference with the physical healthcare system is the abundance of integrated care pathways in mental healthcare. There is often no standard method for the treatment of patients with a specific disease. This makes it hard to compare the performance of healthcare providers on the treatment of specific mental diseases.

[5] The role of health insurance companies in the mental healthcare system is not fundamentally different from their role in the physical healthcare system

[6] Patients may have different types of the same mental disease which may have impact on the treatment duration and the success of the treatment, or patients have multiple mental problems that affect the performance of a treatment.

All these differences together make it difficult to implement a method for performance quantification in the mental healthcare system. One needs to solve at least the issues that are mentioned above in order to introduce effective performance quantification.

10.2.2 Global use

The same trends, as in the Netherlands, towards more competition in healthcare can be found in other countries like the United States (Woolhandler and Himmelstein, 2007). This gives rise to the question whether the HPQ-method can be applied in other countries to provide information to the healthcare market. Whether this is the case may depend on the situation in that specific countries. However, some general remarks on the use of the HPQ-method in other countries can be made.

- The organization of the healthcare market in the Netherlands is quite unique. This is especially valid for the position of the health insurance companies. One should for that reason be careful with the generalization of the HPQ-method to other countries when it concerns the position of the health insurance companies.
- The HPQ-method is not only valuable when there is competition on the healthcare market but may also be used in a regulated market. The HPQ-method may serve as an instrument for improving clinical outcomes in a regulated market as it may serve as a basis for the design of policies, norms and standards in the healthcare market.
- The HPQ-method may be applicable in other countries that follow a similar process towards a competitive healthcare market. However, the healthcare system in each country may be different. This may result in different goals and different models for the evaluation of the performance of integrated care pathways (if they exist).

In general can be stated that the generalization of the HPQ-method to other countries depends on a broad set of characteristics

- The role of an intermediate party (like the health insurance companies)
- The goals of the healthcare system
- The organizational form of the healthcare market
- Current performance evaluation methods that are in place
- Performance indicators that are currently used for the evaluation of healthcare performance

All these characteristics may influence the usability and need for adaptations of the HPQ-method.

10.3 Limitations and challenges for improvement

This research and its outcomes has some limitations that should be discussed in order to know the weaknesses of the method. Subsequently the challenges for improvements are pointed out and solutions for dealing with the limitations are suggested.

10.3.1 Uncertainty and variation in DEA

A first challenge in DEA is the handling of uncertainty and variations in the inputs and outputs. Although the degree of uncertainty and variation differs, uncertainty and variation is always present in data.

Limitation The reliability of the input data is an important determinant for the reliability of the outcomes of the DEA analysis. DEA works only with average input and output values over a predefined time period and is not good in handling perturbations in information. However, there may be a quick solution for doing some sensitivity analyses on the data. One can execute a simple sensitivity analysis by manually varying the values of the most important benchmarks. Varying the performance of inefficient points changes only their own efficiency figures as long as the DMU is not moved across the efficient frontier.

Consequences The existence of variations may result in efficiency figures which are not significant different from each other. This makes it difficult to interpret the efficiency figures of the integrated care pathways. Furthermore, the bandwidth of the efficiency figures may depend on the variation in the input and output values. This has the consequence, that inputs and outputs that are based on a larger population result in more stable efficiency figures. The existence of volatile efficiency figures may have serious consequences for healthcare providers. The outcomes of the DEA analysis in appendix E.2 seems to be accurate as the efficiency figures are rounded to two digits but are not. small variations may lead to serious changes in the efficiency values. A good indication for the volatility of efficiency figures is the ratio between the standard deviation of a data set and the improvement potential of a specific DMU. The smaller the standard deviation is and the bigger the improvement potential is, the lower is the volatility of the efficiency figures. However, problems may occur with DMUs that are on or close to the efficient frontier. Small changes in the input and output values may move the DMU on or from the efficient frontier. This will have impact on many other DMUs, because the DMUs on the efficient frontier serve as a bench mark for other DMUs[7]. It is for that reason important to have reliable information, especially for the DMUs that serve many times as a benchmark for other DMUs.

Solutions It is important to make a distinction between the different sources of variation and uncertainty. One source are unreliabilities in the source data, the data infrastructure and data processing steps. Another form of uncertainty is natural variation. This second form is inherent to the data that is gathered. Natural variations in source data cannot be avoided. However, for both types of variations exist solutions that may help to improve the interpretability of the final efficiency figures

- Uncertainty can be taken into account in the healthcare procurement model instead of during the DEA analysis
- The use of a stochastic frontier in DEA
- Uncertainty can be reduced by focusing on the few DMUs that serve many times as a benchmark for other DMUs.
- The execution of the analysis on a large population may reduce the variation

A first option is to take the uncertainty into account in the healthcare procurement model. One can define for each KPI a certain band with. It is important that the band with is determined with the help of the underlying empirical data. The band with can be calculated for all KPIs, including the efficiency scores. One may see how uncertainty has impact on the preference relations among healthcare providers. The significance of a preference relation can be determined with the help of a simple Monte Carlo simulation in which the KPIs are varied over the full band with. Knowledge about the volatility of the preference relation should be taken into account during the procurement of health services.

The use of a stochastic frontier in DEA is a solution that enables to take uncertainty into account directly in the DEA method. [elaborate on this]

One may also choose to execute a limited sensitivity analysis by varying the inputs and outputs of the most dominant DMUs[8]. There are two options to execute this limited sensitivity analysis. One may speed up the analysis by varying the input and output parameters parallel or by varying these values in a sequential way.

[7] When the benchmark changes, the relative performance of the DMU under evaluation changes as well.
[8] The most dominant DMUs are the DMUs that often serve as a benchmark for other DMUs.

The last option will cost much more time, especially in case of a complex optimization model with many inputs, outputs and DMUs. A last way to reduce the volatility of the efficiency figures for changes in the underlying data is the execution of the DEA analysis on a larger data set. One can reduce the bandwidth of the average performance figures by taking the average of a larger population.

10.3.2 Quantification of qualitative information

DEA is not good in handling qualitative information. This has the consequence that qualitative performance figures needs to be quantified in order to use them as an input or output in a DEA efficiency evaluation study.

Limitation DEA is not good in handling a mix of quantitative and purely qualitative information. However, in reality a set of criteria is often not purely quantitative. This is also the case in this research where is made use of the *CQ-index* as a KPI for the quality of a health service as it is experienced by the patient. The CQ-index is a qualitative measure which may have three different values (1 star, 2 stars or 3 stars). This information cannot directly be used in a DEA analysis when there is no clarity about the existence of a linear relation between these values .

Consequences It is likely that many healthcare providers score the same performance on a qualitative measure as a qualitative measure often has only a few values (in case of the CQ-index only three). This makes it hard to make a distinction between the performance of different integrated care pathways as many DMUs will become efficient. The outcomes of the DEA analysis will become less valuable in that case.

Solutions There are several options to transform qualitative measures to quantitative measures. One can link each state of the quantitative KPI to a numeric value. This is only possible when the gap between the different qualitative states is equal (there is a linear relation between the different qualitative states). Otherwise it is difficult to assign an accurate value to each qualitative state. Another option is to base the quantitative value on the source data of a qualitative measure as qualitative measures are often based on quantitative source data. One can use the source data for the transformation of a qualitative measure to a quantitative measure.

A last option is to exclude the qualitative measures from the analysis. However, this may reduce the quality and effectiveness of the method significantly as the performance of the integrated care pathways is no longer measured adequately on the complete set of goals. In addition, according to appendix E.1.2, the number of efficient DMUs will increase as well when inputs or outputs are excluded from the analysis.

10.3.3 The use of undesirable measures

Input measures are normally minimized and output measures are normalize maximized in a DEA analysis. However, there exist inputs that should be maximized and outputs that should be minimized in order to get accurate efficiency scores. These inputs and outputs are called undesirable measures. DEA does not comprise a standard protocol for handling undesirable measures. This may give rise to problems as different annalists may treat undesirable measures differently.

Limitation The abundance of a clear protocol for handling undesirable measures in DEA may lead to outcomes that cannot be interpreted in a unambiguous way because the outcomes depend on the way how the undesirable measures are handled by the annalist. This makes the outcomes of DEA fuzzy when undesirable measures are involved. Some of the currently proposed ways for handling undesirable measures may even lead to wrong outcomes as they transform the information in a dubious way.

Consequences All kinds of decisions can be based on the outcomes of the DEA method. Healthcare providers may base investment decisions on the improvement potential, which is one of the outcomes of the DEA analysis. Subsequently, health insurance companies may push healthcare providers to improve their performance on the

basis of empirical comparison. However, wrong decisions may be taken when information about the efficiency of integrated care pathways and the improvement potential of healthcare providers has an ambiguous character.

Solutions This problem can be solved by defining an applicable protocol for handling undesirable measures that does not lead to wrong outcomes and is generally applicable for all DEA analyses. Roughly two different methods are found for handling undesirable measures. These methods are presented in appendix D.

10.3.4 Leaking patients

Not all patients in healthcare are treated along an integrated care pathway. Healthcare providers deviate from a standardized treatment when the current treatment is not satisfactory. This is often the case when a patient gets a complication. The patients that are not treated by an integrated care pathway are called *leaking patients*.

Limitation Leaking patients may have a disturbing impact on the performance figures of integrated care pathways as long as they cannot be distinguished from the patients that are treated in a standardized way. Patients that leak from the original pathways get often a more expensive treatment.

Healthcare providers that treat patients with more complex diseases are likely to have more leaking patients. A high ratio of leaking patients at its turn may make the integrated care pathways less efficient. This will lead to a significant increase in the cost of health services at those healthcare providers. Population characteristics of patients that are treated by an integrated care pathway can be seen as an environmental factor that impacts the performance of the integrated care pathways (this is also discussed in section 4.5.1).

Consequences The presence of a large stream of leaking patients may make it more difficult to base health service procurement on the actual performance figures of healthcare providers. Performance figures needs to be adjusted for the stream of leaking patients in order to enable fair procurement. This may be a difficult job as it may not always be possible to determine whether an individual patient is treated in a standardized way or on a different way.

Solutions There are some solutions that enable the procurement of health services in the presence of leaking patients. As mentioned above, one may subtract the performance figures of the leaking patients from the patients that follow the integrated care pathways. One should remark that this requires information about the patients that follow the integrated care pathways and those who do not. A second option is to adjust the performance of the integrated care pathways for the characteristics of the treated population. This requires a lot of information about the statistical relations between the population characteristics and the performance figures of the integrated care pathways for specific diseases.

10.4 Reflection

This section comprises in the first place a reflection on the research process in section . Section gives a reflection on the impact of the research on the healthcare system and what changes can be expected after the introduction of the proposed method.

10.4.1 Reflection on the research process

The author experienced some serious learning points during the execution of the analyses in this research. The main learning points concern the line of argumentation and the use of data for the research.

Line of argumentation The author wants to remark that one should pay sufficient attention to the line of argumentation, especially in case of an extended and complex research as the one presented in this report. You may easily get lost on the line of argumentation when several parts of the research are extended. A good line of argumentation may have two benefits

- Better readability of the report due to consistency among the different parts of the report
- Higher quality of the research due to the fact that all parts are relevant. The line of argumentation is important in determining which parts are relevant because the parts that do not support the line of argumentation should be left out from the research and are for that reason irrelevant for the purpose of the research.

It may be wise to define the line of argumentation in advance. This may help you determining which parts are relevant for the purpose of your research during its execution and may prevent the inclusion of parts that cost you a lot of time. Two points that may help in determining the line of argumentation are making up a table of content for the report and writing a summary of the expected content of the chapters and first level paragraphs. This will force you to think carefully about how to execute the research in order to come up with outcomes that make sense and add value to existing knowledge.

Use of data The use of data may give rise to major problems during the execution of the research. Especially when it concerns highly confidential information. Several important pitfalls may be avoided by taking some necessary steps in the early stages

- Consider carefully what data is necessary for the purpose of the research before the execution of the analyses. The less data that is used the lower the chance on problems with the use of data later on in the project. This should be done in an early stage in order to get insight in the possible issues that may arise later on during the execution of your analyses. This will give you the possibility to look for a strategy how to avoid or deal with the issues that may arise during your research.
- Adapt the scope of the analyses and the expected outcomes with the help of the knowledge about what data can be used (what data is accessible and available) for the purpose of the research. This may help you to keep control over the quality of the research and makes it possible to communicate about scope changes with your client.

10.4.2 Reflection on the research outcomes

Looking back on the research, one may want to evaluate the added of this research for the healthcare system in a realistic way. From the author's perspective it would be ideal when all recommendations that are done in this research are adopted by the relevant parties. However, this may not be realistic. Whether or not the recommendations will be followed up by any actions may depend on

- Developments in politics
- Nature of the recommendations
- Concreteness of the recommendations

Politics play a crucial role in the healthcare sector and will for that reason determine future development in the healthcare system for a larger extent. This will also have its impact on the implementation of the recommendations that are done in this research. The elections at the twelfth of September 2012 may change the political landscape significantly. This may lead to a new government which does not want to continue the introduction of more competition on the healthcare market. However, this does not make all recommendations useless as the HPQ-method may serve as a basis for performance monitoring and interventions on the healthcare market. Furthermore, there should be remarked that the nature of the recommendations will probably not

directly result in concrete actions as many of the recommendations have a problematizing nature and will for that reason result in a broad discussion on the effects of performance based health service procurement and adequate policy measures that help to avoid or reduce the negative consequences of competition on the healthcare market. Next to that, concrete recommendations are done in this research which cannot be executed immediately but ask for a preliminary discussion on the above mentioned topics.

In general two important remarks can be made on the current situation in the healthcare sector. First, the current healthcare system may not be ready for the introduction of fair competition as long as the consequences of fair competition and the role of the health insurance companies is not clear. The first step is for that reason not the implementation of the in this research proposed method but a discussion on the problematic findings that are presented in this research. Second, the introduction of competition may be a slow process as it requires profound understanding of the consequences of actions that are taken towards the introduction of fair competition. This is especially true for the healthcare system as this system provide crucial services for people. In addition, this research states that more research is required in the consequences of performance based healthcare procurement on the performance of the healthcare system, the likelihood of these consequences and their impact and on adequate policy measures that help to reduce or avoid these consequences.

Bibliography

Ablij, H. (2012). Projectgroep de medisch specialist 2015. http://www.orde.nl/over-oms/wat-wil-de-oms/de-medisch-specialist-2015/projectgroep-de-medisch-specialist-2015.html.

Agrell, P. and Bogetoft, P. (2001). DEA-Based regulation of healthcare systems. In *Seventh European Workshop on Efficiency and Productive Analysis*, pages 1–25, Oviedo (Spain).

Anderson, G. M., Halcoussis, D., Johnston, L., and Lowenberg, A. D. (2001). Regulatory barriers to entry in the healthcare industry: the case of alternative medicine. *The Quarterly Review of Economics and Finance*, 40(4):485–502.

Angeletos, G. M. and Pavan, A. (2004). Transparency of information and coordination in economies with investment complementarities. Technical report, National Bureau of Economic Research, Cambridge.

Annema, E., de Blok, J., Engelenburg, H., van Erp, L., van Geest, Y., Kakebeeke, P., Olsthoorn, S., Rutgers, M., Schellekens, W., Vegter, S., and Verhoek, M. (2012). Zorg kan beter en goedkoper. *FD Outlook*, (02):1–51.

Ashton, T., Cumming, J., McLean, J., McKinlay, M., and Fae, E. (2004). Contracting for health services: Lessons from new zealand. Technical Report W74, World Health Organization, Geneva.

Bergfors, M. and Larsson, A. (2009). Product and process innovation in process industry: a new perspective on development. *Journal of Strategy and Management*, 2(3):261–276.

Bergmankliniek (2012). Behandelmethoden spataderen. http://www.bergmankliniek.nl/uiterlijk-en-huid/behandelingen/spatader-behandelingen/behandelmethoden/276_3.

Bijlsma, M., Boone, J., and Zwart, G. (2010). Selective contracting and foreclosure in health care markets. Discussion paper 140, CPB, Den Haag.

Boselie, P., Volberda, H., Heij, K., and De Vries, C. (2012). Trots in plaats van een bonus. *FD Outlook*, (03):28–33.

Breyer, F. and Felder, S. (2006). Life expectancy and health care expenditures: A new calculation for germany using the costs of dying. *Health Policy*, 75(2):178–186.

Britnell, M. (2011). Innovative approaches to high performing hospitals. Healthcare report, KPMG.

Burström, B. (2009). Market-oriented, demand-driven health care reforms and equity in health and health care utilization in sweden. *International Journal of Health Services*, 39(2):271–285.

CBS (2010). clinical hospitalization. http://www.cbs.nl/nl-NL/menu/themas/gezondheid-welzijn/cijfers/extra/2010-ziekenhuisopname.htm.

Coffey, R., Richards, J., Remmert, C., LeRoy, S., Schoville, R., and Baldwin, P. (2005). An introduction to critical paths. *Quality Management in Healthcare*, 14(1):46–55.

Conner-Spady, B. and Suarez-Almazor, M. E. (2003). Variation in the estimation of quality-adjusted life-years by different preference-based instruments. *Medical care*, 41(7):791–801.

Cooper, W., Seiford, L., and Zhu, J. (2011). Data envelopment analysis: History, models, and interpretations. In *Handboek on Data Envelopment Analysis*, page 592. Springer-Verlag Gmbh, New York, 2 edition.

Corkin, D., Clarke, S., and Liggett, L. (2012). *Care Planning in Children and Young People's Nursing*. John Wiley & Sons, Hoboken.

CPB (2010). CPB: geen betere zorg door concurrentie :: archief nrc.nl. http://vorige.nrc.nl/binnenland/article2617462.ece/CPB_geen_betere_zorg_door_concurrentie.

Dalen, H. P. and Swank, O. H. (1996). Government spending cycles: Ideological or opportunistic? *Public Choice*, 89(1):183–200.

Damman, O., Hendriks, M., and Sixma, H. (2009). Towards more patient centred healthcare: A new consumer quality index instrument to assess patients' experiences with breast care. *European Journal of Cancer*, 45(9):1569–1577.

de Boer, J., Vandecasteele, J., and Rau, K. (2001). Use of the balanced scorecard for ICT performance management. *Compact*, 2001(1):6–19.

de Boer, R., Bruggeman, L., Dekker, J., Bontje, M., and Schippers, E. (2011). Bestuurlijk hoofdlijnenakkoord 2012-2015 tussen de nederlandse vereniging van ziekenhuizen, de nederlandse federatie van universitair medische centra, zelfstandige klinieken nederland, zorgverzekeraars nederland en het ministerie van volksgezondheid, welzijn en sport.

de Haan, R., Aaronson, N., Limburg, M., Hewer, R. L., and Van Crevel, H. (1993). Measuring quality of life in stroke. *Stroke*, 24(2):320–327.

Defeuilley, C. (2009). Retail competition in electricity markets. *Energy Policy*, 37(2):377–386.

del-Río-Ortega, A., Resinas, M., and Ruiz-Cortés, A. (2009). Towards modelling and tracing key performance indicators in business processes. *Actas de los Talleres de las Jornadas de Ingeniería del Software y Bases de Datos*, 3(3):57–67.

Doran, T., Fullwood, C., Gravelle, H., Reeves, D., Kontopantelis, E., Hiroeh, U., and Roland, M. (2006). Pay-for-performance programs in family practices in the united kingdom. *New England Journal of Medicine*, 355(4):375–384.

DOT (2009). Prestaties belonen in ziekenhuizen - onderwerp - rijksoverheid.nl. http://www.rijksoverheid.nl/onderwerpen/prestaties-belonen-in-ziekenhuizen.

EconomicsHelp (2012). Technical efficiency. http://www.economicshelp.org/dictionary/t/technical-efficiency.html.

Enthoven, A. C. (1993). The history and principles of managed competition. *Health affairs*, 12(1):24–48.

Enthoven, A. C. and van de Ven, W. P. (2007). Going dutch — managed-competition health insurance in the netherlands. *New England Journal of Medicine*, 357(24):2421–2423.

Eppler, M. J. (2006). *Managing information quality: increasing the value of information in knowledge-intensive products and processes*. Springer-Verlag New York Inc, New York.

Golany, B. and Roll, Y. (1989). An application procedure for DEA. *Omega*, 17(3):237–250.

Gordon, J. B. (2010). Is healthcare a public good? http://www.kevinmd.com/blog/2009/08/is-health-care-a-public-good.html.

Griebsch, I., Coast, J., and Brown, J. (2005). Quality-adjusted life-years lack quality in pediatric care: a critical review of published cost-utility studies in child health. *Pediatrics*, 115(5):600–614.

Grossbart, S. (2006). What's the return? assessing the effect of "pay-for-performance" initiatives on the quality of care delivery. *Medical Care Research and Review*, 63(1):29–48.

Harper, S., Lynch, J., Burris, S., and Smith, G. D. (2007). Trends in the black-white life expectancy gap in the united states, 1983-2003. *the journal of the American Medical Association*, 297(11):1224–1232.

Hollingsworth, B., Dawson, P., and Maniadakis, N. (1999). Efficiency measurement of health care: a review of non-parametric methods and applications. *Health Care Management Science*, 2(3):161–172.

Howie, J. G. R., Heaney, D., and Maxwell, M. (2004). Quality, core values and the general practice consultation: issues of definition, measurement and delivery. *Family Practice*, 21(4):458–468.

Ikkersheim, D., van Schooten, G., van der Meyden, W., Vlieger, E., Bussink, M., van Heems, M., Kampschreur, M., and Wits, B. (2010). Kosten en kwaliteit. Medical report, Plexus and BKB.

Jacobs, L., Lenssen, M., Ikkersheim, D., Berg, M., van Heems, M., and Bakker, M. (2011). De patient centraal? Medical report, Plexus and BKB.

Kahn, B. K., Strong, D. M., and Wang, R. Y. (2002). Information quality benchmarks: product and service performance. *Communications of the ACM*, 45(4):184–192.

Kenagy, J. W., Berwick, D. M., and Shore, M. F. (1999). Service quality in health care. *JAMA: the journal of the American Medical Association*, 281(7):661–665.

Kitchiner, D., Davidson, C., and Bundred, P. (1996). Integrated care pathways: effective tools for continuous evaluation of clinical practice. *Journal of Evaluation in Clinical Practice*, 2(1):65–69.

Koopman, L. and Rademakers, J. (2008). CQ-index mammacare: onderzoek naar het discriminerend vermogen. Medical report, Nivel, Utrecht.

Kooreman, P. (2011). Hoe komen we van sovjet-planning in de zorg af? http://www.mejudice.nl/artikel/744/hoe-komen-we-van-sovjet-planning-in-de-zorg-af.

KPMG (2012). Healthcare leadership message. https://portal.ema.kworld.kpmg.com/markets/LoBs/IGH/Healthcare/Pages/

Lako, C. and Rosenau, P. (2009). Demand-driven care and hospital choice. dutch health policy toward demand-driven care: results from a survey into hospital choice. *Health Care Analysis*, 17(1):20–35.

Lee, Y. W., Strong, D. M., Kahn, B. K., and Wang, R. Y. (2002). AIMQ: a methodology for information quality assessment. *Information & Management*, 40(2):133–146.

Lindenauer, P., Remus, D., Roman, S., Rothberg, M., Benjamin, E., Ma, A., and Bratzler, D. (2007). Public reporting and pay for performance in hospital quality improvement. *New England Journal of Medicine*, 356(5):486–496.

Long, S. and Masi, P. (2009). Access and affordability: an update on health reform in massachusetts, fall 2008. *Health Affairs*, 28(4):578–587.

Mant, J. (2001). Process versus outcome indicators in the assessment of quality of health care. *International Journal for Quality in Health Care*, 13(6):475–480.

NVZ (2009). Vizier op vertrouwen: Brancherapport algemene ziekenhuizen 2009. Branche report, NVZ vereniging van ziekenhuizen, Utrecht.

NVZ (2011). Zorg op doorreis: Brancherapport algemene ziekenhuizen 2011. Branche report, NVZ vereniging van ziekenhuizen, Utrecht.

OECD (2009). Health expenditure and financing. http://stats.oecd.org/Index.aspx?DataSetCode=SHA.

Omachonu, V. and Einspruch, N. (2010). Innovation in healthcare delivery systems: A conceptual framework. *The Innovation Journal: The Public Sector Innovation Journal*, 15(1):1–20.

Ozcan, Y. A. (2007). *Health care benchmarking and performance evaluation: an assessment using data envelopment analysis (DEA)*, volume 120. Springer Verlag.

Pauly, M., McGuire, T., and Barros, P. (2012). *Handbook of Health Economics*, volume 2. North-Holland, Oxford.

Pereira, A. (2004). Live and let live: Healthcare is a fundamental human right. *Connecticut Public Interest Law Journal*, 3(17):480–503.

Philips, C. and Thompson, G. (2009). What is a QALY? Medical report NPR09/1265, Hayward Medical Communications, Newmarket.

Porter, M. and Teisberg, E. (2006). *Redefining health care: creating value-based competition on results*. Harvard Business Press, Boston.

Powell, W. (1990). Neither market nor hierarchy. *The sociology of organizations: classic, contemporary, and critical readings*, 12:295–336.

Purcell, G. P., Wilson, P., and Delamothe, T. (2002). The quality of health information on the internet. *British Medical Journal*, 324(7337):557–558.

Ralston, J. D., Larson, E. B., et al. (2005). Crossing to safety: transforming healthcare organizations for patient safety. *Journal of postgraduate medicine*, 51(1):61–67.

Ramanathan, R. and Ramanathan, U. (2009). A qualitative perspective to deriving weights from pairwise comparison matrices. *Omega*, 38(2010):228–232.

RIVM (2012a). Waiting lists hospitals - nationale atlas volksgezondheid. http://www.zorgatlas.nl/thema-s/wachtlijsten/wachtlijsten-ziekenhuiszorg/.

RIVM (2012b). Waiting lists treatement - nationale atlas volksgezondheid. http://www.zorgatlas.nl/thema-s/wachtlijsten/wachtlijsten-ziekenhuiszorg/wachttijden-behandeling/.

Robinson, J. (1934). What is perfect competition? *The Quarterly Journal of Economics*, 49(1):104–120.

Rosenthal, M. and Dudley, R. (2007). Pay-for-performance. *the journal of the American Medical Association*, 297(7):740–744.

Scott, I. (2007). Pay for performance in health care: strategic issues for australian experiments. *Medical journal of Australia*, 187(1):31–35.

Seiford, L. M. and Zhu, J. (2002). Modeling undesirable factors in efficiency evaluation. *European Journal of Operational Research*, 142(1):16–20.

Seinen, J., Ikkersheim, D., Heineman, E., and Hoekstra, H. (2012). Sarcoomzorg UMCG overstijgt de afdeling. *Medisch Contact*, 67(9):547–549.

Shahin, A. and Mahbod, M. (2007). Prioritization of key performance indicators: An integration of analytical hierarchy process and goal setting. *International Journal of Productivity and Performance Management*, 56(3):226–240.

Smith, K., Humphreys, J., Lenard, Y., Jones, J., Prince, V., and Han, G. (2004). Still the doctor-by a country mile! preferences for health services in two country towns in north-west new south wales. *Medical journal of Australia*, 181(2):91–95.

Steven Goldberg, M. D. (2008). Simplify healthcare's contract and credentialing process. http://managedhealthcareexecutive.modernmedicine.com/mhe/Managed+Care+Outlook/Simplify-Healthcares-Contract-and-Credentialing-Pr/ArticleStandard/Article/detail/482220.

Stevens, S. (2011). Is there evidence that competition in healthcare is a good thing? yes. *BMJ*, 343:1–3.

Stout, R. W. and Crawford, V. (1988). Active-life expectancy and terminal dependency: trends in long-term geriatric care over 33 years. *The Lancet*, 331(8580):281–283.

Strauss, D. J., DeVivo, M. J., Paculdo, D. R., and Shavelle, R. M. (2006). Trends in life expectancy after spinal cord injury. *Archives of physical medicine and rehabilitation*, 87(8):1079–1085.

Sung, L., Feldman, B., Schwamborn, G., Paczesny, D., Cochrane, A., Greenberg, M., Maloney, A., Hendershot, E., Naqvi, A., and Barrera, M. (2004). Inpatient versus outpatient management of low-risk pediatric febrile neutropenia: measuring parents' and healthcare professionals' preferences. *Journal of clinical oncology*, 22(19):3922–3929.

Thompson, L. L. (1991). Information exchange in negotiation. *Journal of Experimental Social Psychology*, 27(2):161–179.

Vaartjes, J. (2012). Wat kost een behandeling? http://www.tandarts.nl/tarieven-verzekering/rekeningen/wat_kost_een_behandeling.

Van Beveren, I. and Vandenbussche, H. (2010). Product and process innovation and firms' decision to export. *Journal of Economic Policy Reform*, 13(1):3–24.

Van der Burgt, M., Van Mechelen, E., and Te Lintel Hekkert, M. (2006). De gezondheidszorg in een notendop. In *Introductie in de gezondheidszorg*, pages 13–19. Bohn Stafleu van Loghum (Springer), Houten, 7 edition.

Vining, A. R. and Boardman, A. E. (1992). Ownership versus competition: Efficiency in public enterprise. *Public choice*, 73(2):205–239.

Vives, X. (2002). Private information, strategic behavior, and efficiency in cournot markets. *RAND Journal of Economics*, 33(3):361–376.

Walker, W. E. (2000). Policy analysis: a systematic approach to supporting policymaking in the public sector. *Journal of multi-criteria decision analysis*, 9(1-3):11–27.

Woolhandler, S. and Himmelstein, D. U. (2007). Competition in a publicly funded healthcare system. *BMJ*, 335(7630):1126–1129.

Zavras, A. I., Tsakos, G., Economou, C., and Kyriopoulos, J. (2002). Using DEA to evaluate efficiency and formulate policy within a greek national primary health care network. *Journal of medical systems*, 26(4):285–292.

Zhu, J. (1996). Data envelopment analysis with preference structure. *Journal of the Operational Research Society*, 47(1):136–150.

Part IV

Appendices

Appendix A

Actors' Preferences

The table in this appendix summarizes the interests, objectives, gaps between the current and the desired situation, and causes for these gaps for the four key actors in healthcare as mentioned in section 1.1.2. These topics are described for the problem situation as described in section 3.1. The classification of interests, objectives, gaps and causes as presented in table A.1 is used to identify the goals of the key actors in the healthcare sector and their attitude towards the problem situation and possible solutions.

Table A.1 – Key actors' preferences and objectives

Actor	**Interests**	**Objectives**	**Gap with current situation**	**Causes**
Patient	The provision of high quality healthcare that is affordable, accessible and available for everyone.	Insight in the current quality and accessibility of healthcare for specific diseases and the possibility to receive healthcare at the best provider.	Currently there is no clear insight in the performance of healthcare providers. Patient therefore do not have a choice where to be treated for a specific disease.	Healthcare providers and health insurance companies do not provide the necessary information to the patient. Patients need that information in order to be able to make a choice.

Actor	Interests	Objectives	Gap with current situation	Causes
Dutch national government	A healthcare system that delivers high quality care for the lowest costs and by efficiently using scarce medical resources.	The situation in which health insurance companies are responsible for the procurement of healthcare on the basis of the actual performance of care pathways.	Currently health insurance companies do not have the insight in the performance of integrated care pathways.	Healthcare providers are not clear about their actual performance. There is no clear definition of KPIs that need to be assessed for determining healthcare performance.
Healthcare providers	The provision of care that meet the quality standards as defined by regulators, and satisfying the patient in their needs.	Having insight in their own relative performance in the healthcare sector in order to be able to improve their current processes.	Currently there is no objective method for comparing the performance of healthcare providers at a detailed level.	Until know, there was too little data available on a detailed level. In addition, Healthcare providers are not willing to be open about these confidential performance figures.
Health insurance companies	Getting as many people insured by delivering the best quality care for the lowest price.	Insight in the actual performance of healthcare providers so that health insurance companies can procure healthcare that meets the highest standards for the lowest price.	Currently, there is no insight in the actual performance of healthcare providers on the care pathway level.	There is too little data available. There is no objective method for examining the performance of integrated care pathways.

Appendix B

Statistical comparison of performance of healthcare providers

This appendix comprises the outputs of a statistical independent samples test for the comparison of the mean output values for different healthcare providers. Table B.1 shows the mean values and table B.2 show the outputs of the independent samples tests. The relevant significance levels are marked gray in table B.2. These significance levels show that there is a significant difference between the mean performance of hospitals and the mean performance of independent treatment centra for this particular disease.

Table B.1 – Group statistics

	healthcare provider	**N**	**Mean**	**Std. Deviation**	**S.E. Mean**
cost of treatment	hospitals	12	142.85	50.52	14.58
	independent treatment centra	23	118.11	17.87	3.73
length of treatment	hospitals	12	7.09	6.95	2.01
	independent treatment centra	23	1.77	1.55	0.32

Table B.2 – Independent Samples Test

		Levene's Test for Equality of Variances		t-test for the equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	S.E. difference	95% confidence interval of the difference	
									lower	upper
cost of treatment	Equal variances	16.71	0.00	-2.13	33.00	.04	-24.74	15.05	-55.37	5.88
	No equal variances			-1.64	12.46	.13	-24.74	15.05	-57.41	7.92
length of treatment	Equal variances	39.27	0.00	-3.55	33.00	.00	-5.32	2.03	-9.46	-1.19
	No equal variances			-2.62	11.57	.02	-5.32	2.03	-9.77	-.88

Appendix C

DEA quantification

This appendix comprises the data tables with the inputs and the outputs that are used for the DEA analysis. All data in the data tables is synthetic data generated with the help of a simple random generator. The analysis can be replicated with the help of this data.

The random numbers for each input and output are generated with simple algorithms in Microsoft Excel and are not related in any way to real data. The following algorithms are used in Microsoft Excel to calculate the random input values[1]

$Input1 = RANDBETWEEN(88; 985)$
$Input2 = RAND() * 14 + 2$
$Input3 = RAND() * 100 + 100$
$Input4 = RAND() * 3 + 2$

The following algorithms are used to calculate the random output values in Microsoft Excel

$Output1 = \frac{RAND()}{5}$
$Output2 = RAND() * 15 + 2$
$Output3 = RAND() * 30 + 5$
$Output4 = RAND() * 43 + 7$

Below are the data tables that comprise the inputs and outputs that are used in the DEA analysis.

[1]The words in capital letters are mathematical functions in Microsoft Excel

Table C.1 – Input and output data of the DEA analysis

DMU	Input1 Cost price of treatment [€/ treatment]	Input2 Employee occupation [day/ treatment]	Input3 Capacity utilization [day/ treatment]	Input4 Treatment duration [day/ treatment]	Output1 Length of waiting lists [week]	Output2 CQ-score [..]	Output3 QALY [QALY/ treatment]	Output4 Complication risk [%]
X1-1	663,00	9,97	146,96	4,73	0,08	2,66	34,29	13,33
X1-2	372,00	4,53	135,99	2,46	0,16	15,14	26,53	8,84
X1-3	397,00	11,33	181,23	2,73	0,15	10,19	27,33	34,74
X1-4	979,00	15,65	148,00	4,30	0,11	15,79	23,51	48,49
X1-5	957,00	9,55	105,95	3,78	0,08	12,73	23,96	32,87
X1-6	172,00	6,61	103,07	4,38	0,15	16,82	32,23	8,26
X1-7	382,00	10,01	114,07	3,80	0,10	16,69	16,74	38,43
X1-8	469,00	2,39	163,33	4,38	0,18	6,24	23,71	30,28
X1-9	922,00	8,87	161,67	3,15	0,13	15,76	22,70	49,59
X1-10	803,00	2,31	125,59	2,12	0,08	3,96	9,30	39,93
X1-11	757,00	12,23	155,86	2,35	0,05	2,74	28,45	41,54
X1-12	270,00	3,68	113,20	4,43	0,08	5,34	16,11	37,36
X1-13	787,00	10,32	183,70	3,46	0,14	3,79	17,92	24,29
X1-14	651,00	14,67	146,65	2,20	0,18	6,46	25,51	47,08
X1-15	512,00	15,01	199,58	4,91	0,15	10,27	13,91	37,82
X1-16	217,00	10,54	103,62	4,54	0,08	14,24	26,33	19,71
X1-17	501,00	13,82	198,16	2,89	0,07	16,98	23,01	49,79
X1-18	267,00	4,05	149,83	2,70	0,06	5,75	20,77	42,97
X1-19	409,00	9,70	114,37	4,38	0,17	11,26	34,87	22,86
X1-20	877,00	10,50	147,76	2,87	0,07	15,48	22,39	16,76
X1-21	517,00	5,68	179,91	2,88	0,07	3,69	18,25	24,76
X1-22	755,00	11,95	112,61	3,11	0,13	14,00	13,22	34,53
X1-23	817,00	5,16	198,19	3,43	0,03	13,13	29,56	19,64
X1-24	355,00	4,94	100,89	4,04	0,11	5,09	19,86	11,88
X1-25	423,00	7,22	113,17	4,45	0,10	2,40	19,77	38,34
X1-26	373,00	3,39	126,82	4,78	0,04	11,05	19,65	27,73
X1-27	771,00	11,67	141,78	3,33	0,02	3,77	23,14	8,13
X1-28	890,00	13,41	132,22	2,39	0,06	15,26	6,98	17,91
X1-29	738,00	7,53	163,54	3,07	0,10	6,87	27,33	13,04
X1-30	719,00	4,91	190,88	3,47	0,08	7,28	15,16	28,81
X1-31	912,00	14,16	180,62	3,60	0,05	13,76	7,56	22,72
X1-32	895,00	9,11	175,37	4,80	0,18	2,76	16,55	7,95
X1-33	794,00	15,07	170,50	3,51	0,11	3,88	16,76	30,56
X1-34	852,00	15,21	198,18	2,41	0,06	16,08	5,74	14,51
X1-35	831,00	15,89	142,99	3,06	0,14	16,53	7,43	31,19
X1-36	707,00	2,32	188,31	4,51	0,11	7,24	24,78	23,57
X1-37	554,00	6,40	165,80	2,50	0,15	14,88	6,50	34,75
X1-38	438,00	2,27	161,94	2,04	0,01	4,63	32,29	35,10
X1-39	543,00	7,44	148,26	4,48	0,17	14,95	26,49	31,41
X1-40	969,00	7,06	104,66	2,28	0,16	9,93	30,39	46,02

DMU	Input1 Cost price of treatment [€/ treatment]	Input2 Employee occupation [day/ treatment]	Input3 Capacity utilization [day/ treatment]	Input4 Treatment duration [day/ treatment]	Output1 Length of waiting lists [week]	Output2 CQ-score [..]	Output3 QALY [QALY/ treatment]	Output4 Complication risk [%]
X1-41	964,00	8,22	140,67	2,84	0,18	2,06	29,69	25,64
X1-42	136,00	3,63	128,69	4,33	0,10	2,83	24,03	8,02
X1-43	324,00	4,96	114,56	4,21	0,02	7,65	16,38	31,27
X1-44	575,00	7,67	174,27	3,05	0,02	3,21	19,04	20,19
X1-45	602,00	4,31	197,01	4,95	0,08	3,80	23,39	40,85
X1-46	468,00	10,67	155,04	4,07	0,14	13,93	5,89	19,64
X1-47	198,00	4,48	113,54	2,21	0,00	12,58	12,91	12,41
X1-48	229,00	5,53	110,76	3,43	0,18	13,81	26,87	32,52
X1-49	485,00	9,16	199,37	2,93	0,04	15,14	15,67	13,82
X1-50	942,00	5,62	109,28	3,03	0,16	7,49	22,22	10,60
X1-51	682,00	6,55	141,26	4,23	0,09	11,05	31,35	49,69
X1-52	306,00	6,54	117,61	4,22	0,08	8,88	23,51	26,12
X1-53	289,00	10,84	153,01	4,19	0,20	14,02	28,80	18,04
X1-54	189,00	8,02	138,45	2,98	0,05	7,25	9,21	15,46
X1-55	600,00	6,47	140,47	4,48	0,18	9,43	34,31	10,54
X1-56	401,00	13,85	138,16	3,56	0,06	12,90	9,78	10,80
X1-57	784,00	12,90	182,19	2,37	0,01	6,25	31,07	42,10
X1-58	590,00	3,56	147,47	4,57	0,18	6,62	6,37	30,78
X1-59	297,00	6,18	106,37	4,87	0,07	10,25	20,16	37,49
X1-60	687,00	6,04	131,83	3,20	0,15	5,68	27,10	21,67
X1-61	538,00	9,26	163,31	3,48	0,12	14,37	28,94	49,76
X1-62	949,00	7,91	142,46	4,14	0,15	14,62	11,74	12,50
X1-63	586,00	4,02	199,69	3,52	0,03	12,83	7,69	17,58
X1-64	704,00	7,42	100,94	3,54	0,15	7,02	29,10	39,11
X1-65	118,00	4,07	179,68	4,89	0,05	14,77	26,08	14,79
X1-66	130,00	5,50	122,09	4,75	0,14	13,53	14,05	38,87
X1-67	322,00	10,99	122,91	2,71	0,11	16,87	11,41	16,39
X1-68	905,00	7,90	174,63	2,36	0,09	5,77	7,09	45,06
X1-69	802,00	14,90	128,40	3,19	0,04	9,22	14,94	35,29
X1-70	260,00	3,09	197,77	3,47	0,10	11,84	6,51	28,82
X1-71	226,00	13,21	139,10	3,31	0,12	11,14	33,43	38,37
X1-72	870,00	13,35	103,73	4,85	0,12	10,17	18,84	41,86
X1-73	851,00	8,46	166,55	4,51	0,01	6,77	31,98	17,83
X1-74	455,00	11,49	177,73	3,68	0,06	11,28	21,70	22,63
X1-75	725,00	14,61	155,25	4,41	0,02	12,71	17,71	39,48
X1-76	242,00	15,10	119,16	4,58	0,14	3,96	25,20	22,04
X1-77	939,00	2,99	125,10	3,08	0,05	4,88	10,98	32,87
X1-78	796,00	4,21	109,90	2,95	0,14	12,79	17,43	13,19
X1-79	736,00	9,02	117,20	3,76	0,02	11,45	19,84	35,65
X1-80	753,00	9,10	122,22	4,86	0,06	15,76	23,22	7,20

DMU	Input1 Cost price of treatment [€/ treatment]	Input2 Employee occupation [day/ treatment]	Input3 Capacity utilization [day/ treatment]	Input4 Treatment duration [day/ treatment]	Output1 Length of waiting lists [week]	Output2 CQ-score [..]	Output3 QALY [QALY/ treatment]	Output4 Complication risk [%]
X1-81	930,00	6,05	104,34	2,34	0,11	15,50	18,87	34,86
X1-82	536,00	14,80	193,62	4,26	0,04	4,05	16,22	12,79
X1-83	415,00	2,71	108,26	3,31	0,19	15,62	30,45	49,70
X1-84	947,00	13,50	126,52	4,37	0,13	15,97	8,07	19,73
X1-85	762,00	10,67	112,92	4,13	0,19	3,04	7,95	9,59
X1-86	678,00	6,27	121,75	3,29	0,04	15,18	20,94	49,76
X1-87	855,00	10,87	104,17	3,56	0,15	7,52	16,83	13,70
X1-88	911,00	8,11	179,45	3,43	0,08	14,28	10,53	32,48
X1-89	303,00	2,11	176,42	4,16	0,01	3,35	30,55	9,20
X1-90	258,00	12,88	198,45	4,28	0,13	5,80	31,38	45,53
X1-91	967,00	12,01	177,35	4,54	0,01	9,59	11,94	28,43
X1-92	108,00	3,23	180,94	2,72	0,07	16,15	21,03	30,49
X1-93	156,00	10,75	109,31	3,57	0,03	14,77	15,43	42,16
X1-94	952,00	14,57	155,79	2,54	0,16	14,84	26,82	34,10
X1-95	270,00	10,27	178,41	2,36	0,04	14,47	7,71	26,31
X1-96	852,00	8,32	175,14	2,91	0,17	3,10	10,17	46,78
X1-97	625,00	12,13	190,75	3,34	0,15	6,63	21,11	18,35
X1-98	782,00	13,62	176,09	4,56	0,10	15,21	30,76	18,03
X1-99	873,00	6,60	110,05	3,75	0,18	15,73	18,98	32,16
X1-100	262,00	9,65	150,57	2,42	0,05	13,73	20,39	37,73

Appendix D

DEA Analysis

dropThis appendix comprises all supplements that are used in the DEA analysis. Section D.1 gives an extensive description of the mathematical models that are used for the calculation of the results. Section D.2 presents the DEA model that is developed in Microsoft Excel with the help of vba-code. This model is developed for the purpose of the research but can be customized for each situation.

D.1 Calculations in DEA

The basis of DEA is formed by the mathematical calculations. The calculations that need to be executed in order to generate the outcomes of the analyses are extensively discussed in this section.

Efficiencies The calculation of the efficiency can be seen as a linear optimization problem which can be solved with the help of Microsoft Excel and the solver add-in. The mathematical formulation of the linear optimization problem for the one stage process[1] is presented below with the DMUs DMU_j $(j = 1, 2, ..., n)$, the inputs x_{ij} $(i = 1, 2, ..., m)$, the outputs y_{rj} $(r = 1, 2, ..., s)$ and the lambda's λ_j.

$$
\begin{aligned}
& obj. && \\
& \theta = minimize(\theta) && \\
& s.t. && \\
& \sum_{j=1}^{n} (\lambda_j * x_{ij}) \leq \theta * x_{i0} && i = 1, 2, ..., m \\
& \sum_{j=1}^{n} (\lambda_j * y_{rj}) \geq y_{r0} && r = 1, 2, ..., s \\
& \sum_{j=1}^{n} (\lambda_j) = 1 && \\
& \lambda_j \geq 0 && j = 1, 2, ..., n
\end{aligned}
\tag{D.1.1}
$$

Some transformations are required when undesirable measures are included in the analysis. The DEA analysis assumes that a DMU is efficient when the outputs are maximized and the inputs are minimized. However, it may occur that in an ideal situation some outputs should be minimized or some inputs should be maximized. These inputs/outputs are called undesirable or bad inputs/outputs or measures in literature (Seiford and Zhu, 2002). Let x_{ij}^g and x_{ij}^b be good and bad inputs and y_{rj}^g and y_{rj}^b be good and bad outputs. There are different ways to change the analyses in order to be able to handle undesirable measures. In literature is proposed to change the undesired inputs and outputs by multiplying the values by " -1" and find a value v_i $(i = 1, 2, ..., n)$ and v_r $(r = 1, 2, ..., s)$ to make the input and output values positive so that

[1] This is the mathematical formulation of the input oriented variable returns to scale (VRS) model where the outputs are kept constant and the inputs are reduced in order to improve performance

$$\overline{x}_{ij}^{b} = -x_{ij}^{b} + v_i > 0 \tag{D.1.2}$$

and

$$\overline{y}_{rj}^{b} = -y_{rj}^{b} + v_r > 0 \tag{D.1.3}$$

Literature proposes to calculate v_i by

$$\max_{j}\{x_{ij}^{b}\} + y \tag{D.1.4}$$

and v_r by

$$\max_{j}\{y_{rj}^{b}\} + z \tag{D.1.5}$$

However, this may lead to disturbance of the efficiency value. The efficiency value is a relative measure and may change by a different value for "y" and "z" while the actual distance to the efficient frontier stays constant.

Therefore is proposed in this research to simply convert all good input and output values by using the following transformation

$$\hat{x}_{ij}^{g} = \frac{x_{ij}}{\max_{j}\{x_{ij}\}} \tag{D.1.6}$$

and

$$\hat{y}_{rj}^{g} = \frac{y_{rj}}{\max_{j}\{y_{rj}\}} \tag{D.1.7}$$

This results in a value between "0" and "1" for the good inputs with 1 $for(x_{ij}) = \max_{j}\{x_{ij}\}$ and 0 $for(x_{ij}) = 0$ and for the good outputs 1 $for(y_{rj}) = \max_{j}\{y_{rj}\}$ and 0 $for(y_{rj}) = 0$. An additional transformation is required for the bad inputs and outputs namely

$$\hat{x}_{ij}^{b} = 1 - \hat{x}_{ij}^{g} \tag{D.1.8}$$

and

$$\hat{y}_{rj}^{b} = 1 - \hat{y}_{rj}^{g} \tag{D.1.9}$$

This results in a value between "0" and "1" for the bad inputs with 1 $for(x_{ij}) = 0$ and 0 $for(x_{ij}) = \max_{j}\{x_{ij}\}$ and for the bad outputs 1 $for(y_{rj}) = 0$ and 0 $for(y_{rj}) = \max_{j}\{y_{rj}\}$.

An alternative way to transform the undesirable measures is

$$\overline{x}_{ij}^{b} = \frac{1}{x_{ij}^{b}} \tag{D.1.10}$$

and

$$\overline{y}^b_{rj} = \frac{1}{y^b_{rj}} \tag{D.1.11}$$

These formulas convert the large values to small values and vice versa. It is important to notice that each transformation gives different outcome figures.

One should remark that additional transformations are necessary to get the real target values. The improvement potential does not require additional transformations as long as these figures are expressed in percentages.

The calculation of the efficiency scores are different in case of the preference structure non radial models that are used for the calculation of efficiency scores per input and output. The mathematical formulation is presented below with the input parameter efficiencyθ_i $(i = 1, 2, ..., m)$ and the DMU efficiency θ_j $(i = 1, 2, ..., n)$.

$$\begin{aligned}
& & & obj. \\
\theta_j = minimize(\frac{\sum_{i=1}^{m}(A_i * \theta_i)}{\sum_{i=1}^{m}(A_i)} - \varepsilon * \sum_{r=1}^{s} s_r^+) & & & i = 1, 2, ..., m - and - r = 1, 2, ..., s \\
& & & s.t. \\
& \sum_{j=1}^{n}(\lambda_j * x_{ij}) = \theta * x_{i0} & & \\
& \sum_{j=1}^{n}(\lambda_j * y_{rj}) - s_r^+ = y_{r0} & & \\
& \sum_{j=1}^{n}(\lambda_j) = 1 & & \\
& \theta_i \leq 1 & & \\
& \lambda_j \geq 0 & & j = 1, 2, ..., n
\end{aligned} \tag{D.1.12}$$

Slacks Some additional steps are needed in case of input and output slacks. Input and output slacks can be calculated with the linear optimization problem formulation in a two stage process with the input slacks $s_i^-(i = 1, 2, ..., n)$ and output slacks $s_r^+(r = 1, 2, ..., s)$.

$$\begin{aligned}
& & & obj. \\
maximize((\sum_{i=1}^{m}(s_i^-) + \sum_{r=1}^{s}(s_r^+)) & & & \\
& & & s.t. \\
& \sum_{j=1}^{n}(\lambda_j * x_{ij}) + s_i^- \leq \theta * x_{i0} & & i = 1, 2, ..., m \\
& \sum_{j=1}^{n}(\lambda_j * y_{rj}) - s_r^+ \geq y_{r0} & & r = 1, 2, ..., s \\
& \sum_{j=1}^{n}(\lambda_j) = 1 & & \\
& \lambda_j \geq 0 & & j = 1, 2, ..., n
\end{aligned} \tag{D.1.13}$$

This linear optimization problem give the optimal slack values for the efficiency calculated in equation D.1.1.

Target values The DEA analysis can be used to generate more interesting values for the DMUs that are under evaluation. One can calculate the target value for each DMU based on the values of the benchmarks $(\lambda > 0)$ with the help of equation D.1.14 and equation D.1.15 with the target input value x_{ij}^t $(i = 1, 2, ..., m)$ and the target output value y_{rj}^t $(r = 1, 2, ..., s)$.

$$x_{ij}^t = \sum_1^j (\lambda_j * x_{ij}) \qquad j = 1, 2, ..., n \tag{D.1.14}$$

and

$$y_{rj}^t = \sum_1^j (\lambda_j * y_{rj}) \qquad j = 1, 2, ..., n \tag{D.1.15}$$

Improvement potential The improvement potential of the inputs $p_{x_{ij}}$ $(i = 1, 2, ..., m)$ and outputs $p_{y_{rj}}$ $(r = 1, 2, ..., s)$ of a DMU can be determined by calculating the difference between the target input/output values and the initial input/output values.

$$p_{x_{ij}} = ABS(x_{ij} - x_{ij}^t) \tag{D.1.16}$$

and

$$p_{y_{rj}} = ABS(y_{rj} - y_{rj}^t) \tag{D.1.17}$$

D.2 DEA model in Microsoft Excel

This section comprises the model that is developed for the execution of the DEA analysis in this research. Section D.2.1 comprises the description of the lay-out of the Excel model. The vba-code that is used for the automation of the DEA models is presented in section D.2.2.

D.2.1 Model lay-out

This section gives insight in the lay-out of the DEA model in Microsoft Excel. The Microsoft Excel model consists of seven sheets.

- Calculation of efficiencies and lambdas (sheet 1)
- Calculation of target values and improvement potential (sheet 2)
- Calculation of input and output slacks (sheet 3)
- Transformed input data (sheet 4)
- Transformed output data (sheet 5)
- Raw input data (sheet 6)
- Raw output data (sheet 7)

The process input and output values for the DMUs are inserted in the sheets for the raw input and output data (sheet 6 and sheet 7). Sheet 4 and sheet 5 automatically apply the transformations to the data based on whether the inputs/outputs needs to be maximized or minimized. Sheet 1 comprises the core of the model which calculates the efficiency scores and lambdas (benchmarks) with the help of the transformed input/output data. The model on sheet 1 also calculates the target values and improvement potential of each input and output for each DMU with the help of the benchmarks (see equation D.1.14 to equation D.1.17). The target values and the improvement potential are printed on sheet 2. Sheet 3 calculates the slack values based on the efficiency scores that are calculated on sheet 1.

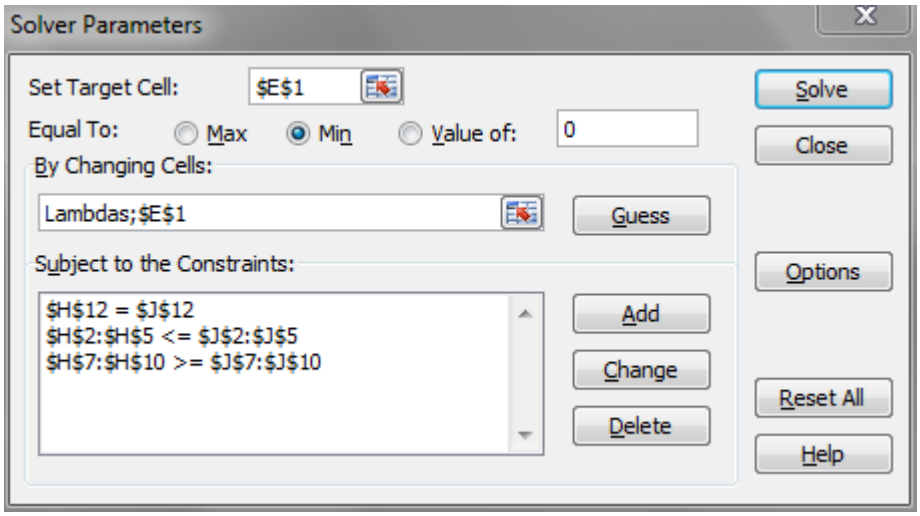
D.2.2 VBA code and solver settings

The excel model runs on vba code that helped automatizing the execution of the DEA analysis. The code is invoked when the buttons on the excel sheets are pressed. This section presents the raw code and gives a short functional description of the code. Only the sheets 1 and 3 comprise buttons that run on vba code. The calculations that are executed in the VBA based model are linear optimization problems. These problems are solved by using the Microsoft Excel Solver add-in. This add-in makes use of optimization algorithms to find the optimal solution for the linear problems. This section also includes the settings for this add-in.

D.2.2.1 VBA code sheet 1

The Microsoft Excel model comprises several buttons that each invokes some code. This section presents the code that is invoked by the buttons on sheet 1 and the settings for the Solver add-in.

Solver settings sheet 1 The following solver settings where used for the calculation of the input-oriented VRS model on sheet 1 of the Microsoft Excel workbook.



The target cell comprises the objective function which is defined in equation D.1.1. This function is minimized by the algorithm. The changing cells are the values that will be changed by the algorithms in order to get the optimal efficiency. The constraint cells comprise the constraints as defined in equation D.1.1.

VBA-code *Input-oriented VRS Model* The code in this section is invoked by the button *Output-oriented VRS* on sheet 1. This first part of code is used for the calculation of the efficiencies and lambdas with the help of the solver add-in

```
'calculate efficiencies & lambdas

Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer, rng1 As Range

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

Dim i As Integer
For i = 1 To NDMUs
Range("E3") = i

SolverOk SetCell:="$E$1", MaxMinVal:=2, ValueOf:="0", ByChange:=Union(Range(Cells(14, NInputs + NOutputs + 4), _
Cells(14 + (NDMUs - 1), NInputs + NOutputs + 4)), Range("E1"))
SolverSolve UserFinish:=True

Range("A13").Offset(i, NInputs + NOutputs + 4) = Range("E1")

Range(Cells(14, NInputs + NOutputs + 4), Cells(14 + (NDMUs - 1), NInputs + NOutputs + 4)).Copy
Range("A13").Offset(i, NInputs + NOutputs + 6).Select
Selection.PasteSpecial Paste:=xlPasteValues, _
    Operation:=xlNone, _
    SkipBlanks:=False, _
    Transpose:=True
Next i
```

The part of code below is used for the calculation of the target values on sheet 2.

```
'calculate and print target values

Sheets("target values").Select
Sheets("target values").Range("B3").Select
Selection.FormulaArray = _
"=SUMPRODUCT(TRANSPOSE(OFFSET(efficiency_lambdas!R[11]C1,0,efficiency_lambdas!R3C2+efficiency_lambdas!R2C2+6,1,efficiency_lambd

Selection.AutoFill Destination:=Sheets("target values").Range(Cells(3, 2), _
Cells(3 + (NDMUs - 1), 2)), Type:=xlFillValues
Sheets("target values").Range(Cells(3, 2), Cells(3 + (NDMUs - 1), 2)).Select
Selection.AutoFill Destination:=Sheets("target values").Range(Cells(3, 2), _
Cells(3 + (NDMUs - 1), 2 + (NInputs - 1))), Type:=xlFillValues

Sheets("target values").Cells(3, NInputs + 3).Select
Selection.FormulaArray = _
"=SUMPRODUCT(TRANSPOSE(OFFSET(efficiency_lambdas!R[11]C1,0,efficiency_lambdas!R3C2+efficiency_lambdas!R2C2+6,1,efficiency_lambd

Selection.AutoFill Destination:=Sheets("target values").Range(Cells(3, NInputs + 3), _
Cells(3 + (NDMUs - 1), NInputs + 3)), Type:=xlFillValues
Sheets("target values").Range(Cells(3, NInputs + 3), Cells(3 + (NDMUs - 1), NInputs + 3)).Select
Selection.AutoFill Destination:=Sheets("target values").Range(Cells(3, NInputs + 3), _
Cells(3 + (NDMUs - 1), (NInputs + NOutputs - 1) + 3)), Type:=xlFillValues
```

The part of code below is used for the calculation of the improvement potential on sheet 2.

```
'calculate & print improvement potential

Sheets("target values").Cells(3, 2 * NInputs + 2 * NOutputs + 8).Select
ActiveCell.FormulaR1C1 = "=IF(RC[-11]>0,ABS(RC[-11]-RC[-22])/RC[-11],0)"

Sheets("target values").Cells(3, 2 * NInputs + 2 * NOutputs + 8).Select
Selection.AutoFill Destination:=Sheets("target values").Range(Cells(3, 2 * NInputs + 2 * NOutputs + 8), _
Cells(3 + (NDMUs - 1), 2 * NInputs + 2 * NOutputs + 8)), _
Type:=xlFillValues

Sheets("target values").Range(Cells(3, 2 * NInputs + 2 * NOutputs + 8), _
Cells(3 + (NDMUs - 1), 2 * NInputs + 2 * NOutputs + 8)).Select
Selection.AutoFill Destination:=Range(Cells(3, 2 * NInputs + 2 * NOutputs + 8), _
Cells(3 + (NDMUs - 1), 2 * NInputs + 2 * NOutputs + 8 + (NInputs + NOutputs))), _
Type:=xlFillValues

Sheets("target values").Columns(3 * NInputs + 2 * NOutputs + 8).Select
Selection.ClearContents

Sheets("target values").Range(Cells(3, 2 * NInputs + 2 * NOutputs + 8), _
Cells(3 + (NDMUs - 1), 2 * NInputs + 2 * NOutputs + 8 + (NInputs + NOutputs))).Select
Selection.Style = "Percent"
```

VBA-code *Reset Model* The code in this section is invoked by the button *Reset Model* on sheet 1. The code below is used for setting all lambdas to zero and the DMU under evaluation to one.

```
Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

'reset lambdas to zero

Dim myrng As Range

Set myrng = Sheets("efficiency_lambdas").Range(Cells(14, 4 + NInputs + NOutputs), _
Cells(14 + (NDMUs - 1), 4 + NInputs + NOutputs))

myrng.Value = "0"

Sheets("efficiency_lambdas").Cells(1, 5).Value = "0"

'reset DMU under evaluation to one

Sheets("efficiency_lambdas").Cells(3, 5).Value = "1"
```

VBA-code *Clear Cells* The code in this section is invoked by the button *Clear Cells* on sheet 1. The code below is used for clearing all output cells on sheet 1 and sheet 2 that are generated by the code invoked by the button *Output-oriented VRS*.

```
Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

'clear outputs in sheet "efficiency&lambdas"

Sheets("efficiency_lambdas").Range(Cells(14, NInputs + NOutputs + 5), _
Cells(14 + (NDMUs - 1), NInputs + NOutputs + 5)).Select
Selection.ClearContents

Sheets("efficiency_lambdas").Range(Cells(14, NInputs + NOutputs + 7), _
Cells(14 + (NDMUs - 1), NInputs + NOutputs + 7 + (NDMUs - 1))).Select
Selection.ClearContents

'clear outputs in sheet "target values"

Sheets("target values").Select

Sheets("target values").Range(Cells(3, 2), Cells(3 + (NDMUs - 1), 2 + NInputs + NOutputs)).Select
Selection.ClearContents

Sheets("target values").Range(Cells(3, 8 + 2 * NInputs + 2 * NOutputs), _
Cells(3 + (NDMUs - 1), 8 + 3 * NInputs + 3 * NOutputs)).Select
Selection.ClearContents

'go back to start sheet

Sheets("efficiency_lambdas").Select
```

VBA-code *Make Charts* The vba code in this section is invoked by the button *Make Charts* on sheet 1. The code is used for printing bar charts with the efficiency scores of the DMUs. The color of the bar charts is dependent on the efficiency score. The green bars represent the best performing DMUs and the red bars the worst performing DMUs.

```
Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

Dim chartno As Integer
chartno = Range("B1").Offset(0, 0)

Dim i As Integer
For i = 1 To chartno

'Set chart characteristics

ActiveSheet.Shapes.AddChart.Select
ActiveChart.SetSourceData Source:=Cells(13, NInputs + NOutputs + 5).Offset(i, 0)
    ActiveChart.ChartType = 57
    ActiveChart.Legend.Delete
    ActiveChart.Axes(xlCategory).Delete
    ActiveChart.ChartGroups(1).GapWidth = 0
    ActiveChart.Axes(xlValue).Delete
    ActiveChart.Axes(xlValue).MinimumScale = 0
    ActiveChart.Axes(xlValue).MaximumScale = 1
    ActiveChart.Axes(xlValue).MajorUnit = 0.25
    ActiveSheet.Shapes(i).Left = Sheets("efficiency_lambdas").Cells(13 + i, NInputs + NOutputs + 6).Left
    ActiveSheet.Shapes(i).Top = Sheets("efficiency_lambdas").Cells(13 + i, NInputs + NOutputs + 6).Top
    ActiveSheet.Shapes(i).Height = Sheets("efficiency_lambdas").Cells(14, NInputs + NOutputs + 6).Height
    ActiveSheet.Shapes(i).Width = Sheets("efficiency_lambdas").Cells(14, NInputs + NOutputs + 6).Width
    ActiveChart.PlotArea.Select
    Selection.Top = 1
    Selection.Height = 7

    If Cells(13 + i, NInputs + NOutputs + 5) > 0.999 Then
    ActiveChart.ChartStyle = 5
    Cells(13 + i, NInputs + NOutputs + 5).Select

    Else
    If Cells(13 + i, NInputs + NOutputs + 5) > 0.75 And Cells(13 + i, NInputs + NOutputs + 5) < 0.999 Then
    ActiveChart.ChartStyle = 8
    Cells(13 + i, NInputs + NOutputs + 5).Select

    Else
    ActiveChart.ChartStyle = 4
    Cells(13 + i, NInputs + NOutputs + 5).Select

End If

End If

Next i
```

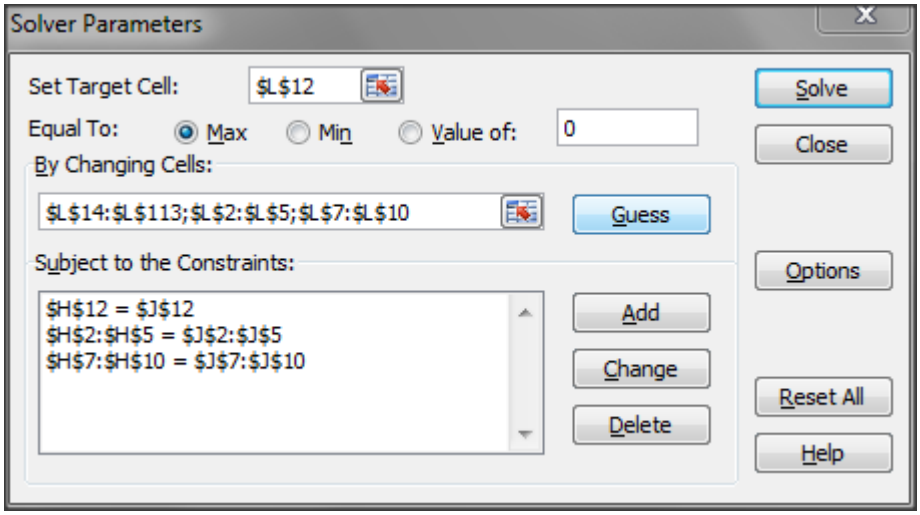
VBA-code *Delete Charts* The vba code in this section is invoked by the button *Delete Charts* on sheet 1. The code is used for deleting all charts on worksheet 1.

```
'Delete all charts in worksheet

    Dim sheet As Worksheet
    Dim chart As ChartObject

    For Each sheet In ThisWorkbook.Worksheets

        For Each chart In sheet.ChartObjects

            chart.Delete

        Next

    Next
```

D.2.2.2 VBA code sheet 3

This section presents the vba code that is invoked by pressing the buttons on sheet 3 for the calculation of the input and output slacks.

Solver settings sheet 3 The following solver settings where used for the calculation of the slack values for the input-oriented VRS model on sheet 3 of the Microsoft Excel workbook.



The target cell comprises the objective function which is defined in equation D.1.13. This function is maximized by the algorithm. The changing cells are the values that will be changed by the algorithms in order to get the optimal efficiency. The constraint cells comprise the constraints as defined in equation D.1.13.

VBA-code *Calculate Slacks* The vba code in this section is invoked by the button *Calculate Slacks* on sheet 3. The part of code below is used for the calculation of the input and output slacks based on the efficiency scores calculated in sheet 1.

```
'model for the calculation of DEA slacks

Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

Dim i As Integer
For i = 1 To NDMUs
Range("E2") = i

SolverOk SetCell:="$L$12", MaxMinVal:=1, ValueOf:="0", ByChange:=Union(Range(Cells(14, NInputs + NOutputs + 4), _
Cells(14 + (NDMUs - 1), NInputs + NOutputs + 4)), Range(Cells(2, 12), Cells(2 + (NInputs - 1), 12)), _
Range(Cells(7, 12), Cells(7 + (NOutputs - 1), 12)))
SolverSolve UserFinish:=True
```

The part of code below is used for printing the calculated input slacks, output slacks and the lambdas.

```
'print input and output slacks

Range("L2:L" & 2 + (NInputs - 1)).Copy
Range("A13").Offset(i, NInputs + NOutputs + 6).Select
Selection.PasteSpecial Paste:=xlPasteValues, _
    Operation:=xlNone, _
    SkipBlanks:=False, _
    Transpose:=True

Range("L7:L" & 7 + (NOutputs - 1)).Copy
Range("A13").Offset(i, 2 * NInputs + NOutputs + 6).Select
Selection.PasteSpecial Paste:=xlPasteValues, _
    Operation:=xlNone, _
    SkipBlanks:=False, _
    Transpose:=True

'print lambdas

Range(Cells(14, NInputs + NOutputs + 4), Cells(14 + (NDMUs - 1), NInputs + NOutputs + 4)).Copy
Range("A13").Offset(i, 2 * NInputs + 2 * NOutputs + 7).Select
Selection.PasteSpecial Paste:=xlPasteValues, _
    Operation:=xlNone, _
    SkipBlanks:=False, _
    Transpose:=True
Next i
```

VBA-code *Reset Model* The vba code in this section is invoked by the button *Reset Model* on sheet 3. The code resets all input slacks and output slacks to zero and the DMU under evaluation to one.

```
Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

'reset lambdas to zero

Dim myrng As Range

Set myrng = Sheets("slacks").Range(Cells(14, NInputs + NOutputs + 4), _
Cells(14 + (NDMUs - 1), NInputs + NOutputs + 4))

myrng.Value = "0"

Sheets("slacks").Range(Cells(2, 12), Cells(11, 12)).Value = "0"

'reset DMU under evaluation to one

Sheets("slacks").Cells(2, 5).Value = "1"
```

VBA-code *Clear Cells* The vba code in this section is invoked by the button *Clear Cells* on sheet 3. The code is used for clearing all output cells on sheet 3 that are generated by the code that is invoked by button *calculate slacks*.

```
Dim NDMUs As Integer, NInputs As Integer, NOutputs As Integer

NDMUs = Range("B1").Offset(0, 0)
NInputs = Range("B2").Offset(0, 0)
NOutputs = Range("B3").Offset(0, 0)

'clear outputs in sheet "slacks"

Sheets("slacks").Range(Cells(14, NInputs + NOutputs + 7), _
Cells(14 + (NDMUs - 1), 2 * NInputs + 2 * NOutputs + 6)).Select
Selection.ClearContents

Sheets("slacks").Range(Cells(14, 2 * NInputs + 2 * NOutputs + 8), _
Cells(14 + (NDMUs - 1), (NDMUs - 1) + 2 * NInputs + 2 * NOutputs + 8)).Select
Selection.ClearContents
```

Appendix E

DEA Analysis Outcomes

This appendix comprises extended analyses of the outcomes of the DEA method.

E.1 Testing impact of DMUs, inputs and outputs

This section comprises some statistical tests that examine the relationships between the number of DMUs, inputs and outputs and the effectiveness of the DEA method.

E.1.1 Impact of DMUs on efficiency figures

This section examines the relationships in DEA between the total number of DMUs used in the analysis and the number of efficient/inefficient DMUs. This gives an indication of the quality of the efficient frontier and shows the added value of a large number of DMUs. Figure E.1 visualizes the relationship between the total number of DMUs that are subject to the analysis and the number of DMUs on the efficient frontier[1]. Table E.1 shows that the number of DMUs on the efficient frontier is significantly higher in case of a larger number of total DMUs in the analysis. This means that the quality of the efficient frontier becomes higher, although the number of DMUs on the efficient frontier rises slowly with the number of total DMUs (see table E.2).

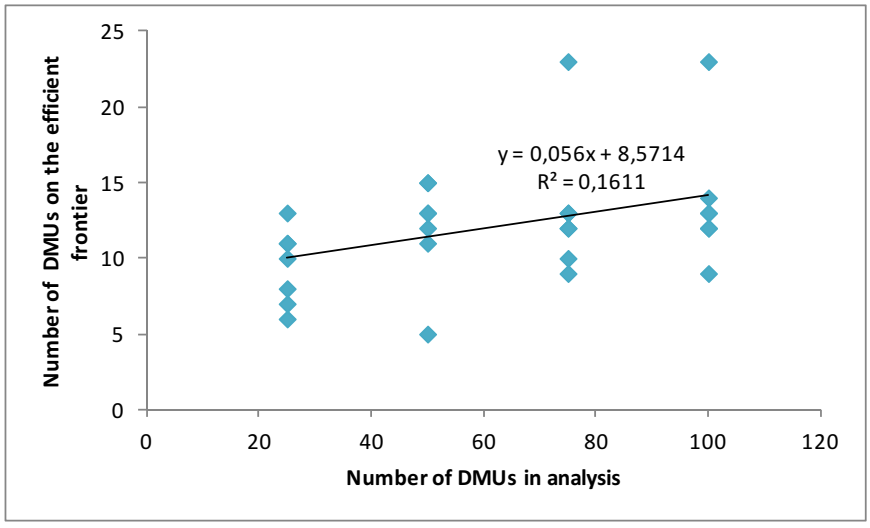


Figure E.1 – Number of efficient DMUs vs total number of DMUs

[1] The number of inputs and outputs is kept constant.

Table E.1 – Regression analysis for relationship between total number of DMUs and number of efficient DMUs

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	8.57	1.72	.00	5.00	.00
Number of DMUs	.06	.03	.40	2.23	.03

Table E.2 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.40	.16	.16	3.71

Figure E.2 shows how the ratio of efficient DMUs is related to the total number of DMUs that are subject to the analyses. From this figure becomes clear that the ratio of efficient DMUs decreases quite fast with an increasing number of DMUs subject to the DEA analyses. This is confirmed by table E.3 which shows that there is a significant negative relation between the number of DMUs subject to the analyses and the ratio efficient DMUs. Table E.4 show that the linear relation explains an important part of the variations in the ratio of efficient DMUs.

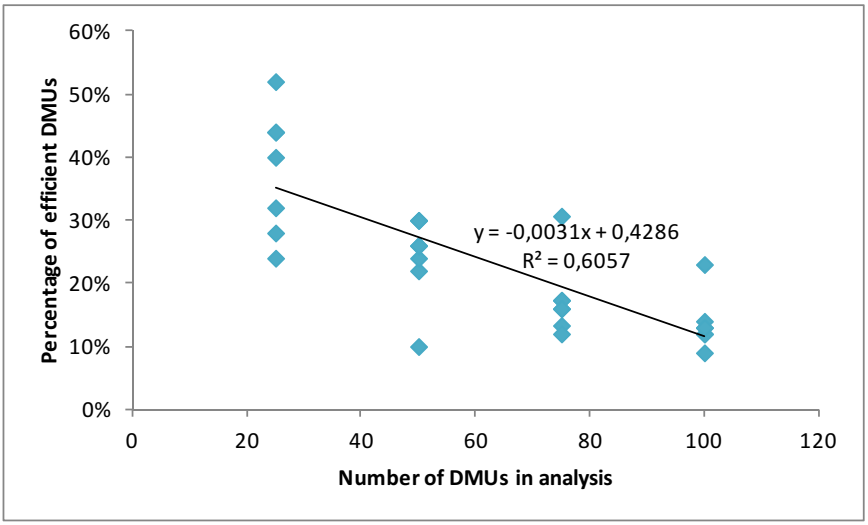


Figure E.2 – Ratio efficient DMUs

Table E.3 – Regression analysis for relationship between total number of DMUs and number of efficient DMUs

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	.43	.03	.00	12.60	.00
Number of DMUs	.00	.00	-.78	-6.32	.00

Table E.4 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.78	.61	.61	.07

E.1.2 Impact of inputs and outputs on efficiency figures

This section examines the impact of the number of inputs and outputs on the number of points on the efficient frontier. This section shows that the number of efficient DMUs increases significantly with the number of inputs and outputs. This is visualized by figure E.3. However the number of inputs and outputs is not the only explanatory variable. As seen in section E.1.1, the number of DMUs is also an explanatory variable. Table E.5 shows that both variables are significant in explaining the number of DMUs on the efficient frontier. Based on this table can be said that in case of random input and output figures the number of efficient DMUs increases by 5.92 for each additional input or output within the range of four to eight inputs and outputs and 25 to 100 DMUs. The number of efficient DMUs increases by .23 for each additional DMU added to the analyses within the range of 25 to 100 DMUs and four to eight inputs and outputs

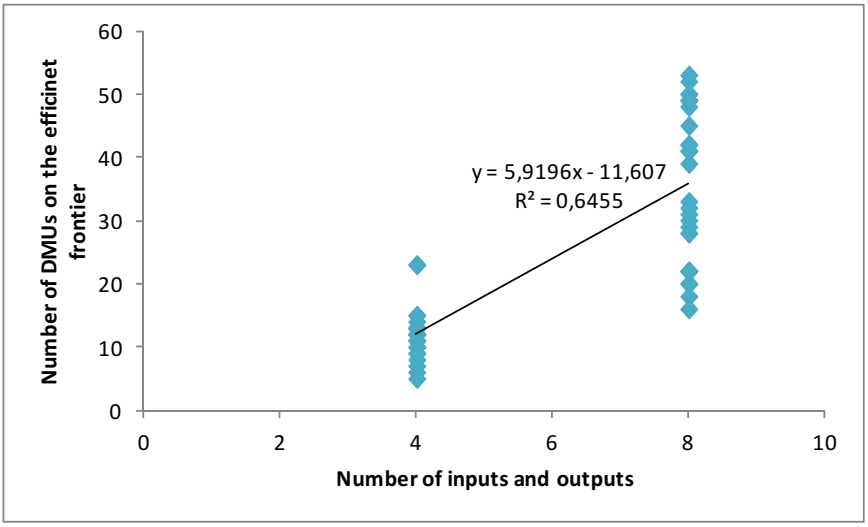


Figure E.3 – Number of inputs and outputs versus number efficient DMUs

Table E.5 – Regression analysis for relationship between number of inputs and outputs and number efficient DMUs

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	-26.13	3.14	.00	-8.32	.00
Number of inputs/outputs	5.92	.41	.80	14.60	.00
Number of DMUs	.23	.03	.44	8.01	.00

Table E.6 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.92	.84	.84	6.07

Figure E.4 shows the relation between the ratio of efficient DMUs versus the number of inputs and outputs by also varying the number of DMUs that are subject to the analyses. Table E.7 shows that both the total number of DMUs and the total number of inputs and outputs has a significant impact on the ratio of DMUs on the efficient frontier. Based on this table can be said that in case of random input and output figures the number of efficient DMUs increases by 9.66 percent for each additional input or output within the range of four

to eight inputs and outputs and 25 to 100 DMUs. The number of efficient DMUs decreases by .34 percent for each additional DMU added to the analyses within the range of 25 to 100 DMUs and four to eight inputs and outputs

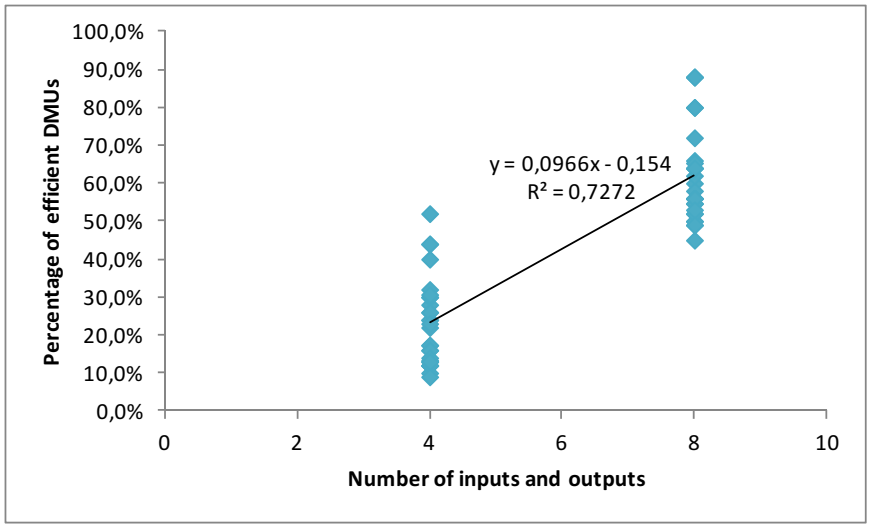


Figure E.4 – Number of inputs and outputs versus ratio efficient DMUs

Table E.7 – Regression analysis for relationship between number of inputs and outputs and ratio efficient DMUs

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	6.10	3.67	.00	1.66	.10
Number of inputs/outputs	9.66	.47	.85	20.42	.00
Number of DMUs	-.34	.03	-.42	-10.16	.00

Table E.8 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.95	.91	.91	7.08

Figure E.5 shows the relation between the average efficient points per dimension in relation to the number of inputs and outputs in the analysis. The average efficient points per dimension give an indication of the quality of the efficient frontier. Each input and output is one dimension. The number of efficient point per dimension is calculated by

$$Efficient - points - per - dimension = \frac{total - efficient - points}{number - of - dimensions}$$

From table E.9 becomes clear that both the number of DMUs and the number of inputs and outputs have a significant impact on the quality of the efficient frontier. Each additional input or output leads to an increase of .36 efficient DMUs per dimension. Each additional DMU leads to an increase of .03 efficient DMUs per dimension.

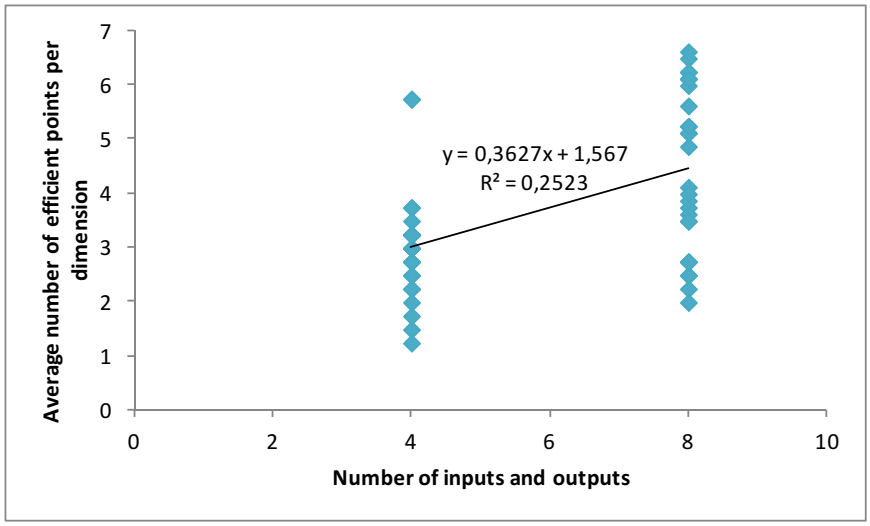


Figure E.5 – Number of inputs and outputs versus average efficient points per dimension

Table E.9 – Regression analysis for relationship between number of inputs and outputs and average efficient points per dimension

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	-.47	.46	.00	-1.02	.31
Number of inputs/outputs	.36	.06	.50	6.17	.00
Number of DMUs	.03	.00	.63	7.74	.00

Table E.10 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.81	.65	.64	.88

E.1.3 Impact of DMUs on slack ratio

The slack ratio is an indicator for the quality of the efficiency figures generated by the DEA model. The slack ratio determines the extent to which healthcare providers can improve their inputs and outputs without actually changing their performance figure. The existence of input and output slacks is problematic for the interpretation of the efficiency figures and is a disincentive for healthcare providers to improve their performance and invest in innovation because improved performance do not necessary lead to a higher efficiency score, even when the performance of the competitors is kept constant. The slack ratio is expressed as the ratio of DMUs that face slacks for a specific input. Table E.11 shows that there is a significant relation between the number of DMUs included in an analysis and the slack ratio. This can be explained by the fact that efficient DMUs do not have slacks. From section E.1.1 and E.1.2 becomes clear that the ratio of inefficient DMUs increases with the number of DMUs in the analysis.

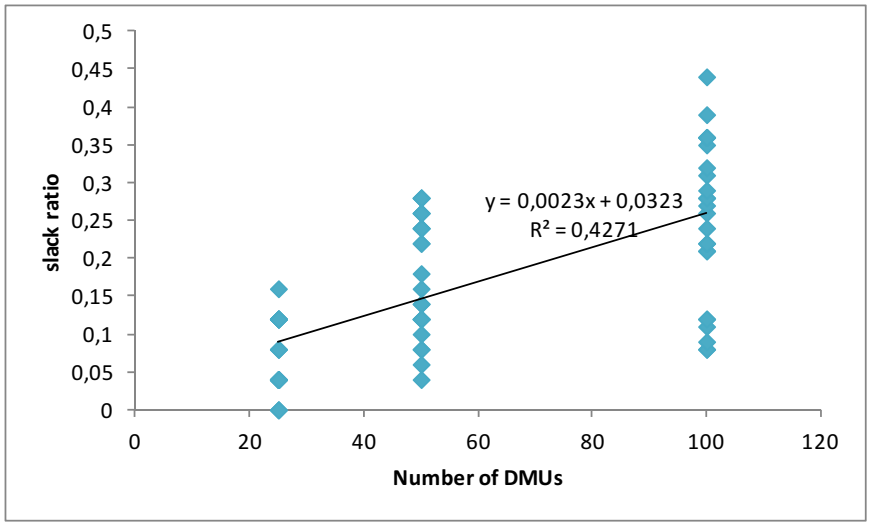


Figure E.6 – Impact of Number of DMUs on slack ratio

Table E.11 – Regression analysis for relationship between total number of DMUs in the analysis and the slack ratio

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	.03	.02	.00	1.56	.12
Number of DMUs	.0023	.00	.65	7.22	.00

Table E.12 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.65	.43	.43	.08

E.2 DEA analysis outcomes

This section comprises data tables with the outcomes of the DEA analysis.

E.2.1 Efficiencies and benchmarks

Table E.13 comprises the efficiency scores and the benchmarks for all DMUs. A graphical representation of the benchmarks is given in figure E.7. From this figure becomes clear which DMUs often function as benchmark for inefficient DMUs. The highlighted DMUs serve more than ten times a benchmark for inefficient DMUs.

Table E.13 – Efficiencies and benchmarks

DMU	Efficiency	bench-mark1	bench-mark2	bench-mark3	bench-mark4	bench-mark5	bench-mark6
X1-1	83,1%	X1-19	X1-38	X1-40	X1-83		
X1-2	100,0%	X1-2					
X1-3	99,7%	X1-2	X1-14	X1-48	X1-71	X1-92	
X1-4	77,0%	X1-7	X1-17	X1-81	X1-83		
X1-5	97,2%	X1-6	X1-64	X1-81			
X1-6	100,0%	X1-6					
X1-7	100,0%	X1-7					
X1-8	100,0%	X1-8					
X1-9	97,0%	X1-14	X1-17	X1-40	X1-83		
X1-10	100,0%	X1-10					
X1-11	91,3%	X1-10	X1-14	X1-38	X1-40		
X1-12	100,0%	X1-12					
X1-13	68,4%	X1-2	X1-14	X1-40	X1-47	X1-83	
X1-14	100,0%	X1-14					
X1-15	61,5%	X1-14	X1-47	X1-48	X1-83	X1-100	
X1-16	100,0%	X1-16					
X1-17	100,0%	X1-17					
X1-18	100,0%	X1-18					
X1-19	100,0%	X1-19					
X1-20	84,8%	X1-2	X1-17	X1-81			
X1-21	77,5%	X1-2	X1-10	X1-14	X1-38	X1-47	X1-83
X1-22	93,0%	X1-6	X1-24	X1-40	X1-64	X1-81	X1-83
X1-23	79,4%	X1-2	X1-38	X1-40	X1-83		
X1-24	100,0%	X1-24					
X1-25	93,1%	X1-24	X1-59	X1-64	X1-83	X1-93	
X1-26	89,5%	X1-12	X1-42	X1-83			
X1-27	75,8%	X1-6	X1-24	X1-40	X1-47		
X1-28	97,5%	X1-47	X1-81				
X1-29	76,4%	X1-2	X1-38	X1-40	X1-47	X1-83	
X1-30	67,7%	X1-2	X1-10	X1-14	X1-38	X1-47	X1-83
X1-31	62,9%	X1-38	X1-47	X1-81			
X1-32	62,2%	X1-2	X1-40	X1-48	X1-83		
X1-33	67,7%	X1-2	X1-14	X1-40	X1-47	X1-83	

DMU	Efficiency	bench-mark1	bench-mark2	bench-mark3	bench-mark4	bench-mark5	bench-mark6
X1-34	100,0%	X1-34					
X1-35	100,0%	X1-35					
X1-36	100,0%	X1-36					
X1-37	100,0%	X1-37					
X1-38	100,0%	X1-38					
X1-39	72,9%	X1-6	X1-40	X1-47	X1-83		
X1-40	100,0%	X1-40					
X1-41	100,0%	X1-41					
X1-42	100,0%	X1-42					
X1-43	92,7%	X1-6	X1-12	X1-83	X1-93		
X1-44	71,2%	X1-10	X1-38	X1-40	X1-47		
X1-45	62,9%	X1-38	X1-83	X1-89	X1-92		
X1-46	72,8%	X1-2	X1-40	X1-47	X1-48	X1-83	
X1-47	100,0%	X1-47					
X1-48	100,0%	X1-48					
X1-49	83,1%	X1-2	X1-34	X1-67	X1-95		
X1-50	96,3%	X1-24	X1-40	X1-64	X1-83		
X1-51	100,0%	X1-51					
X1-52	89,7%	X1-6	X1-24	X1-47	X1-83	X1-93	
X1-53	100,0%	X1-53					
X1-54	92,3%	X1-6	X1-47	X1-48	X1-92		
X1-55	100,0%	X1-55					
X1-56	78,9%	X1-6	X1-24	X1-40	X1-47	X1-81	
X1-57	94,3%	X1-14	X1-38	X1-40	X1-83		
X1-58	75,1%	X1-8	X1-10	X1-83			
X1-59	100,0%	X1-59					
X1-60	84,3%	X1-2	X1-40	X1-47	X1-48	X1-83	
X1-61	100,0%	X1-61					
X1-62	74,0%	X1-6	X1-40	X1-81	X1-83		
X1-63	75,0%	X1-10	X1-47	X1-83	X1-92		
X1-64	100,0%	X1-64					
X1-65	100,0%	X1-65					
X1-66	100,0%	X1-66					
X1-67	100,0%	X1-67					
X1-68	95,3%	X1-10	X1-14	X1-18	X1-40		
X1-69	82,7%	X1-40	X1-47	X1-64	X1-93		
X1-70	92,8%	X1-8	X1-83	X1-89	X1-92		
X1-71	100,0%	X1-71					
X1-72	99,6%	X1-64	X1-81	X1-83			
X1-73	70,0%	X1-19	X1-38	X1-40	X1-83		
X1-74	68,0%	X1-38	X1-40	X1-47	X1-83		
X1-75	68,9%	X1-24	X1-40	X1-47	X1-81	X1-93	
X1-76	88,7%	X1-6	X1-48	X1-83	X1-93		
X1-77	91,5%	X1-10	X1-47	X1-83			
X1-78	97,4%	X1-47	X1-81	X1-83			
X1-79	88,0%	X1-6	X1-64	X1-81	X1-83	X1-93	
X1-80	84,3%	X1-6	X1-64	X1-81			

DMU	Efficiency	bench-mark1	bench-mark2	bench-mark3	bench-mark4	bench-mark5	bench-mark6
X1-81	100,0%	X1-81					
X1-82	57,3%	X1-6	X1-24	X1-40	X1-47		
X1-83	100,0%	X1-83					
X1-84	81,8%	X1-6	X1-64	X1-81			
X1-85	98,5%	X1-53	X1-83				
X1-86	100,0%	X1-64	X1-81				
X1-87	97,1%	X1-87					
X1-88	69,2%	X1-38	X1-47	X1-81	X1-83	X1-92	X1-100
X1-89	100,0%	X1-89					
X1-90	100,0%	X1-90					
X1-91	60,0%	X1-24	X1-40	X1-47	X1-64		
X1-92	100,0%	X1-92					
X1-93	100,0%	X1-93					
X1-94	100,0%	X1-94					
X1-95	100,0%	X1-95					
X1-96	87,6%	X1-2	X1-10	X1-14	X1-40	X1-83	
X1-97	70,8%	X1-2	X1-14	X1-40	X1-47		
X1-98	73,1%	X1-6	X1-71	X1-83			
X1-99	100,0%	X1-99					
X1-100	100,0%	X1-100					

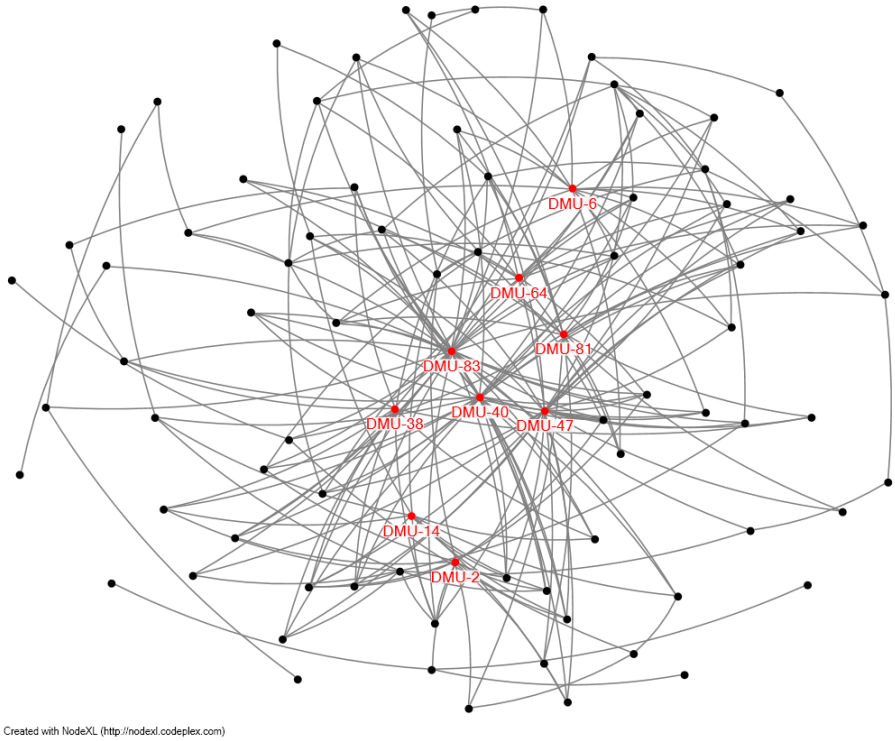


Figure E.7 – Graphical representation of benchmarks

Table E.14 comprises the overall efficiency scores and the parameter specific efficiency scores calculated with a preference structure model.

Table E.14 – Efficiencies calculated by preference structure model

DMU	overall efficiency	efficiency input1	efficiency input2	efficiency input3	efficiency input4
X1-1	77%	63%	80%	85%	81%
X1-2	100%	100%	100%	100%	100%
X1-3	87%	100%	70%	77%	100%
X1-4	55%	42%	25%	76%	78%
X1-5	68%	40%	37%	100%	95%
X1-6	100%	100%	100%	100%	100%
X1-7	100%	100%	100%	100%	100%
X1-8	100%	100%	100%	100%	100%
X1-9	76%	50%	71%	84%	100%
X1-10	100%	100%	100%	100%	100%
X1-11	75%	84%	31%	84%	100%
X1-12	100%	100%	100%	100%	100%
X1-13	56%	46%	30%	60%	89%
X1-14	100%	100%	100%	100%	100%
X1-15	51%	50%	26%	66%	64%
X1-16	100%	100%	100%	100%	100%
X1-17	100%	100%	100%	100%	100%
X1-18	100%	100%	100%	100%	100%
X1-19	100%	100%	100%	100%	100%
X1-20	64%	25%	31%	100%	99%
X1-21	68%	22%	58%	99%	93%
X1-22	67%	46%	27%	98%	96%
X1-23	62%	49%	53%	60%	87%
X1-24	100%	100%	100%	100%	100%
X1-25	73%	82%	45%	97%	67%
X1-26	83%	74%	100%	100%	59%
X1-27	58%	42%	29%	95%	66%
X1-28	76%	74%	40%	90%	100%
X1-29	64%	51%	39%	76%	89%
X1-30	63%	41%	75%	58%	78%
X1-31	48%	25%	28%	68%	70%
X1-32	51%	45%	31%	62%	68%
X1-33	52%	40%	23%	65%	81%
X1-34	100%	100%	100%	100%	100%
X1-35	100%	100%	100%	100%	100%
X1-36	100%	100%	100%	100%	100%
X1-37	100%	100%	100%	100%	100%
X1-38	100%	100%	100%	100%	100%
X1-39	64%	72%	39%	73%	71%
X1-40	100%	100%	100%	100%	100%

DMU	overall efficiency	efficiency input1	efficiency input2	efficiency input3	efficiency input4
X1-41	100%	100%	100%	100%	100%
X1-42	100%	100%	100%	100%	100%
X1-43	82%	92%	72%	100%	66%
X1-44	61%	48%	50%	71%	75%
X1-45	62%	45%	68%	72%	61%
X1-46	62%	45%	48%	78%	78%
X1-47	100%	100%	100%	100%	100%
X1-48	100%	100%	100%	100%	100%
X1-49	59%	28%	39%	81%	88%
X1-50	78%	53%	60%	100%	100%
X1-51	100%	100%	100%	100%	100%
X1-52	79%	86%	53%	100%	79%
X1-53	100%	100%	100%	100%	100%
X1-54	82%	89%	52%	100%	86%
X1-55	100%	100%	100%	100%	100%
X1-56	60%	52%	35%	82%	73%
X1-57	71%	82%	33%	71%	100%
X1-58	73%	69%	78%	74%	72%
X1-59	100%	100%	100%	100%	100%
X1-60	71%	54%	50%	83%	97%
X1-61	100%	100%	100%	100%	100%
X1-62	57%	39%	38%	77%	75%
X1-63	66%	27%	97%	72%	69%
X1-64	100%	100%	100%	100%	100%
X1-65	100%	100%	100%	100%	100%
X1-66	100%	100%	100%	100%	100%
X1-67	100%	100%	100%	100%	100%
X1-68	82%	96%	70%	63%	100%
X1-69	60%	41%	23%	86%	91%
X1-70	84%	72%	100%	82%	83%
X1-71	100%	100%	100%	100%	100%
X1-72	70%	66%	41%	100%	72%
X1-73	55%	50%	29%	91%	51%
X1-74	57%	30%	28%	100%	72%
X1-75	52%	49%	22%	71%	68%
X1-76	73%	89%	36%	92%	73%
X1-77	81%	45%	86%	100%	95%
X1-78	84%	57%	81%	100%	100%
X1-79	63%	45%	37%	94%	77%
X1-80	61%	46%	32%	100%	67%

DMU	overall efficiency	efficiency input1	efficiency input2	efficiency input3	efficiency input4
X1-81	100%	100%	100%	100%	100%
X1-82	47%	33%	29%	68%	57%
X1-83	100%	100%	100%	100%	100%
X1-84	58%	36%	28%	84%	83%
X1-85	66%	53%	30%	99%	82%
X1-86	100%	100%	100%	100%	100%
X1-87	74%	55%	42%	100%	100%
X1-88	55%	34%	43%	63%	82%
X1-89	100%	100%	100%	100%	100%
X1-90	100%	100%	100%	100%	100%
X1-91	46%	30%	31%	63%	59%
X1-92	100%	100%	100%	100%	100%
X1-93	100%	100%	100%	100%	100%
X1-94	100%	100%	100%	100%	100%
X1-95	100%	100%	100%	100%	100%
X1-96	70%	70%	47%	62%	100%
X1-97	59%	36%	44%	58%	96%
X1-98	52%	49%	23%	63%	74%
X1-99	100%	100%	100%	100%	100%
X1-100	100%	100%	100%	100%	100%

One can see that the efficient DMUs still are efficient but that the efficiency scores of the inefficient DMUs changed a little. This is especially true for the DMUs that where confronted with large input slack values. Table E.15 shows that there is a significant relation between the decrease in efficiency and the amount of slack that is present in the input oriented VRS DEA model.

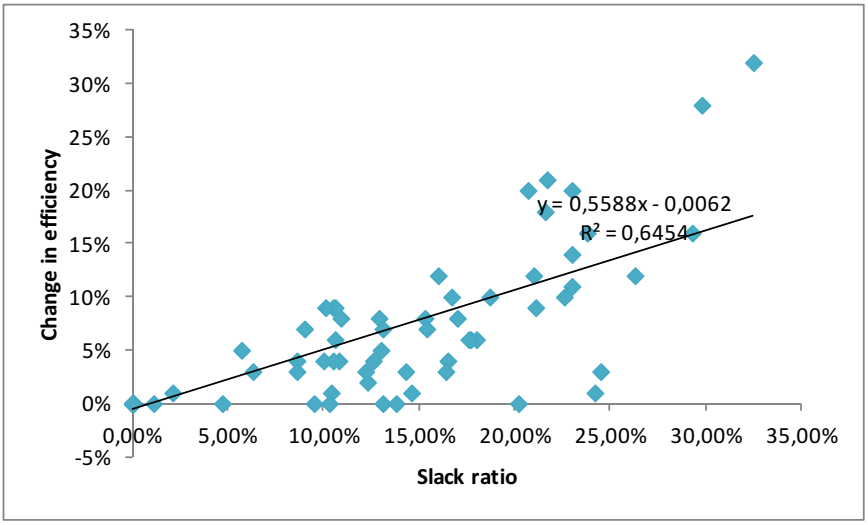


Figure E.8 – amount of slack versus change in efficiency

Table E.15 – Regression analysis for relationship between amount of slack and decrease in efficiency

Coefficients					
	B	Std. Error	Beta	t	Significance
Constant	3.86	.67	.00	5.75	.00
amount of slack	1.15	.09	.80	13.35	.00

Table E.16 – Regression model summary

Model summary			
R	R square	Adjusted R square	Std. Error of the estimate
.80	.65	.65	5.56

E.2.2 Input and output slacks

This section comprises the data tables with the input and output slacks for the analyzed DMUs. The input slacks are linked to the following input parameters

- Cost price of treatment
- Employee occupation
- Capacity utilization
- Treatment duration

The output slacks are linked to the following output parameters

- Length of waiting lists
- CQ-score
- QALY
- Complication risk

Table E.17 – Input and output slacks

DMU	input slack1	input slack2	input slack3	input slack4	output slack1	output slack2	output slack3	output slack4
X1-1	127,21	0,00	0,00	0,00	0,06	7,52	0,00	12,42
X1-2	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-3	0,00	1,08	40,02	0,00	0,00	0,79	0,00	0,00
X1-4	327,31	8,01	0,00	0,00	0,06	0,00	5,13	0,00
X1-5	177,35	2,69	0,00	0,65	0,05	0,00	0,20	0,00
X1-6	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-7	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-8	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-9	424,66	0,00	4,13	0,00	0,00	0,00	3,97	0,00
X1-10	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-11	46,61	3,96	0,00	0,00	0,05	3,62	0,00	0,00
X1-12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-13	0,00	0,72	0,00	0,00	0,00	8,66	7,83	0,00
X1-14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-15	0,00	2,39	0,00	0,00	0,00	3,04	11,68	0,00
X1-16	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-17	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-18	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-19	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-20	80,94	2,84	0,08	0,00	0,06	0,00	0,00	8,54
X1-21	0,00	0,00	0,00	0,00	0,00	5,87	6,17	0,00
X1-22	0,00	5,88	0,00	0,00	0,00	0,00	9,55	0,00
X1-23	123,77	0,00	36,86	0,00	0,12	0,00	0,00	16,63
X1-24	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-25	0,00	0,00	0,00	0,00	0,00	7,94	2,97	0,00
X1-26	0,00	0,00	0,00	0,60	0,11	0,43	7,64	10,95
X1-27	0,00	2,95	0,00	0,00	0,08	7,13	0,00	20,33
X1-28	0,00	7,14	23,58	0,00	0,04	0,00	11,37	15,07
X1-29	0,00	1,13	0,00	0,00	0,00	3,55	0,00	19,90
X1-30	0,00	0,00	0,00	0,00	0,00	2,29	4,99	0,00
X1-31	47,04	3,77	3,43	0,00	0,01	0,00	8,29	0,00
X1-32	0,00	1,58	0,00	0,00	0,00	11,23	13,54	37,78
X1-33	0,00	4,07	0,00	0,00	0,00	7,81	6,36	0,00
X1-34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-36	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-37	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-38	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-39	0,00	2,08	0,00	0,00	0,00	0,30	2,59	11,43
X1-40	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

DMU	input slack1	input slack2	input slack3	input slack4	output slack1	output slack2	output slack3	output slack4
X1-41	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-42	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-43	0,00	0,00	0,00	0,10	0,15	8,21	14,13	0,00
X1-44	0,00	1,34	0,00	0,00	0,01	6,46	0,00	4,21
X1-45	0,00	0,00	0,00	0,00	0,07	10,49	6,12	4,33
X1-46	0,00	3,25	0,00	0,00	0,00	0,00	19,25	11,97
X1-47	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-49	0,00	0,00	11,01	0,00	0,08	0,00	2,74	0,64
X1-50	208,07	0,00	0,00	0,00	0,00	3,68	7,14	33,02
X1-51	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-52	0,00	0,00	0,00	0,00	0,04	4,45	1,64	0,00
X1-53	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-54	0,00	2,83	0,00	0,00	0,00	6,92	9,52	1,84
X1-55	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-56	0,00	5,70	0,00	0,00	0,00	0,00	9,15	4,73
X1-57	0,00	7,07	45,17	0,00	0,09	1,94	0,00	0,00
X1-58	6,34	0,00	0,00	0,15	0,00	8,11	22,77	17,84
X1-59	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-60	0,00	0,00	0,00	0,00	0,00	7,15	0,45	15,62
X1-61	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-62	82,61	0,50	0,00	0,00	0,00	0,00	16,00	23,76
X1-63	103,01	0,00	0,00	0,00	0,05	0,00	11,49	17,09
X1-64	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-65	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-66	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-67	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-68	0,00	0,00	49,22	0,00	0,05	2,36	18,44	0,00
X1-69	0,00	5,69	0,00	0,00	0,08	0,88	9,88	0,00
X1-70	0,00	0,00	22,09	0,00	0,00	1,48	18,37	3,20
X1-71	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-72	229,35	7,35	0,00	1,45	0,04	0,00	9,87	0,00
X1-73	22,38	0,00	0,00	0,00	0,14	4,42	0,00	20,92
X1-74	0,00	4,25	0,00	0,00	0,00	0,71	0,00	5,04
X1-75	0,00	1,53	0,00	0,00	0,06	0,00	2,74	0,00
X1-76	0,00	7,05	0,00	0,08	0,00	11,99	3,98	0,00
X1-77	335,70	0,00	0,00	0,00	0,08	6,58	10,81	10,12
X1-78	173,29	0,00	0,00	0,00	0,00	2,61	7,54	28,65
X1-79	0,00	1,20	0,00	0,00	0,12	0,00	6,41	0,00
X1-80	336,68	1,04	0,00	0,00	0,08	0,00	7,38	6,64

DMU	input slack1	input slack2	input slack3	input slack4	output slack1	output slack2	output slack3	output slack4
X1-81	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-82	0,00	3,59	0,00	0,00	0,00	7,63	0,00	3,63
X1-83	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-84	287,89	4,62	0,00	0,02	0,01	0,00	18,83	0,00
X1-85	343,98	7,26	0,00	0,69	0,00	12,47	22,39	38,01
X1-86	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-87	111,40	3,23	0,00	0,00	0,00	0,06	11,59	25,13
X1-88	0,00	0,00	0,00	0,00	0,00	0,00	9,29	0,00
X1-89	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-90	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-91	0,00	1,28	0,00	0,00	0,09	0,00	10,80	0,00
X1-92	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-93	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-94	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-95	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-96	0,00	0,00	38,96	0,00	0,00	7,73	19,08	0,00
X1-97	0,00	1,47	0,00	0,00	0,00	5,91	3,78	1,61
X1-98	178,70	6,17	17,54	0,00	0,08	0,00	0,00	29,85
X1-99	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
X1-100	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

E.2.3 Target values

The target input and output values for a DMU are calculated as a linear combination of the inputs and outputs of its benchmarks times the lambdas. Table comprises the absolute target values. The vba based Microsoft Excel model also calculates the relative values.

Table E.18 – Target values

DMU	target input 1	target input2	target input3	target input 4	target out-put1	target out-put2	target out-put3	target out-put4
X1-1	423,92	8,29	122,16	3,93	0,14	10,18	34,29	25,75
X1-2	372,00	4,53	135,99	2,46	0,16	15,14	26,53	8,84
X1-3	395,77	10,22	140,65	2,72	0,15	10,98	27,33	34,74
X1-4	426,85	4,04	114,01	3,31	0,17	15,79	28,64	48,49
X1-5	752,97	6,60	102,99	3,02	0,13	12,73	24,16	32,87
X1-6	172,00	6,61	103,07	4,38	0,15	16,82	32,23	8,26
X1-7	382,00	10,01	114,07	3,80	0,10	16,69	16,74	38,43
X1-8	469,00	2,39	163,33	4,38	0,18	6,24	23,71	30,28
X1-9	469,82	8,60	152,71	3,05	0,13	15,76	26,67	49,59
X1-10	803,00	2,31	125,59	2,12	0,08	3,96	9,30	39,93

DMU	target input 1	target input2	target input3	target input 4	target out-put1	target out-put2	target out-put3	target out-put4
X1-11	644,26	7,20	142,24	2,14	0,10	6,35	28,45	41,54
X1-12	270,00	3,68	113,20	4,43	0,08	5,34	16,11	37,36
X1-13	538,55	6,35	125,71	2,37	0,14	12,44	25,75	24,29
X1-14	651,00	14,67	146,65	2,20	0,18	6,46	25,51	47,08
X1-15	315,02	6,84	122,79	3,02	0,15	13,31	25,59	37,82
X1-16	217,00	10,54	103,62	4,54	0,08	14,24	26,33	19,71
X1-17	501,00	13,82	198,16	2,89	0,07	16,98	23,01	49,79
X1-18	267,00	4,05	149,83	2,70	0,06	5,75	20,77	42,97
X1-19	409,00	9,70	114,37	4,38	0,17	11,26	34,87	22,86
X1-20	662,92	6,06	125,24	2,44	0,13	15,48	22,39	25,30
X1-21	400,42	4,40	139,34	2,23	0,07	9,56	24,42	24,76
X1-22	701,85	5,23	104,68	2,90	0,13	14,00	22,78	34,53
X1-23	525,21	4,10	120,57	2,73	0,15	13,13	29,56	36,26
X1-24	355,00	4,94	100,89	4,04	0,11	5,09	19,86	11,88
X1-25	393,65	6,72	105,31	4,14	0,10	10,34	22,74	38,34
X1-26	333,93	3,03	113,53	3,68	0,15	11,48	27,29	38,69
X1-27	584,70	5,90	107,52	2,53	0,10	10,90	23,14	28,46
X1-28	867,54	5,93	105,30	2,33	0,10	15,26	18,35	32,98
X1-29	563,59	4,61	124,89	2,35	0,10	10,42	27,33	32,93
X1-30	486,45	3,32	129,15	2,35	0,08	9,57	20,14	28,81
X1-31	526,67	5,14	110,20	2,27	0,05	13,76	15,85	22,72
X1-32	556,34	4,09	109,01	2,99	0,18	13,99	30,08	45,73
X1-33	537,15	6,12	115,35	2,37	0,11	11,69	23,12	30,56
X1-34	852,00	15,21	198,18	2,41	0,06	16,08	5,74	14,51
X1-35	831,00	15,89	142,99	3,06	0,14	16,53	7,43	31,19
X1-36	707,00	2,32	188,31	4,51	0,11	7,24	24,78	23,57
X1-37	554,00	6,40	165,80	2,50	0,15	14,88	6,50	34,75
X1-38	438,00	2,27	161,94	2,04	0,01	4,63	32,29	35,10
X1-39	396,09	3,35	108,15	3,27	0,17	15,25	29,08	42,84
X1-40	969,00	7,06	104,66	2,28	0,16	9,93	30,39	46,02
X1-41	964,00	8,22	140,67	2,84	0,18	2,06	29,69	25,64
X1-42	136,00	3,63	128,69	4,33	0,10	2,83	24,03	8,02
X1-43	300,25	4,60	106,17	3,81	0,16	15,86	30,52	31,27
X1-44	409,46	4,12	124,10	2,17	0,03	9,66	19,04	24,40
X1-45	378,77	2,71	123,96	3,11	0,15	14,29	29,51	45,18
X1-46	340,60	4,51	112,83	2,96	0,14	13,93	25,14	31,61
X1-47	198,00	4,48	113,54	2,21	0,00	12,58	12,91	12,41
X1-48	229,00	5,53	110,76	3,43	0,18	13,81	26,87	32,52
X1-49	403,02	7,61	154,67	2,43	0,12	15,14	18,41	14,46
X1-50	698,74	5,41	105,20	2,91	0,16	11,17	29,36	43,62
X1-51	682,00	6,55	141,26	4,23	0,09	11,05	31,35	49,69
X1-52	274,52	5,87	105,51	3,79	0,12	13,33	25,15	26,12
X1-53	289,00	10,84	153,01	4,19	0,20	14,02	28,80	18,04
X1-54	174,42	4,58	127,77	2,75	0,05	14,17	18,74	17,30
X1-55	600,00	6,47	140,47	4,48	0,18	9,43	34,31	10,54

DMU	target input 1	target input2	target input3	target input 4	target out-put1	target out-put2	target out-put3	target out-put4
X1-56	316,51	5,24	109,05	2,81	0,06	12,90	18,93	15,53
X1-57	739,49	5,09	126,68	2,24	0,10	8,19	31,07	42,10
X1-58	436,97	2,68	110,81	3,28	0,18	14,73	29,14	48,61
X1-59	297,00	6,18	106,37	4,87	0,07	10,25	20,16	37,49
X1-60	578,88	5,09	111,09	2,70	0,15	12,84	27,56	37,29
X1-61	538,00	9,26	163,31	3,48	0,12	14,37	28,94	49,76
X1-62	619,22	5,35	105,36	3,06	0,15	14,62	27,74	36,26
X1-63	336,32	3,01	149,71	2,64	0,09	12,83	19,18	34,67
X1-64	704,00	7,42	100,94	3,54	0,15	7,02	29,10	39,11
X1-65	118,00	4,07	179,68	4,89	0,05	14,77	26,08	14,79
X1-66	130,00	5,50	122,09	4,75	0,14	13,53	14,05	38,87
X1-67	322,00	10,99	122,91	2,71	0,11	16,87	11,41	16,39
X1-68	862,68	7,53	117,24	2,25	0,14	8,13	25,53	45,06
X1-69	663,61	6,64	106,24	2,64	0,11	10,10	24,82	35,29
X1-70	241,22	2,87	161,39	3,22	0,10	13,31	24,88	32,02
X1-71	226,00	13,21	139,10	3,31	0,12	11,14	33,43	38,37
X1-72	637,32	5,94	103,33	3,38	0,16	10,17	28,70	41,86
X1-73	573,17	5,92	116,56	3,15	0,15	11,19	31,98	38,76
X1-74	309,45	3,57	120,87	2,50	0,06	11,99	21,70	27,67
X1-75	499,28	8,53	106,91	3,04	0,08	12,71	20,44	39,48
X1-76	214,74	6,35	105,74	3,98	0,14	15,95	29,19	22,04
X1-77	523,83	2,74	114,51	2,82	0,13	11,46	21,79	42,99
X1-78	602,01	4,10	107,04	2,88	0,15	15,40	24,97	41,84
X1-79	647,63	6,74	103,13	3,31	0,14	11,45	26,25	35,65
X1-80	297,85	6,63	102,99	4,10	0,15	15,76	30,61	13,83
X1-81	930,00	6,05	104,34	2,34	0,11	15,50	18,87	34,86
X1-82	307,30	4,90	111,01	2,44	0,04	11,68	16,22	16,42
X1-83	415,00	2,71	108,26	3,31	0,19	15,62	30,45	49,70
X1-84	486,73	6,42	103,49	3,55	0,13	15,97	26,90	19,73
X1-85	406,64	3,25	111,23	3,37	0,19	15,51	30,34	47,60
X1-86	678,00	6,27	121,75	3,29	0,04	15,18	20,94	49,76
X1-87	718,90	7,33	101,16	3,46	0,15	7,58	28,42	38,83
X1-88	630,58	5,61	124,21	2,38	0,08	14,28	19,82	32,48
X1-89	303,00	2,11	176,42	4,16	0,01	3,35	30,55	9,20
X1-90	258,00	12,88	198,45	4,28	0,13	5,80	31,38	45,53
X1-91	580,13	5,92	106,40	2,72	0,10	9,59	22,74	28,43
X1-92	108,00	3,23	180,94	2,72	0,07	16,15	21,03	30,49
X1-93	156,00	10,75	109,31	3,57	0,03	14,77	15,43	42,16
X1-94	952,00	14,57	155,79	2,54	0,16	14,84	26,82	34,10
X1-95	270,00	10,27	178,41	2,36	0,04	14,47	7,71	26,31
X1-96	745,98	7,28	114,38	2,55	0,17	10,83	29,24	46,78
X1-97	442,31	7,11	135,00	2,36	0,15	12,54	24,90	19,96
X1-98	392,64	3,78	111,11	3,33	0,18	15,21	30,76	47,88
X1-99	873,00	6,60	110,05	3,75	0,18	15,73	18,98	32,16
X1-100	262,00	9,65	150,57	2,42	0,05	13,73	20,39	37,73