Values in Health Technology

Understanding the Creation of Value in the Value Chain of Point-of-care Diagnostics

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SIM-Master Thesis

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The doctor of the future will give no medicine,
but will interest her or his patients in the care of the human frame,
in a proper diet, and in the cause and prevention of disease.
Thomas A. Edison *(1847 - 1931)*

Try not to become a man of success but rather to become a man of value.
Albert Einstein *(1879 - 1955)*

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In this research I aimed to connect my ideals with academic research and practical hands-on experience and insights from people in the 'industry'. I hope I have succeeded in the sense that this thesis provides an integrative perspective on how to manage technological innovation in healthcare.

Puck ten Kate

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Abstract

Health care in Western countries will face a number of challenges in the next following years. There is growing recognition that a solution resides in a shift towards value-based competition in health care. (Porter and Teisberg, 2006; Gaynor, 2006) In addition, there are high expectations of high-value medical technologies being a part of the solution for a more efficient allocation of resources in healthcare, for example E-health, smart homes, preventive medicine, and diagnostics and screening (Rathenau, 2007; Mongan et al, 2008). Point-of-care (POC) diagnostics is one of these high-value medical technologies, that is considered very promising. POC diagnostics are defined as *analytical testing activities near or at the site of patient care, outside clinical laboratories.* These new diagnostic devices deliver quick results possibly within minutes, are small and handheld, and enable data management and communication with a larger IT environment. The devices can be designed for primary, secondary and home care diagnostics. (Lee, 2008) There is a gap between the economic and societal need for high-value medical technologies, and successful examples of competition driving value innovations. In addition, countries seem to perform differently in delivering value through medical innovation. This suggests a need for a more sophisticated model for developing high-tech medical innovations, taking into account system specific influences of the health care system. These observations have lead to the main question of this research: *What is the influence of the healthcare system on the value chain of Point-of-Care diagnostics, and how can differences be explained between the Dutch and the UK health system?* To be able to analyse the systemic influences, a comparison in made between the Dutch and the British health care system. This comparison is interesting because both countries have introduced elements of value-based (managed) competition in health care, and will face the same sort of challenges (Gruijters, 2011; OECD, 2011). These countries have distinctive ways of financing health care, which makes it possible to generalize findings to some extend to other countries. (Gaynor et al, 2010; Ven and Schut, 2008) In order to answer the main research question, the research is structured according to 4 sub-questions: *1) how can value be defined in health care?* 2) *Which characteristics of biosensor technology are important in terms of value and how is value created in the value chain of POC diagnostics? 3) What is the influence of the key components in the British health care system (…) ? 4) What is the influence of the key components in the Dutch health care system on the creation of value through POC diagnostics?*

There is increasing awareness that value based competition may be a solution towards a more sustainable allocation of resources in health care, but an ongoing discussion on how value should be defined and how to adjust current structures underpins the usefulness of better understanding of how value is created (Buxton and Chambers, 2011; Faden and Chalkidou, 2011; Meijboom et al, 2011; Rhin et al, 2009). High-value emerging medical technologies as biosensor technology answer a societal need for proactive, full cycle healthcare services as preventive care, personalized medicines, and active health risk monitoring (Porter and Teisberg, 2006). However, these technologies have little chance of delivering value in health care when using current business models. Innovation research on value-based competition in health care aims at bridging the gap between the societal need for high-value healthcare services and emerging medical technologies.

The theoretical framework is built on Porter's model of value-based competition, insights on the value chain and the innovation systems' approach. (Porter and Teisberg, 2006; Burns et al, 2002; Hekkert et al, 2006). A conceptual model is used as an analytical framework in the comparison of the British and Dutch health care system. The methodological function of the research question is comparative. The intended domain of the research is the Dutch and the British Health care system, defined as the network of institutions in the public and private sector whose activities and interactions initiate, import, modify and diffuse point-of-care diagnostics (Kuhlmann and Arnold, 2002). Technical, medical and innovation literature on biosensor technology and POC diagnostics are used to explore the value chain of POC diagnostics. For the empirical analysis representatives of the main organizations and institutions in the health care system around point-of-care diagnostics are interviewed in the Netherlands and the United Kingdom. Point-of-care diagnostics is an emerging technology and the concept of value-based competition is introduced only recently, which both make it difficult to assess in quantitative terms (Gaynor, 2009). Therefore possible influences from the health care system on the creation of value through POC diagnostics is analyzed in a qualitative manner.

The concept of value as defined in theory seems to apply to the various ways that Point-of-care diagnostics can deliver value in practice. The different dimensions of the way that POC diagnostics can deliver value are 1) Analytical accuracy, 2) Diagnostic accuracy, 3) Clinical utility, 4) Cost-effectiveness (the financial case), and 5) Indirect utility ((non-)medical impact on post-diagnostic care path). Biosensor-based POC diagnostics have the potential to deliver value in the health care system in diverse applications. This study has indicated that different types of POC applications and different points of care are related to different end-users, different regulation, and a different *process to deliver value*. To increase the chance for manufacturers/other parties involved in the development of POC diagnostics, ánd develop a business case that is interesting to all parties, a more sophisticated approach/business model is required. In this research we present a value chain approach to deliver value through POC diagnostics. In line with theory, a number of activities are found to be important for the success of a value chain. These are communication, coordination, integration, and keeping the end-user in mind. In case of POC diagnostics, this end-user is heterogeneous and dependent on type and point of application.

With regard to influences of the health care system on the creation of value, there are a number of findings. The anticipated challenges in the health system induce a strong focus on technologies enabling self-management, screening and prevention, smart homes and more efficiency. The political system has an indirect positive effect on the creation of value. Education and research is considered very important in developing POC diagnostics: objective scientific proof is essential to establish analytical, diagnostic, clinical utility and cost-effectiveness claims. Intermediaries can play a facilitating role in the adoption of POC diagnostics by formalizing procedures, conducting policy research, and writing guidance. A social health care system often requires a complex role for a risk bearing third party payer, which may hamper efficiency and innovation. This indicates that manufacturers and third party payers need to collaborate to overcome these barriers. The industrial system needs to adopt an integrative and cooperative model. Regulatory infrastructure is an important requirement for the development of POC diagnostic devices to guarantee quality and safety of the device over time. Physicians are concerned with, and involved in the development of POC diagnostics. Based on findings in this research, the involvement of an experienced practicing physician in the development of POC diagnostics is essential, as this person can identify opportunities and barriers on a medical level that are crucial for the creation of value. Home POC diagnostics are in a very early phase of development. Safety regulations, availability and information are considered important for the use and adoption of home POC diagnostics.
The British health system seems to perform better in delivering value through POC diagnostics in relation to the Netherlands. The lagging behind of the Netherlands in home POC diagnostics might be related to the slow development of the concept of self-management. In the UK, there is a proactive strategy towards patient empowerment and self-management. The infrastructure around POC diagnostics in healthcare is more crystallized in the UK compared to the Netherlands, suggesting more direction and strategy within the health system. Findings have lead to a more thorough insight on the creation of value, and enabled to refine the conceptual model. The aim of the refined model is to be a starting point towards conceptualisation of the creation of value through POC diagnostics.

One of the limitations of using the innovation system's approach is that the explanatory power of the approach lies mainly on macro level, and less on the actions of the 'entrepreneur' (Hekkert et al, 2007). The innovation system suffers from an 'institutional determinism' while the role of the entrepreneur is very important and determining in innovation in reality. This leads to a new question which asks how to organize value chains and chains of care? A value chain approach is considered a promising new approach in health care, but who should coordinate the value chain? Should this role be performed by an independent organization, or is the industrial system most capable to pick up this role?

Findings in this research imply that it is worthwhile to consider diagnostic devices as a completely new and different category in research and policy. The emergence of the Diagnostics Assessment Program supports this view, as it answers a need for complex health technology assessment required for many diagnostic devices. This program underlines that a disruptive innovation as POC diagnostics requires a flexible and response innovation system, in order to enable successful innovation. Findings in this research imply that there are number of enabling factors on a political level for delivering value through POC diagnostics, for example safety and quality legislation of diagnostic devices, which are much more important in health care than in other industries developing new technological applications.

Content

List of Abbreviations & Definitions

Abbreviations:

ACS	Acute Coronary Syndrome
BMA	British Medical Association
DAP	Diagnostics Assessment Program
DBC	Diagnose-behandel combinatie (EN: diagnose-treatment combination)
DH	Department of Health (UK)
EAG	External Assessment Groups
EPR	Electronic Patient Record, (NL: Electronisch Patienten Dossier)
GP	General Practitioner (NL: huisarts)
HCS	(National) Health Care System
IVD	In Vitro Diagnostics
MedTech	Medical Technology
MHRA	The Medicines and Health care Products Regulatory Agency
MTEP	Medical Technologies Assessment Program
NICE	National Institute of Clinical Excellence
NHS	National Health Service
NIS	National Innovation System
NZA	Nederlandse Zorg Autoriteit (EN: Dutch Healthcare Authority)
OTC	Over-the-counter
POC	Point-of-care
POCT	Point-of-care testing
PSA	Prostate Specific Antigen
QALY	Quality Adjusted Life Year
QIPP	Quality Innovation Production and Prevention (DH program)
SHA	Strategic Health Authorities
STD	Sexually Transmitted Diseases
THE	Total Health Expenditures (OECD, 2011)
TTP	Third Party Payer
UMC	University Medical Centre
VC	Value Chain
VWS	Ministry of Volksgezondheid, Welzijn en Sport (Ministry of Health, NL)
WHO	World Health Organization

Definitions:

Analytical accuracy	*Validity and reliability proven by means of medical scientific results (CVZ, 2011)*
Clinical utility	*The health related outcome of test-plus-treatment-strategy (CVZ, 2011)*
Cost/effectiveness	*Total costs of test-plus-treatment-strategy and (unwanted) side-effects (CVZ, 2011)*
Diagnostic accuracy	*The value of the diagnostic test is that difference in health outcome resulting from the test (Fineberg, 1987)*
DBC	*Diagnosis-treatment combination: a reflection of actitivities and treatments that take place in the hospital, based on the diagnosis and needs of the patient, from first consultation to the final control appointment. A set amount of money is to be reimbursed per specific DBC. (DBC-Onderhoud)*
In Vitro Diagnostics	*A medical device that is used in the diagnostic process to rule out a disease or condition by indicating the presence or absence of marker for this disease* (EDMA, 2011).
OTC/Home care	*Non-prescription drugs/health services/medical devices sold by non-pharmaceutical retailers*.
Point-of-Care (testing)	*Analytical testing activities near or at the site of patient care, outside clinical laboratories* (Burnell, 2008)
Primary care	*First point of contact for people needing care, freely accessible health services. The general practitioner has a central role in primary care.*
Secondary care	*Acute care or specialist care, accessible after referral from primary health professional* (NL: tweedelijns zorg)
Supersession	*1) the act of replacing a thing or person by another one especially held to be superior; 2) when a queen bee is superseded by a younger and superior queen bee; 3) "creative destruction".*
Supersession case	*Incorporating the (cost-, time-, labor-) savings of replacing a medical procedure/ process/device by a new one in the cost-effectiveness of the new product.*

1. Introduction

Health care spending grew rapidly in most countries between 1960 and 1980, and has continued to grow ever since. Switzerland spent 7.3% of their GDP on health in 1980, which has increased to 10.7% in 2008. Similar patterns can be seen in the Netherlands, Canada - resp. 9.9% and 10.3% in 2008 - and other OECD countries (Folland et al, 2010; OECD, 2011). There is broad agreement that ageing of the population, treatment of chronic diseases, and medical technology has changed the scope of health care in the past decades. To address the increasing need for health care and to prevent healthcare from becoming unaffordable (Wolf et al, 2005), governmental policy has primarily focused on cost and efficiency. These measures have not yet resulted in a better allocation of resources in health care, neither has it reduced the rate of growth in health care spending (Folland et al, 2010). The growing body of scientific, policy, and management research in this field reflect an urgent need for better, high-value health care. (Mongan et al, 2008).

In many sectors, competition drives improvements in quality and cost. Innovation leads to diffusion of technology, excellent competitors prosper, and weak ones go out of business. (Porter & Teisberg, 2006). In line with innovation theory, one can say that competition drives innovation, and innovation drives competition. Entrepreneurs seek to use technological innovation – an opportunity created by a new combination of technological means and market needs – to achieve competitive advantage. A new entrant in the market with a highly innovative product will force competitors to keep improving and innovating as well (Tidd et al, 2005). However, competition in health care does not always reward excellent competitors, and does not drive value improvement as expected. This can partly be explained by some specific features that distinguish health care from other sectors. Consumers are less price-sensitive because they are insured for much of the costs via reimbursement schemes. Also due to the complexity of many health care services, it is difficult for the end-consumer to assess the quality of the health care (Gaynor, 2006).

There is growing recognition that a solution towards a “healthy” and sustainable health care system resides in a shift from classic zero-sum competition towards value-based competition (Berwick, 2003; Steele and Schomer, 2008). Zero-sum competition refers to competition where the sum of the total gains and total loses equals zero, and no added value or objectives are created. Competition in health care should aim at creating value, intended at a patient’s specific medical condition over the full cycle of care (Porter and Teisberg, 2006). Value in health care should be determined by the outcomes and costs of the whole cycle of care, *not only by the costs of individual components*.
The United Kingdom and the Netherlands are one of the first countries that started to integrate the concept of value-based competition into their health care policy, by introducing competition elements aiming at creating quality, innovation and prevention for example (MinVWS, 2011; NHS QIPP, 2011). It is expected that value-based competition will lead to the creation of more value in the healthcare system and more effective allocation of health care resources (Porter and Teisberg, 2006). Parallel to these insights in health care policy and research, there is an increasing attention from consumers for higher-value care within the complete cycle of health care. Consumers are increasingly involved in their health status: managing their health risks, measuring their BMI, and checking cholesterol levels (Rathenau Instituut, 2007). They monitor their own health status using internet information and forums (Yinjiao, 2010; Kendall et al, 2011), illustrating a trend towards value based patient-centered care.

Biosensor-based POC diagnostics are an example of a high value medical technology that is expected to create value in health care. A biosensor is a diagnostic device that couples a recognition element with a transducer and converts the recognition event into an electrical signal (a diagnosis) (Lee, 2008). The diagnostic test device can have the size of a mobile phone, delivering test-results within minutes. The device is sometimes referred to as called lab-on-a-chip, as it saves the laboratory step in the diagnostic process. It is expected to add value, because results are quicker, and it is handheld and user-friendly. The technology also enables storing data over time and communicating with a larger IT environment.

It is expected that biosensor technology will play an important role in point-of-care diagnostics (Luong et al, 2008). Point of care diagnostics (POC) can be defined as *analytical testing activities near or at the site of patient care, outside clinical laboratories*. POC diagnostics answer a need for patient-centred care, where the diagnosis takes place at the site of the patient, at the bedside for instance. Although biosensor technology is being used in a number of care settings at the moment, the technology is still in early phase of development and no dominant design has emerged yet (Frederix, 2011).

1.1. Problem Description

There is a societal and economic need for high-value medical innovations as biosensor technology that add value in health care. Value-based competition seems to be a good instrument to stimulate high-value medical innovation, but successful examples of competition driving these innovations remain scarce (Christensen, 2009). In addition, countries seem to perform differently in the successful adoption of medical innovations, which suggests that systemic factors play a role. The gap between a need for high-value medical innovation, and the successful adoption of these technologies into the health care system, suggests a need for a more sophisticated innovation model for value-based competition in health care, taking into account the surrounding system influences (Christensen et al, 2009; Mittra et al, 2010). This requires a more thorough understanding of how value is created in the health care value-chain, and what the influence is of the surrounding health care system. To be able to take into account system specific differences, an international comparison can be very insightful. The Netherlands and the UK are of interest for this purpose, as they both have introduced elements of value-based competition into the health system, but both have different ways of financing their health care. Biosensor technology is an interesting technology in this context, because it is in an early phase of development, and considered to be high-value in a value-based healthcare system.

1.2. Aim & Research Question

The aim of this research is to explore how value is created through biosensor technology within the value chain of POC diagnostics, and to explore the influence of the surrounding health care system on this creation of value. To take into account system specific differences, an international comparison is made. The central research question that is derived:

> *What is the influence of the healthcare system on the value chain of Point-of-Care diagnostics, and how can differences be explained between the Dutch and the UK health system?*

In order to answer the research question, the following sub-questions are formulated. These sub-questions reflect the structure of this research.

1. *How can value be defined in health care?*
2. *Which characteristics of biosensor technology are important in terms of value and how is value created in the value chain of POC diagnostics?*
3. *What is the influence of the key components in the British health care system in relation to the value chain of Point-of-Care diagnostics?*
4. *What is the influence of the key components in the Dutch health care system in relation to the value chain of Point-of-Care diagnostics?*

1.3. Demarcation

To take into account possible system specific differences in answering the research question, the Dutch and the UK health care system will be compared. These countries are interesting because both were relatively early in adopting managed competition, which is related to value-based competition, into their health systems. This indicates that the fairly new concept of value-based competition should be in development in these countries (Ven and Schut, 2008). The UK started with the implementation of

managed competition in 2006, by introducing competition between hospitals under set prices (Gaynor et al, 2010). The Netherlands implemented the concept of managed competition also in 2006, by introducing mandatory private insurance and competition between insurance companies (Ven and Schut, 2008). The comparison between these two countries is interesting because the structure of health care financing is different. The Netherlands has social security based health care (SSH) with mandatory private health insurance. The UK, on the other hand, has a national health service (NHS), which means that the basic package is paid by the government from general taxation. More countries are introducing the managed competition concept (Zee and Kroneman, 2006; Gaynor et al, 2010), but experience shows that it is important to remain cautious in generalizing results in a field as country specific as the health care system (Mossialos et al, 2002).

1.4. Scientific Relevance

This research compliments the fairly new, but growing body of literature on value-based competition and innovation in health care technologies. Porter & Teisberg (2006) were one of the first to introduce the concept of value-based competition and innovation in health care for a more effective allocation of resources in health care. The concept of value in health care has gained more and more support in the past years by health experts and scientists (Porter and Kimball, 2008; Rhin et al, 2009). Iribarne et al (2009) address the challenges of the current system of health technology assessment in defining the value of emerging technologies. Perleth and Lühmann (2010) underline that medical technologies often receive the same procedure of value-assessment as medication, illustrating that the health care system is a barrier for innovators. There is increasing awareness that value based competition may be a solution for sustaining effective resource allocation in health care, but an ongoing discussion on how value should be defined and how to adjust current structures underpins the usefulness of better understanding of how value is created (Buxton and Chambers, 2011; Faden and Chalkidou, 2011; Meijboom et al, 2011; Rhin et al, 2009). This research contributes to innovation theory by building on insights from Porter and Teisberg (2006) and Christensen et al (2009), on value based competition and successful innovation in health care. More specifically, theory on the subject will be used to understand the creation of patient-value in the health care value chain of POC diagnostics. Insights may provide a useful starting point towards new innovation models in health care.

1.5. Societal Relevance

High-value emerging medical technologies as biosensor technology answer a societal need for proactive, full cycle healthcare services as preventive care, personalized medicines, and active health risk monitoring (Porter and Teisberg, 2006). These new medical technologies are expected to play an important role in patient empowerment and self-management, which developments are also referred to as “patient 2.0”. Examples are new ‘assistive’ medical technologies and (diagnostic) home care applications that enable independent living for the elderly and the chronically ill (Rathenau, 2007; Christensen et al, 2009). Developments in nano-technology promise a technological revolution that will take place in the health care sector for a large part (Rathenau Nano-Dialoog, 2011; Yogeswaran and Chen, 2008), and biosensor technology is just one example of a technology that experiences a wide scala of new opportunities by incorporating nano-technology (Staples et al, 2005).
However, these technologies have little chance of delivering value in health care when using current business models. Innovation research on value-based competition in health care aims at bridging the gap between the societal need for high-value healthcare services, and emerging medical technologies. Substantial gains in health care delivery can be possible, if competition in health care would drive the pursuit of value for patients, resulting in a healthier population (Porter and Teisberg, 2006).

Outline

Chapter 2 starts with the related theories and presents the conceptual model that will function as framework in this research. In chapter 2 the definition of value in health care will be set out, which is the first sub-question. Chapter 3 present the methods and research design. Chapter 4 answers the second sub-question on biosensor technology and the value chain of POC diagnostics. Chapter 5 and 6 contain the findings on the British and Dutch health care systems, and answer the third and fourth sub-question. Chapter 7 presents an analysis of the results, a comparison between both health systems in order to find an answer to the question how the health care system influences the creation of value in the value chain of Point-of-care diagnostics, and how differences between the UK and NL health care systems can be explained. The research will end with the conclusion in chapter 8 and the discussion in chapter 9.
After chapter 9 the appendices can be found, followed by a list of references.

2. Theory

The theoretical framework is based on two strands of theory within innovation research: the model of value-based competition and the innovation systems' approach. The first theory relates to an emerging field of research advocating that the right use of competition elements in health care stimulates innovation and drives value in health care. The theory of value-based competition provides an insightful framework how to create value in healthcare. However, as the healthcare system is highly specific per country, it is important for innovators to take into account system specific influences (Mossialos et al, 2002). Therefore the theoretical model is complemented by the innovation systems' approach. This theory builds on the insight that differences between national, regional or sectoral 'innovation cultures' originate in historical, industrial, scientific differences and different state and politico-administrative institutions and networks (Kuhlmann and Arnold, 2002).
First the concept of value-based competition, and how value is created throughout the value chain of POC diagnostics will be elaborated. Then the innovation system's approach is briefly described, followed by a conceptual model that combines both theories, and will serve as an analytical framework to find an answer to the main research question.

2.1. Value Based Competition

The concept of value-based competition originated in the work of Alain Enthoven (1988, 1993) on the concept of managed competition, and has emerged from increasing difficulty of various countries in providing access to affordable care (Christensen et al, 2009). Enthoven advocated a new approach in health care, to introduce carefully managed competition elements to stimulate patient value. He defined managed competition as "*A purchasing strategy to obtain maximum value for consumers using rules for competition (...) to reward those health plans that do the best job of improving quality, cutting cost, and satisfying patients.*" (Enthoven, 1993). In their work *Redefining Healthcare* (2006) Porter and Teisberg were able to refine this concept into an approach for manufacturers, buyers, and suppliers of health care services to stimulate value based competition. In their work they highlight the need for a new model for innovation in health care, away from zero-sum competition, towards value-based competition. Zero-sum competition is competition where the sum of the total gains and total loses equals zero, and no added value or objectives are created.

Value based competition is competition in health care aimed at creating added value, intended at a patient's specific medical condition over the full cycle of care, and rewarding positive outcomes (Porter and Teisberg, 2006; Christensen et al, 2009). Research has shown that if healthcare services are focused around a specific medical condition as diabetes type 2 for instance, and not around a medical specialism as cardiology, efficiency and quality of health services increase (Porter and Kimball, 2008; Bloem, 2011). Second, actors in the system should be rewarded according to positive outcomes - being healthy patients. This means that self-management, prevention, and stimulating healthy lifestyles are investments that should be valued in the health system (Christensen et al, 2009; Folland et al, 2010). But what is value, and how should that be measured?

2.1.1. Value in Health Care

The overall goal of providing a definition for value is to help form/force the health care system towards the generation of more value to the patient, higher efficacy (quality) and efficiency, and towards a model that rewards positive health outcomes (Christensen et al, 2009).
There are number of institutions that use *patient-value*, as measurable definition as output measure, in line with Porter and Teisberg (2006). A quantitative way to express patient-value is in QALY for example, which expresses the value of a product in *costs per quality adjusted life-year (see box 2.1)*. Several institutions use QALY's in technology adoption decisions (Anupam and Philipson, 2008). The advantage of formalizing value in a quantitative measure as QALY, is that difficult decisions regarding the allocation

of resources can be made transparent and explicit (Buxton & Chambers, 2011). The restriction of the concept of patient-value is that it considers only value around a patient's medical condition. Other social values as are supposed to be taken into deliberation as well by the assessing committee, but this has shown to be very difficult and challenging in practice (Faden and Chalkidou, 2011). Another important difficulty in healthcare is that there is often no such thing as patient-choice. Determining value on the basis of only patient-needs is risky, as patients are very often not the persons making the buying decision (Folland et al, 2010). One of the reasons is that patients do not have all the information or knowledge that the physician or insurance party has (Folland et al, 2010). Second, decisions and values regarding treatment are constructed throughout the healthcare system and do not only take place at the patients' bedside. Decisions are also constructed through regulation, in insurance contracts, by hospital advisory boards, by quality advisory committees, and routines and preferences of nurses and physicians.

Box 2.1. QALY Calculation

(*Bandolier, Medical Science Division Oxford University, 2011*)

The Quality Adjusted Life Year (QALY) has been created to combine the quantity and quality of life.
The basic idea of a QALY is straightforward. It takes one year of perfect health-life expectancy to be worth 1, but regards one year of less than perfect life expectancy as less than 1. Thus an intervention which results in a patient living for an additional four years rather than dying within one year, but where quality of life fell from 1 to 0.6 on the continuum will generate:

1. 4 years extra life @ 0.6 quality of life values 2.4
2. less 1 year @ reduced quality (1 - 0.6) 0.4
3. QALYs generated by the intervention 2.0

The aim of value-based competition is that it should drive innovations throughout the complete cycle of health care, motivate manufacturers to invest in healthcare, and motivate providers of care to search for quality and comprehensive patient-centred services. Therefore the concept of value should be comprehensive and cover those facets in its definition.

To define the value of POC diagnostics, Publication 293 of the College voor Zorgverzekeringen (CVZ) is used, published in January 2011, which is a guidance on technology assessment of medical tests. Publ. 293 is one of the most recent opinions on how to assess medical devices, a field that is still in full development. In their publication CVZ defines the requirements that a medical diagnostic test should suffice to be reimbursed in the Dutch healthcare system, in line with method on evidence based medicine (EBM), and in line with WHO-opinion on medical tests (CVZ report 293, 2011, Derksen, 2011). CVZ is a Dutch independent committee that advises the government, and hospitals and insurers on request. The opinion by CVZ is valued highly by private and public parties, which makes their assessment criteria of value a useful standard. In addition to the CVZ report, exploratory interviews with experts in the field are held to identify important dimensions of value in point-of-care diagnostics, and imply the value of the medical device in light of the 'manufacturer' and 'consumer'.

It is important to note that the dimensions of value take into account both positive and negative impact in the different dimensions. Value is often assessed in comparison/relation to current practice.

The following list shows the dimensions of value of POC diagnostics in this research, and together form an answer to the first sub-question "how can value be defined in health care?" specifically for POC diagnostics.

Dimensions of value of point-of-care diagnostics in health care:

1. **Analytical accuracy**; validity and reliability proven by means of medical scientific results.
2. **Diagnostic accuracy**; "the value of the diagnostic test is that difference in health outcome resulting from the test" (Fineberg, 1987, Raport CVZ). Diagnostic accuracy does not necessarily need to be proven before point 3 in technology assessments (Lijmer et al, 2009).
3. **Clinical utility**; the health related outcome of test-plus-treatment-strategy. This implies that for each indication and diagnose-treatment combination a specialized assessment should take place. Clinical utility can be divided in two aspects;
    a. Physical: testresult > clinical response > yes/no intervention > health outcome
    b. Mentally: emotional, social, cognitive, behavioral > health outcome

    It is best to prove the clinical use by at least 2 RCT's (randomized controlled trials).
4. **Cost-effectiveness**; total costs of test-plus-treatment-strategy and (unwanted) side-effects. This also includes the long-term cost of maintanance of analytical accuracy. This 'financial case' should take into account the manufacturer's and the third party payer's perspective as well (Kooij, 2011).
5. **Indirect Utility**; non-health related (efficiency) impact on the procedures, routines, social behavioural impacts, life-style, or other non-medical effects. Next to the medical impact of technology, technology might have a profound indirect impact on society for instance, which can be an additional value as well (Rathenau, 2008).

As the concept of value of POC diagnostics in healthcare is defined, the following step is to understand how value is created/delivered. A useful model to illustrate how value can be created is Porter's value chain, developed from supply chain management literature. This model is appropriate as it already encompassess the concept of value, and provides an cooperative approach for organizations involved in delivering a specific product, which is often suggested a useful model especially in healthcare (Lushai, 2011). The following section will briefly describe the value chain theory, towards model for Point-of-care diagnostics, which will be used during the research to answer the second sub-question.

2.2.2. The Value Chain

A company's value chain is a system of inter-dependent activities, which are connected through linkages. When one activity is performed this affects the cost or output of other activities, so managing linkages often result in optimization of performance. The value chain of one specific company is often embedded in an industry or sector. (Porter and Millar, 1985) This larger system also exists of linkages between different companies, and can also be seen as a value chain (figure 1). The notion of value chain management is increasingly being used in health management and economics research and practice (Ahgren and Axelsson, 2007; Meijboom et al, 2010). Several countries (The Netherlands, Sweden e.g.) use the concept of 'chain care' to describe the total of interconnected care efforts by various care providers to a patient's specific medical condition. A value chain for medical devices can be defined as: "*a virtual network that facilitates the movement of a product from its earliest point of production, through packaging and distribution to point of consumption*" (McFadden et al, 2000).

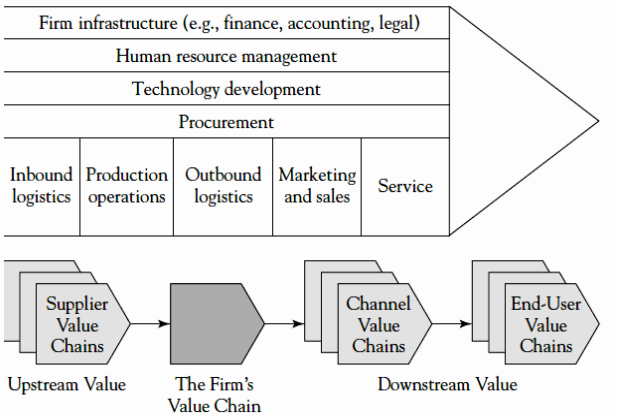


Figure 2.1 - Porter's Value Chain (Burns et al, 2002)

"The product" that the value chain concerns is point-of-care (POC) diagnostics in this case. The earliest relevant point of production is the new combination of biochemical knowledge with the measuring component that delivers a signal. In classic supply chain management the start of the value chain is the processing of raw materials needed for the device. However, speaking of a value chain, we mean the process of adding value in each step, *starting from the point of the user and then backwards* (Burns et al,

2001; Meijboom et al, 2011). Innovation theory defines the start of an innovation as an opportunity created by a new combination of technological means, knowledge, and market needs (Tidd et al, 2005). Therefore the first step in the value chain that adds value to the user is the newly combined knowledge. The biochemical knowledge does not provide value and neither do the individual components. It is the combination of the two that potentially adds value.
The physical point of consumption is dependent on the application, and on whether the device will be used in primary, secondary, or home care. Primary care is in principle the first point of contact for most consumers with health care, and is delivered by general practitioners, dentists, and pharmacists for instance. Secondary care is known as acute care, and can be emergency or specialist care. Specialist care is often planned specialist medical care or surgery. A third area of application of POC diagnostics is over-the-counter or home care. However, if the point of consumption is defined as 'point of care' then elements of the value chain remain the same for each of the markets, making it possible to make some general observations. Point of care is defined as 'near the patient, at the point of need', which then covers primary, secondary and home care. (Biosensor Summit, 2010)
From health research and explorative interviews with experts in the field, five main actors can be identified that are involved in delivering value in medical technology. No research was found that describes the actors in the value chain of POC diagnostics specifically. The actors identified are manufacturers of medical technologies (medtech), (conceptual) designers of medical technologies, third party payers, sellers of care, and providers of care (Burns et al, 2002; Meijboom et al, 2010). Figure 2 shows the value chain of POC diagnostics. The actors in the value chain do not have fixed positions and are supposed to have cross-chain linkages.

The output of this value chain is *value through POC diagnostics*.

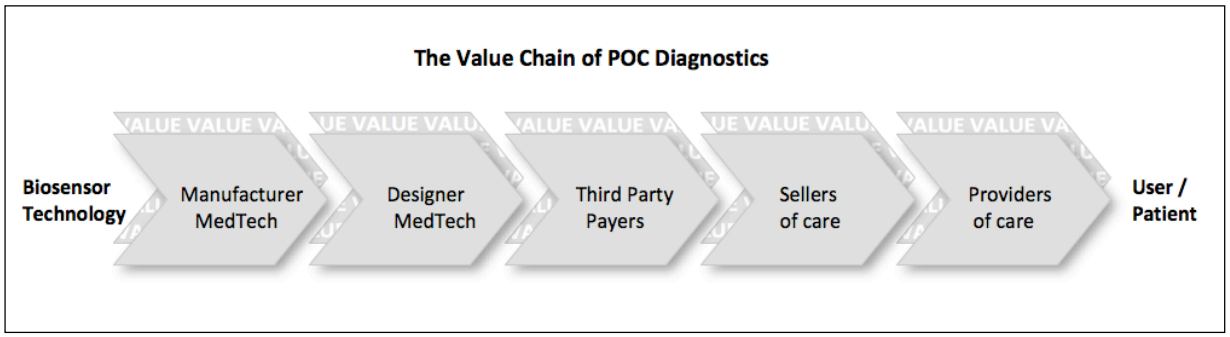


Figure 2.2 – The Value Chain of POC diagnostics (adjusted from Burns et al, 2002)

Value chains, as networks of interconnected companies, are supposed to develop as strategies of competitive advantage in which one set of trading partners seeks to create more value than a rival set of trading partners. Companies find it more difficult to enter and survive the health care market, as this market involves complex regulation, not a single buyer, and large number of involved parties. A value chain (VC) approach is increasingly considered a promising competitive strategy in health care (Burns et al, 2002; Meijboom et al, 2010). In line with innovation theory, there should be a feedback loop from the end-user to the value chain, to enable incremental innovation and create a *sustainable* strategy (Tidd et al, 2005). Based on research a number of important activities are identified that should be taken care of by the organizations within the VC to successfully create value.

2.2.1. User needs as starting point

As explained, the process of adding value in each step of the value chain starts from the point of the user and then backwards. In the 'heart' of value chain management are the needs of the patient or the user of the diagnostic device. Delivering value to the end user, developing relations, and investing in feedback information flows from users, enables the value chain to respond to those needs in a timely, qualitative, effective, and innovative way (Tidd et al, 2005; Al-Mudimigh et al, 2004).

2.2.2. Communication

Careful management and optimalization of linkages is often seen a powerful source of competitive advantage (Porter and Millar, 1995), Essential activities are communication and collaboration between organizations within the value chain (Meijboom et al, 2010; Al-Mudimigh et al, 2004).

2.2.3. Integration

Another element important in a value chain is integration. Core activities and processes of the involved organizations need to be complementary throughout the value chain, accumulating value. In addition, the activities within the value chain should aim at delivering a product that can be integrated in health care. Studies have shown that a value chain that is focused around a specific medical condition, increases quality and experience in the health care service. Quality in healthcare is driven by provider experience, scale and learning at the medical conditions level (Porter and Teisberg, 2006; Christensen et al, 2009). Because activities within the value chain are integrated, and aim a specialized care path, this generates experience and enables quick learning throughout the value-chain (Christensen et al, 2009).

2.2.4. Coordination

Two of the most important activities, communication and integration are the most difficult factors in value chains in healthcare (Meijboom et al, 2010; Ahgren and Axelsson, 2007). That is because this approach requires completely new methods of cross-organizational communication, and trust. Also acceptation from the medical profession is often a barrier (Ahgren and Axelsson, 2007). From several fields of research increasingly an important coordinating leader-role is emphasized for the success of the value chain and innovation in healthcare.
Health care research points out the importance of a (Point-of-) care coordinator in care chains, to bridge the gap between health professionals and organizations involved in delivering care (Meijboom et al, 2010). However, current 'health managers' do not seem to have the management equipments necessary for coordinating the care chain (Ahgren and Axelsson, 2007). Policy should stimulate the provision of more coordinated services. "*Using the supply chain metaphor for health care would require the appointment of some kind of power broker in the chain playing the role as 'leader' and using its commercial power to enforce cooperation*" (Meijboom et al, 2010, p. 15)

The creation of value through value-based competition can be a useful way to drive innovation and quality in the health care system. Added value with point-of-care diagnostics can be expressed in 1) analytical and 2) diagnostic accuracy, 3) clinical utility, 4) cost-effectiveness, 5) indirect utility.
Within the value chain of POC diagnostics, which can be seen as network of interrelated linkages, a number of important actors can be identified: manufacturers and designers of medical technologies, third party payers, and sellers and providers of care. Within the VC of POC diagnostics, a number of important activities are identified that should take place within the value chain, to be able to create value throughout the value chain.
The value chain of POC diagnostics, which aims at delivering value, interacts with the surrounding health care system. The environment shapes opportunities and innovations, and technology shapes the environment (Lente and Rip, 1998). During the development of a technology, this interaction plays a substantial role in the possibilities and outcome of the technology (Edquist, 2004). This makes it useful to assess the creation of value in context of the surrounding innovation system.

2.2. The Innovation System's Approach

The concept national, regional or sectoral "systems of innovation" originated from the work by economists Freeman (1987), Lundvall (1992), and Edquist (2004) as explanations for the varying degrees of competitiveness of economies, with special focus on their technological performance and the ability to innovate (Hekkert et al, 2007). It is generally agreed that innovation is not an isolated process of individuals or firms but is the outcome of the interaction between firms, customers, suppliers,

competitors and various other private and public organisations in a system (Lundvall, 1992).
The innovation systems' approach offers a holistic, multi-disciplinary approach to innovation, incorporating industrial and scientific differences and different state and politico-administrative institutions and networks. These systemic differences crucially affect the ability of innovators to produce and support successful innovations, which is a way of adding value (Kuhlmann and Arnold, 2002).
The classic map of the innovation system describes seven important institutions and organizations that interrelate and influence each other. In healthcare an eighth important component can be identified, being the third party payer that bares the financial risk within the system (Ven, Schut, Rutten, 1994). The third party payer is added to the classic system map, shown in figure 3.

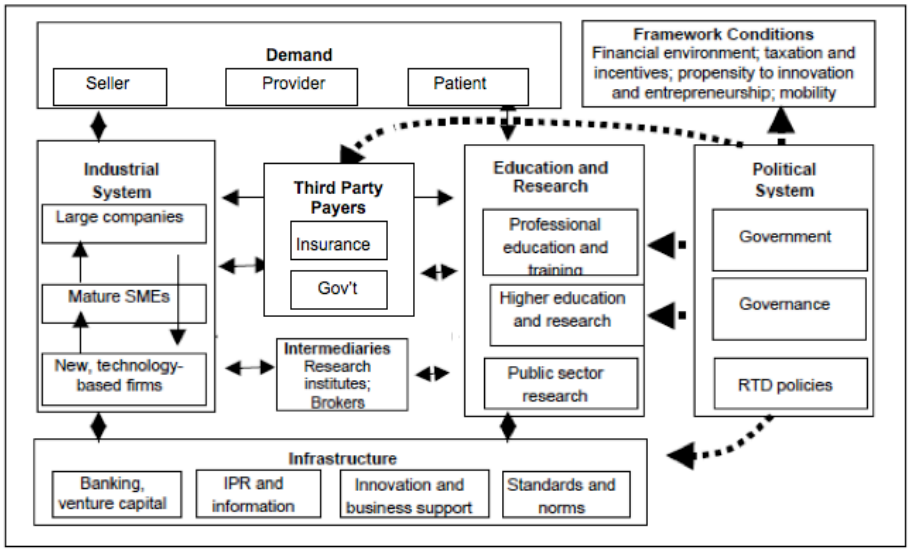


Figure 2.2 - The Health System (Adjusted from Kuhlmann & Arnold, 2002)

The innovation system approach is a way to explore the influence of different components in the system on the development, diffusion and use of innovations (Edquist, 2004). Biosensor-based Point-of-care diagnostics is considered a high-value medical innovation. So the creation of value through point-of-care diagnostics in the health systems, can be considered a succesful innovation. In the same line of reasoning, *if a specific component in the health care system has a hampering effect on the innovation process of POC diagnostics, then this will have a hampering effect on the creation of value through POC diagnostics in the health care system*.
In the following sections the role of the different components in the healthcare system will shortly be elaborated. In addition the assumed effect of the organizations and institutions in the system on the value chain of point-of-care diagnostics will be provided, based on innovation and health management literature. These assumptions are summarized in hypothesis 1 to 8.

2.3.1. Framework Conditions

The framework conditions of an innovation system contain the financial environment, taxation and incentives (subsidies), propensity to innovation and entrepreneurship, and mobility (Kuhlmann and Arnold, 2002). A number of developments currently determine the current framework conditions in the health system. Many western countries currently have a challenging financial position, and focus on cost-savings in all (public) sectors. In addition, the growth in health expenditures as % of the GDP is larger than the inflation rate in many countries, putting pressure on solidarity and universal accessibility of health care (Folland et al, 2010; Vossenaar, MinVWS, 2011). Overall the framework conditions are strongly focused on cost-savings, suggesting less investment in innovation. If framework conditions have a hampering effect on innovation, it is possible to assume that there will be a hampering effect on the creation of value through point-of-care diagnostics.

H1: *The framework conditions have a negative influence on the creation of value through biosensor technology in the value chain of POC diagnostics*.

2.3.2. The Political System

The Political System entails a system's government structure, the governance, and RTD policies. This group contains the government in general, the Ministry of Health, and health regulating bodies. The political system is a source of regulations on competition and prices, and guidance on technology assessment (NZA, 2011; VWS, 2011). Ideally guidance and regulations are frequently updated and revised according to research, or EMA, or WHO standards for example (CVZ, 2011). Research has shown however that there is little flexibility in regulation towards disruptive initiatives, as there are always many people that benefit if everything stays the same. The regulations are toppled only when disruptive innovators find applications or markets beyond the reach of the regulators. If they succeed in that context – the regulation ultimately succumbs to the evidence (Christensen et al, 2009). Innovations that fit in current regulation may be supported by the political system, disruptive innovations might be negatively influenced by the political system. As POC diagnostics are an emerging and disruptive innovation, the political system may have a positive and negative influence on the creation of value:

H2: *The political system may have a positive and negative influence on the creation of value through biosensor technology in the value chain of POC diagnostics*

2.3.3. Education & Research

The group education and research contains professional and educational training, higher education and research, and public sector research. The important role of education and research in the creation of patient-value is that it can work as a catalyst. One of the specific difficulties in health care at the moment is that all stakeholders are fragmented, disciplines are fragmented and goals are fragmented (Christensen, 2009). Theory states that if all stakeholders, specifically the end users of the product are involved and educated about developments in medical technology, that the adoption barrier of new technology is lowered (Tidd, et al, 2005). Another important role research and education can have is that knowledge is shared throughout the value chain, which is an important determinant for the competitive success of a value chain (Burns et al, 2002).

H3: *Education and Research has a positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics*

2.3.4. Intermediaries

The main role of intermediaries is the information scanning and gathering, and communication of that information, often referred to as the 'bridge' function (Howells, 2006). Intermediaries in the health care system are research institutes, professional organizations, organizations providing health care guidance for instance. The role of intermediaries is also related to expert knowledge on a specific technology, in which they have insight and foresight and can advice components within the system. This is very useful for companies in a very early stage of development to already take into what would be patient-value at the end of the value chain. In addition, the role of intermediaries can be important to facilitate the knowledge (by research and education) to be shared throughout the value chain, which is an important determinant for the competitive success of a value chain (Burns et al, 2002).

H4: *Intermediaries have a positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics.*

2.3.5. Third Party Payers

Based on one of the specific characteristics of healthcare, namely risk and uncertainty for the consumer, the concept of third party payers was introduced. In healthcare is often spoken of a three-party system of consumers, 'sellers of care', and 'third party payers' of care. Because the consumer/patient does not know when he will need healthcare, how much healthcare he will need, and he cannot assess the effect of the often complex treatment, there is a large financial risk for the patient may he become ill. Through national taxation or health insurance, this risk can be transferred from the individual patient, to a third party – the insurance or the government. Because there is a 'knowledge asymmetry' between the consumer and the 'seller', the third party payer can take the role of prudent buyer in choosing the right care. A third motive for a third party payer is that the system creates externalities: the possibility to respond to infectious diseases and manage public health. (Ven, Schut & Rutten, 1994) Based on these special characteristics of health care, the following main functions of third-parties are distinguished:

1. The ***insurance*** function: taking over the consumers' financial risk of becoming ill.
2. The agency function:
   - Reducing moral hazard (overuse of care by consumers)
   - Providing information about the quality of care;
   - Being a prudent buyer of care on behalf of the consumer.
3. The access function: to guarantee universal access to basic health services.

Third party payers can be the government, private organizations or a combination. Intuitively it would seem that independent of the system of financing, a third party payer benefits most from a healthy patient as they often receive a fixed amount of money per person (Porter and Teisberg, 2006). Creation of value should then be positively rewarded by the third party payers. However, in practice this is more complex. A third party payer system often comes with a complex risk equalisation scheme, and many regulations, which makes that incentives to invest in a healthy population are reduced or indirectly play a role (Hasekamp, 2011). The budget for health care can be privately or publicly managed, and whether a product will get access to the health system, may be 'open' or regulated (CVZ, 2011). The role, activities and responsibilities of the third-party payer in healthcare determine the influence of the third party payer on the value chain of POC diagnostics.

H5: *The Third Party Payer may have a positive and negative influence on the creation of value through biosensor technology in the value chain of POC diagnostics.*

2.3.6. Industrial System

Organizations or entities that fall within this group in case of point-of-care diagnostics can be (large) pharmaceutical or medical devices companies, mature SME's or new technology based firms. It is important in health research to not only take into account health related companies, as innovation often originates from new combinations of knowledge (Tidd et al, 2005). The industrial system needs a systemic approach if they want to launch radical high-value innovations, this is because "*When disruptive innovators assume that relying on the existing value network is cheaper, they invariably find that ensconcing their 'piece' of the system into the old value network kills their innovation*" (Christensen, 2009). A value network needs an initiator to form a new disruptive value chain for high-value innovation, and examples have illustrated that this leader initiative often lies with a key initiator in the industrial system (Burns et al, 2002, Tidd et al, 2005).

H6: *The industrial system has a positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics.*

2.3.7. Infrastructure

Infrastructure usually refers to the complex of non-natural resources that are collectively used. This includes energy supply systems, water supply, transport systems, but also non-physical components as technical standards, educational provision and legal systems. Infrastructure can be very influential on the innovation opportunities in the industrial system (Edquist, 1997). The UK and the Netherlands have comparable physical public infrastructure in the sense of telecommunication, banking and transport. Especially with regard to the medical innovations, the legal infrastructure often plays an important role (FitzGibbon et al, 2010). Currently legal infrastructure regarding health care relies heavily on evidence-based (rational) decision making, which might not match to value-based competition. Infrastructure is more likely to reflect old values and norms, than new ones which is often considered a barrier for innovators (Tidd et al, 2005). If infrastructure forms a barrier for the innovation process, then it is possible to assume that there will be a hampering effect on the creation of value through biosenser-based POC diagnostics.

H7: *Infrastructure negatively influences the creation of value through biosensor technology in the value chain of POC diagnostics.*

2.3.8. Final Demand

The last important component of the health care system can be defined as final demand. Three groups of demand can be identified when it concerns medical devices: 1) consumer/patient, 2) the health care provider (health professional/doctor/nurse), and 3) the 'seller of care' (Folland et al, 2010). The seller of care buys the medical device from a supplier, and may negotiate reimbursement prices with the third party payer if relevant. This party is called seller of care, as the product is being sold here, from the manufacturer's point of view. The seller of care can be the hospital, an elderly home, a pharmacy, or a health management centre for example. The overall theoretical assumption is that demand is homogenous and represents 'user needs', which are defined by the patient mainly and by the provider, and affect all steps of development in the value chain.
Research has shown that when a technology moves from a conceptual and experimental stage, to the search of a dominant design, it is essential to take into account user-input (Teece, 1986, Tidd et al, 2005). The user of the diagnostic medical device can be the patient or the provider of care, dependent on the application. In addition, provider involvement in an early stage may reduce distrust in the health value chain. Distrust from the provider of care that the concept is supply-driven, is often considered a barrier in health care value chains (Burns et al, 2002).

H8a: *Early patient and provider involvement has a positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics.*

H8b: *Early user involvement increases the chance of successful innovation, and thus has a positive influence on value chain of POC diagnostics.*

There is an important development in the perception of patients of the health care system, which could also be called a paradigm shift (Tidd et al, 2005). The patient, or the consumer, is becoming more active in self-management of their health. They self-diagnose by use of the Internet, they take increased

responsibility for their own health, they visit their GP prepared with questions, and do not hesitate to ask a second opinion (Kendall et al, 2010, Yinjiao, 2010). Research suggests that self-management does not lead to increased demand in health care, but decrease in demand (Bloem, 2011). The shift is at least partly (information and communication) technology driven (Rathenau Nano-dialoog, 2011), which enables the patient to access information, ask questions, and share knowledge about conditions. This empowered self-managing patient can be a positive driver for the creation of value in the health care value chain. The informed patient knows that quality equals experience multiplied by scale, and wants to choose his own hospital based on specialization (Christensen et al, 2009). The informed patient requires the third party payer to purchase high value health care (Porter and Teisberg, 2006). The needs of this patient is developing towards a need for a health network, where the general practitioner is replaced by a health and wellbeing manager that stays and advices throughout the full cycle of care (Rathenau, 2007; Bloem, 2011).

H8c: *The patient has a positive influence on the creation of value in the value-chain of POC diagnostics, in specific with regard to the role of the third party payer*.

H8d: *The patient has a positive influence on the creation of value in the value-chain of POC diagnostics, in specific with regard to the role of the health care sellers.*

H8e: *The patient has a positive influence on the creation of value in the value-chain of POC diagnostics, in specific with regard to the role of the health care supplier*.

2.3. Conceptual Model

The theoretical framework is summarized in the following conceptual model, that will be used to find an answer to the main research question: *What is the influence of the healthcare system on the value chain of Point-of-Care diagnostics, and how can differences be explained between the Dutch and the UK health system?* First the "creation of value", illustrated by the gray value chain is studied. Then the influence of the surrounding health care system on the value chain is explored which is illustrated in the model by the black arrows and hypotheses. The analysis is conducted by means of a comparison between the UK and the Dutch health care system.

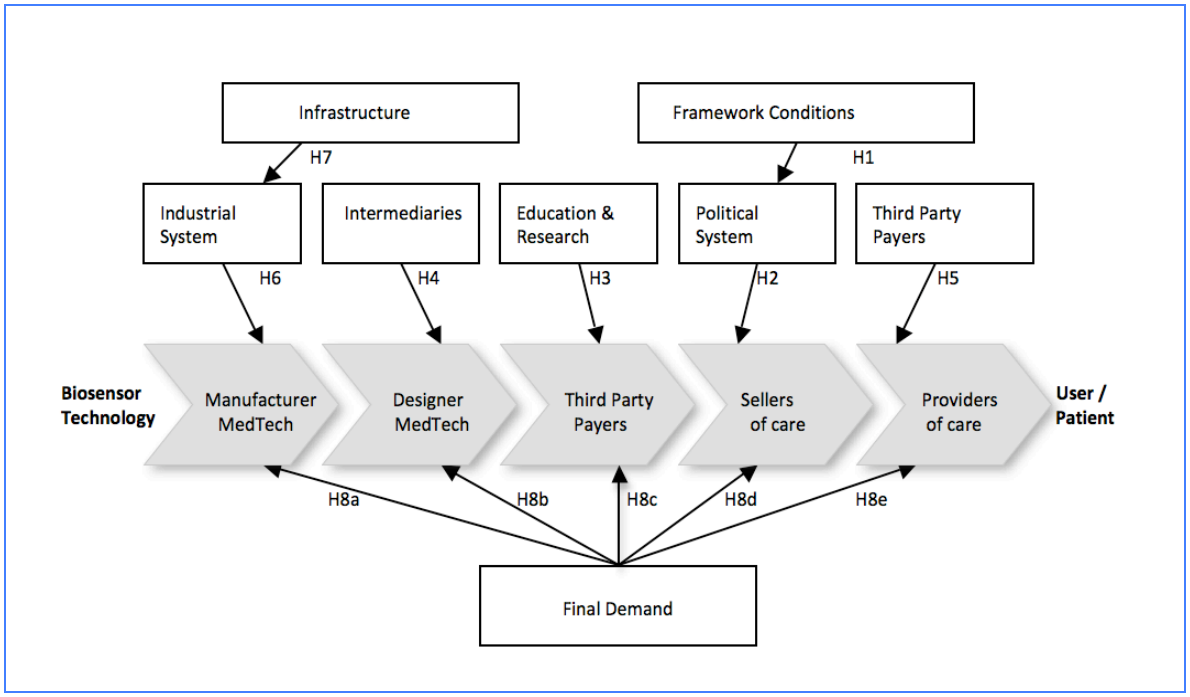


Figure 2.3 - Conceptual Model of the Creation of Value in POC Diagnostics

3. Methodology

3.1. Research Design

The main research question is defined as: *What is the influence of the healthcare system on the value chain of Point-of-Care diagnostics, and how can differences be explained between the Dutch and the UK health system?* The methodological function of the research question is comparative. The British and the Dutch health system are compared in order to get more insight in how value is created in the value chain of Point-of-care diagnostics.

The intended domain of the research is the Dutch and the British Health care system, defined as the network of institutions in the public and private sector whose activities and interactions initiate, import, modify and diffuse point-of-care diagnostics (Kuhlmann and Arnold, 2002). The reason why these countries are selected is because they both face increasing pressure on the sustainability and affordability of good quality care, and they spent around the same % of the GDP is spent on healthcare (8,8 and 9.9% in 2008), which puts the Netherlands and the UK for similar challenges (Gruijters, 2011; OECD, 2011). Both countries have introduced elements for value driving managed competition in the health system. In the UK the system is slowly reformed to make quality and value more visible and subject of competition. In the Netherlands, competition between hospitals is stimulated through increased transparency and development of quality output measures. (Ven and Schut, 2008, Gaynor, 2009). The main difference between the two countries concerns their system of financing health care, which makes it an insightful comparison for gaining knowledge on the influence of the health care system. A comparison between the Netherlands and the United Kingdom makes it possible to analyze the impact of system-specific differences and similarities on the value chain of Point-of-care diagnostics.

For the empirical analysis the main components – organizations and institutions - in the health care system around point-of-care diagnostics were identified for the Netherlands and the United Kingdom. Representatives of the main components were interviewed. The innovation system's approach is a heuristic attempt to analyze all organizations, institutions, and subsystems in their way of influencing Point-of-care diagnostics (Hekkert et al, 2006). These representatives of the important organizations and institutions should cover all relevant perspectives and influences that play a role in the health system. If possible two or more representatives from each important component were interviewed. In the Netherlands a total of 12 interviews were held, and two conferences on the topic were visited. Due time, in the UK 6 interviews were held, and 1 conference was visited. Results are balanced with additional literature research, and presentations on the subject (P).
Table 3.1 on the following page shows an overview of the interviews, and reflects the achieved domain of the research. The interviews are indicated in boldface. The other names and positions in the table concern important presentations or conferences on the subject.

The research is explorative. Point-of-care diagnostics is an emerging technology which means that price, application, and the regulatory framework have not reached a mature stage of development yet. In addition, the concept of value-based competition is introduced only recently. Both issues make it difficult to assess quantitatively (Gaynor, 2009). Therefore possible influences from the health care system on the creation of value through POC diagnostics will be analyzed in a qualitative manner.
Technical, medical and innovation literature on biosensor technology and POC diagnostics will help defining and describing the value chain of POC diagnostics and the creation of value. Based on the interviews and presentations, the influences of system institutions and actors in the Netherlands and the United Kingdom are explored and mapped out according to the innovation system's framework. Results are analyzed by means of a comparison between the Dutch and UK health care system. Conclusions are drawn carefully, because experience has shown that it is important to remain cautious in generalizing results in a field as country specific as health care (Normand 2002).

Table 3.1 – Overview of representatives that were interviewed in the Dutch and UK health system:

Institutions/Actors	NL Representative	UK Representative
Political System	Ministry VWS, Director Chronic Care (P) NZA, Counsil Advisor NZA (P) DBC Onderhoud, Coord. ZorgInnovatie (P)	Department of Health (DH)
Research and Education	**Rathenau, Researcher Technology Assessmt** **UMCN, Med. Specialist Infectiuous Diseases** *Congress SBO, Zorginkoop, April 2011* *Congress UMCU, ZorgInnovatie, May 2011*	*Congress Brunel University, June 2011* Uxbridge London,
Intermediaries	**CVZ – Advisor specialist Care, Gynaecologist** **ZIW – Coordinator ZIW** ZonMW, Staff Member Implementation (P)	**DAP – *Director Diagnostics Assmt Program*** **NICE – Consultant Biomedicine & Society** British Medical Association (BMA) (enquiry)
Third Party Payers	**Menzis, Zorgprogramma Manager** CZ, Directeur ZorgInnovatie (P)	NHS trusts Additional Literature
Industrial System	**Pharmaceutical company,New Business Mgr** **Semiconductor Company,** **- New Business Manager** **- Sr. Scientist Central R&D** Mijnzorgnet.nl (P), consultant neurologist (P)	Start-ups in medical technology Brunel Congress, London **Lifesciences-Healthcare Ltd, Director new market entry**
Demand	**Assistent General Surgery, Leiderdorp** **Medical Specialist Emergency Care, LUMC** **Medical Specialist General Surgery, MMC** **Patient – Diabetes**	**General Practitioner, Manchester** **Chiropractor, (Public & Private care)** **Patient – Prostate Cancer**

3.2. Data Collection

Chapter 4. Chapter four can be divided in two main parts. The first part, section 4.1 and 4.2. sets out the characteristics of biosensor technology and explores how this technology can deliver value in point-of-care diagnostics. The second part, section 4.3. than tries to answer how value can be delivered in the value chain of POC, and what activities are important. Chapter 4 is mainly based on literature research: scientific and medical literature on biosensor technology and Point-of-care diagnostics were used to define and describe biosensor technology and the value chain of POC diagnostics. Important sources of information were the *British Medical Journal, Sensors*, *Point-of-Care, British Journal of Cancer*, books, market reviews and explorative interviews/conversations with technological and medical experts.

Chapters 5 and 6. The following step after chapter 4 is to map out the health care system in the UK and Netherlands and assess the influence of the different components on the creation of value. The main method of collecting data in this phase is by means of interviews with representatives, who were experts in the field of point-of-care diagnostics and represented one of the main components in the health care system. The interviewees had to be involved in developing, implementing, managing or using biosensor technology or POC diagnostics. If the organisation had no expertise in point-of-care diagnostics, the expert on technological innovation in healthcare or medical devices was consulted. The interviews were checked and balanced with additional literature research and presentations to compensate possible hiatuses in the information, or in case not all groups were covered with interviews. Sources of information were conferences and presentation on the topic, OECD information, white papers, health policy and public health research.
The interviews were semi-structured to safeguard replicability and be able to take into account new insights, which could have been overlooked preparing the questions (Yin, 2009). In the interviews, that usually took 60 minutes, the interviewees were asked a number of general questions and a number of specific questions. If possible at least two representatives per component were asked their expert knowledge on their role and influence on the value chain of POC diagnostics, and the influence of other important institutions and organizations from their point of view. The specific questions were designed to take into account specialized expert knowledge, experience and insights on the value chain of POC diagnostics (for interview questions see Appendix A and B).

In order to assess the influence of the health system on the creation of value, a performance measure is required that shows the success of delivering value through POC diagnostics in the Dutch and UK health system. The concept of value and the fact that POC diagnostics are an emerging technology, make it hard to assess this performance in a formal way. However, successful adoption and diffusion of the POC diagnostic devices in health care is related to the way that the technology is able to deliver value. Therefore the extent to which POC diagnostics are adopted - in size of the market – is a way to illustrate the creation of value through POC diagnostics in the UK and in the Netherlands as output factor. POC diagnostics make up for approximately 30% of the market of in vitro diagnostic (IVD) testing devices (EDMA, 2011). In addition to this indicator, value can be expressed in the extend to which POC diagnostics are being used already in primary, secondary and home care, and the public and professional opinion give insight in the way POC is able to deliver value. These indicators will form a qualitative output measure of the creation of value through POC diagnostics in the research. Information is mainly based on literature research

3.3. Analysis of the Results

Chapter 7. For the analysis of the results, the results on the British and the Dutch health care systems are compared. The conceptual model provides a framework on which the results of both health care systems can be compared, to gain insight on the creation of value in the value chain of point-of-care diagnostics influenced by a health system. The comparative method is a suitable research function, as it enables a comparison of macro-social differences and similarities, to explain variations in within-system relationships (Ragin, 1987). The analytic strategy for comparing the two health systems is *explanation building* to assess possible causal links. The starting point is eight theory-based hypotheses on the assumed influence of the key component on the value chain of POC diagnostics. The Dutch and the UK health system are compared on each of the exploratory narratives on the influence of the key components on the value chain. A comparison of the findings per component may lead to general observations or recommendations (Yin, 2009). In exploratory and explanatory research design there is often a risk that the qualitative data is not specific (enough). “Better comparative case studies are the ones in which the explanations reflect some theoretically significant propositions” (Yin, 2009, p. 141). Therefore the theoretical framework and the hypotheses function as a guideline and safeguard specificity of the analysis, as this research is explorative in essence.
The overall findings will be summarized in a refined conceptual framework, which creates a consolidated perspective on the creation of value in POC diagnostics.

3.4. Research Quality

This section addresses the quality of the chosen research methods, in terms of construct validity, internal validity, external validity and reliability.

Construct validity
The concept of construct validity regards whether the concepts as you have defined them are correctly expressed in the measurements you choose (Hancké, 2009). The creation of value through POC diagnostics is the object of study, but this is an emerging and developing field of study. To make sure that concepts are defined properly, they were defined in several research cycles. First the value chain and its characteristics are identified in innovation and health management theory. As a following step, scientific, medical and innovation research on point-of-care diagnostics are used to refine the theory. As a final step, the interviewees were asked to describe the main activities in the value chain of point-of-care diagnostics for delivering value, to verify the findings. During several stages in the research the results were reviewed by key informants which also strengthens construct validity (Yin, 2009).

Internal validity
To address internal validity it is necessary to assess the causal relations that are proposed, and to distinguish these from spurious (fake) relationships. A way to address internal validity is by making use of explanation building as analytical strategy (Yin, 2009). Instead of searching for information that

support or falsify the expected causal relation, qualitative explanatory narratives on the influence of the different components in the system provide insight in the relationship, which makes it possible to make some general observations and recommendations about the relationship (Yin, 2009). This explanations are then checked with a number of hypothesis that are defined at the start of the research. The theoretical framework and the hypotheses function as a guideline and safeguard specificity of the analysis, and strengthen the internal validity of the research.

External validity

The external validity issue addresses whether the study's findings are generalizable beyond the immediate domain of research. Assessment of two different health systems increases the external validity of the research, as results may be generalizable to other western countries. The fact the both countries have different ways of financing health care and thus have very different reimbursement and regulatory systems, adds to external validity in the sense that if certain influences are the same for both the Dutch and the UK health system, it increases the chance that this is also the case in other Western countries irrespective of the system of financing health care.

What is also important however is whether insights contribute to the intended field and discipline of research (Hancké, 2009). The innovation system approach offers a suitable approach to gain insight in the influence of the components in the health care system on innovation and successful development, adoption, and diffusion of technology, in this case POC diagnostics (Edquist, 2004). This is in line with the aim of this exploratory research, being a starting point towards better understanding of the creation of value through POC diagnostics, and towards new models for technological innovation in healthcare.

Reliability

Reliability concerns demonstrating that the operations of the study can be repeated with the same results. Reliability in this research is strengthened by clear theoretical framework and definitions. This framework and hypotheses enable a structured comparison, that is clear and reproducable. In addition, using several sources of information – medical and technical research, innovation and health management research, interviews and conferences – enables objectivity and provides a complete perspective which strengthens the reliability as well. This is supported by the fact that interviewees are selected to represent all important groups the health care system and represent the complete health care system: the political system, the industrial system, third party payers (insurers), intermediaries, research & education, and demand. Triangulation is a useful method to secure reliability of the research. Especially in qualitative research, using an 'informal' approach as the innovation system, it is important to verify results by means of triangulation. Because this research is interdisciplinary and touches the field of innovation, technology and health care, all results are checked and corrected by an innovation expert, technical experts in the field of microelectronics and chemical biology, and a medical specialist/surgeon.

The chosen research design has its limitations as well. These will be elaborated in detail in the discussion section of this research. The following chapter 4. will first start with the creation of value through biosensor technology.

4. Point-of-Care Diagnostics

This chapter answers the second sub-question, which is formulated as: "*Which characteristics of biosensor technology are important in terms of value and how is value created in the value chain of POC diagnostics?"* Describing the technology is necessary to define the technology-specific concepts and describe the state-of-the-art of biosensor technology. The overall aim of this study is to explore the role and influence of the key components on the creation of patient-value with biosensor technology. To answer this research question it is necessary to understand the value chain of POC diagnostics.
The chapter starts in section 4.1. and 4.2. with the technological characteristics of biosensor technology and what its role can be in point-of-care diagnostics. Section 4.3. gives a short recapitulation.
Section 4.4. provides a description of the value chain of POC diagnostics. The chapter finishes with a summarizing conclusion, followed by a brief discussion in paragraph 4.5. Chapter 4 is based on technological, medical and innovation literature research, and experience from experts in this field.

4.1. Biosensor Technology

On the 10th world congress on biosensors which took place in Shanghai in 2008 the biosensor was defined as "*analytical devices incorporating a biological material (for example microorganisms, organelles, cell receptors, enzymes, etc), a biologically derived material, or a biomimic intimately associated with or integrated within a physiochemical transducer or transducing microsystem, which may be optical, electrochemical, thermometric, piezoelectric, magnetic, or micromechanical"* (Biosensors, 2008).

The beginning of the field of biosensors originated in the work of Clark and Lyons (1962) and Guilbault et al. (1962) amongst others. Clark and Lyons (1962) describe how the improvements in design and construction of electrode systems, combined with the development of stable amplifiers and recorders, has provided satisfactory systems for the rapid and accurate measurement of blood pH, pCO2, and pO2. Different types of biosensors have been developed since then for the detection of ions, molecules, proteins, deoxyribonucleic acids, and cells. Developments in the field of nano-technology are expected to catalyze the technical possibilities of biosensor technology, specifically the detection limit range and sensitivity (Mitra et al, 2009; Yogeswaran and Chen, 2008). The platforms -incorporating the complete mechanism- can be built on nano- or microscale, enabling small, hand-held devices, for example the size of a mobile phone. This leaves enough 'space' for design, comfort, or other aesthetic considerations. In addition, the device may include data storage functions, wireless connection possibilities, or other complementary attributes, without compromising the size of the device (Lee, 2008; Suy, 2011).

The increasing number of publications and patents issued on the technology of the platform and target biomolecules illustrate the advances in technology and the commercial expectations of biosensor technology (Mitra et al, 2009). The direct value of the technology when comparing to current available methods would be that it is fast, specific, easy to use, and inexpensive (Luong et al, 2008). The device leaves out the laboratory step in the diagnostic process, also referred to as lab-on-a-chip, which enables the physician to make decisions based on real-time information.
Because the technology can be built on micro or nano-scale, the device can be small, handheld, which makes it a user-friendly device. Ideally the device is capable of data storage over time, and linked to a larger IT environment in a hospital, or physician's practice for instance, enabling screening and monitoring over time. However before the technology will actually live up to those expectations, significant upfront Research and Development (R&D) efforts are required. Currently commercialization of the technology has lagged behind expectations, and only for glucose applications high-volume markets exist (Luong et al, 2008).

The possibilities of commercialization strongly relate to the application, size of the market, technical requirements, level of performance of current clinical labs, and many other factors (Luong et al, 2008;

Kooij, 2011). The paragraphs 4.1.1 and 4.2. discuss important factors that determine how biosensor technology can add value. 4.1.1. starts with a brief overview of the technical possibilities of biosensor technology. A more elaborate description can be found in appendix A.

4.1.1. Technical Characteristics

A biosensor consists of two main elements: the transducer and the recognition element. The recognition element is a target-specific bio-sensitive receptor, which is attached to the transducer. When targets are present in the sample, the bio-sensitive receptor couples, or a reaction takes place. The transducer translates the (coupling) event into a signal, which can be interpreted in terms of presence/absence, and concentration of the target (Frederix, 2011; Lee, 2008). Other names for the target molecule are (bio)marker or analyte.

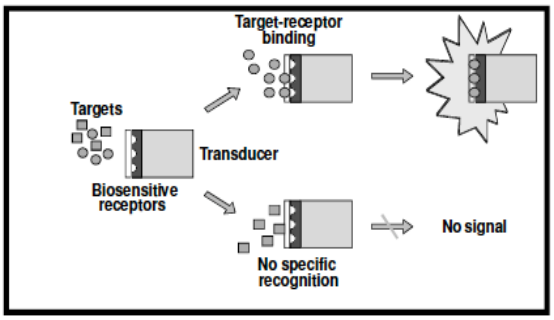


Figure 4.1 – Elements of a Biosensor (Frederix, 2011, University of Leuven)

Bio-sensitive Receptor

The recognition element in biosensor technology is a target specific bio-sensitive receptor, which is attached to the transducer by a linking layer. The transducer, the linking layer and the receptor together form the platform of the biosensor. The bio-sensitive receptor (biorecepter) is an antibody or a strand of DNA of the target molecule. When a sample is washed over the platform, the target will bind to the bioreceptor, which causes a (change in the) signal (Frederix, 2011). A bio-sensitive receptor can detect *enzymes, cells, (deoxyribo-)nucleic acids, antibody/antigen interactions, and gases* (Luong et al, 2008). An important feature of the biosensor is that it can contain a number of different receptors, which makes it possible to measure a combination of targets at the same time, called multiplexing.

The use of enzymes as the biosensitive receptor was very popular in the first generation biosensors (Laschi et al, 2000). The last 15 years the attention shifted to affinity biosensors. These biosensors make use of binding mechanisms between antibodies to antigens, cell receptors to their ligands, DNA and RNA to their complementary sequences, and metabolic pathways (Luong et al, 2008). Also proteins can be detected with biosensor technology. The presence or absence or the amount of certain proteins within our body has proven useful to gain insights in our health status. Examples are human chorionic gonadotropin (hCG) for pregnancy, prostate specific antigen (PSA) for prostate cancer, and troponin I (cTnI) for myocardial infarction (Lee, 2008). A biosensor is also able to detect gases or metabolites as an indication of a persons' health profile. There is increasing interest in the use of gases as biomarkers as a new inexpensive and rapid tool to collect diagnostic information. 'Breathalizers' are already being used to detect acetone in a persons' breath as indicator for diabetes. Increasing research is being conducted on metabolites detectable in breath, as a first indicator of cancer. (ScienceDaily, 2010)

The Transducer

One element of the biosensor is the bio-sensitive receptor, and the other the transducer that detects the coupling/binding event, and translates the event into a signal. The transduction principles can be *calorimetric, magnetic, electrical, acoustic, or optical* (Lee, 2008).

Although all transduction principles are used, and have been feasible in biosensor technology, the most common/popular methods are electrochemical and optical detection (Luong et al, 2008). Electrochemical biosensors seem to be very appropriate in 'field' applications as point-of-care, and for miniaturization. Due to the high sensitivity, simplicity and cost competitiveness that can be achieved with electrochemical biosensors, more than half of the biosensors reported in the literature are based on electrochemical transducers (Luong et al, 2011). Optical biosensors are very suitable for screening a larger number of samples simultaneously, but the disadvantage is that they cannot be as easily miniaturized as electrochemical sensors for instance, which is important in point-of-care settings. Nevertheless, research and development leads to improved optical methods that have the potential to replace the use of electrochemical methods for some applications. (Luong et al, 2008)

The Target

The biosensitive receptor is closely related to the target molecule that the device is supposed to detect. The target is often referred to as biomarker, and can be defined as: *"A biochemical parameter - eg, DNA sequences, glucose levels, proteins - that (indirectly) indicates normal biochemical processes, psychological abnormalities, pathogenic processes, or the pharmacological response to therapy"* (Madu and Lu, 2010).

The quality and clinical applications of the biosensor is strongly dependent on the quality of biomarkers. For example if the biosensor platform guarantees an analytical accuracy of 100%, which means that it is 100% certain that a specific biomarker is present. If that biomarker is related to a 5% chance to develop breast cancer at a certain point, the test has very low clinical impact: there will be no influence of the test on the treatment of the patient.

Active research is done on biomarkers to improve the diagnostic accuracy in their relation to specific conditions. For example research is being conducted on combinations of biomarkers to detect prostate cancer in an early phase, or the relation between gene expression profiles and the disease path of an infection (Mitra et al, 2009; Hermans, 2009; Madu and Lu, 2010). Box 4.1. provides additional information on biomarkers.

Box 4.1. Biomarkers
(Biotechcircle, 2011)

The simplest biomarkers are heart rate and blood pressure. Even the ancient Greeks could already diagnose diabetes on the basis of glucose levels in urine. The field of biomarkers has made its real developments the last 50 years, spurred by emerging infectious diseases, new biomarkers for types of cancer, cholesterol and cardiac biomarkers.

Another driver behind biomarker development was the Human Genome Project. From insights in DNA sequence variations, RNA and transcriptional alterations, and proteins and peptides, the field of biomarkers exploded in providing new biomarkers at the molecular level.

4.2. Point-of-Care Diagnostics

Biosensor technology is expected to play a role in diverse industries, which are often divided in six main industries: Research Laboratories, Point-of-care Diagnostics, Food Quality Assurance, Environmental Monitoring, Security/Bio-Defense, and Industrial Processing Quality Control (Frost and Sullivan, 2007; Strategic Business Insights, 2011). This research focuses on biosensor technology applied in Point-of-care (POC) diagnostics, as biosensor technology is emerging and considered very promising in this field (Walhout, 2011; Lee, 2008).

Point-of-care testing is often defined as: *analytical testing activities near or at the site of patient care, outside clinical laboratories* (Cambridge Consultants, 2006). This as supposed to tests that need to take place in central laboratories or hospital labs. Central laboratory testing requires the collection of a sample, logistics to get it to a lab, and receiving and communication of results. The time this laboratory process takes varies from 10 minutes to several days (Groot, 2011; Kooij, 2011). Personalized medicine, increasing demand for healthcare due to the ageing population, and budget restrictions drive a need for quicker, more complex, and more precise tests, enabling more *effective* treatment (Van Hoof, 2010). Another important driver of biosensor technology in diagnostics is a trend towards self-management throughout the complete cycle of care, expanding health care to life style, comes with a need for monitoring, screening, and home diagnostics. (Walhout, 2011; Vossenaar, 2011; Equity & Excellence, 2010).

Box 4.2. Markets of In Vitro Diagnostics
(Kalorama, 2010):

- Glucose
- Cardiac Markers
- Infectious Diseases
- Cholesterol/Lipids
- Coagulation
- Oncology
- Immunoassays
- Hematology
- Drugs of Abuse
- Pregnancy
- Urinalysis

Diagnostics markets are often divided according to the type of biomarker concerned (see box 4.2.). For point-of-care diagnostic devices it is more useful to make a distinction according to the physical point of use: primary care, secondary care and home care. This is because the definition of point-of-care is related to the place and time of application. Also, the technology is expected to develop differently in the three fields (Van Hoof, 2010). In addition it can be more insightful to assess the value of the medical device

throughout the complete cycle of care, which is often cross-disciplinary.
The following paragraphs will set out the differences relevant to Point-of-care diagnostics in primary, secondary, and home care briefly.

4.2.1. POC Diagnostics in Primary Care

Primary care is in principle the first point of contact for most consumers with health care, and is delivered by general practitioners, dentists, and pharmacists for instance. In primary care, POC diagnostics are expected to play an important role in the general practitioners' office and health management centers. A health management center combines different disciplines as physiotherapy, a GP, the dentist and fitness facilities with the goal to facilitate a person's own health cycle management. (Folland et al, 2010). Health management centers are expected to play a big role in the trend towards patient centered care. This construction makes it possible for GP's to acquire more expensive medical (diagnostic) devices, because they can share the investment with the physiotherapist or the chiropractor for example (Sutcliff, 2011).
Many diagnostic tests take place at the GP's office and are sent to central laboratories, which deliver results in a (few) day(s). These laboratories can provide good prices because they 'batch' the samples: they save up to a large amount of samples and then run the analysis. (Kooij, 2011). This is the case when a person is tested for STD (sexually transmitted diseases) for instance. In some cases, it is worthwhile to replace the moment of testing to the GP's office at the Point-of-care. But to know if POC adds value there it is necessary to understand the impact of the POC test on the (post-) diagnostic care pathway of that specific test. This impact can be medical or non-medical. If a patient needs two GP appointments of 10 minutes for a STD test and result, because on the first appointment the sample is collected, and the second appointment results are discussed, then a POC devices can add value because it saves out the second appointment. However, if the results of the STD test are communicated per phone or letter the value of the POC test for this application is less obvious. To assess whether a point-of-care test adds value in primary care or that it has no impact and test should remain centralized, it is important to take into account the clinical impact but also the impact of the POC test on the (post-) diagnostic care pathway, which can be medical or non-medical.

Some researchers expect that diagnostic testing will be largely decentralized to point-of-care, supported by developments in IT, electronic patient records, and flexibility in sales channels as the supermarket even. Other researchers expect that the health system will slowly restructure around care pathways or health value chains (Burnell, 2008). These changes are not necessarily mutually exclusive, and in both scenarios the role of the GP or health manager will be more elaborate. On this moment the use of biosensor technology at the GP's office is still in an early stage of development. It is expected that when quality, connectivity, and regulatory standards are set in hospital settings developments in GP settings will follow (Van Hoof, 2010).

4.2.2. POC Diagnostics in Secondary Care

Secondary care is known as acute care, and can be emergency or specialist care. Specialist care is often planned specialist medical care or surgery. In many countries the GP acts as a 'gatekeeper' for secondary care, and a referral from the GP is needed to get secondary care. In secondary care most diagnostic tests still take place in the central hospital laboratory, which is often optimized to deliver very quick results, with smart logistic systems (Groot, 2011). POC tests are increasingly being used in secondary care, for the detection of heart problems (ACS), or anticoagulation factors for example (Pearsons, 2006). POC diagnostics in hospital settings enable a faster diagnoses and stabilization in emergency situations, and enable immediate risk assessment. POC devices are observed to diffuse first in cases in which the added value is rather transparent.
If a POC device in emergency care saves 10 minutes in the complete time that a patient is present at the emergency department and sent home or at a different department, this time saving can be calculated in terms of a capacity increase of the emergency room. For example the emergency room is independently managed and financially rewarded according to the number of patients they have helped. A

capacity increase would increase the turnover. (Groot, 2011) If the POC device costs less than the increase in turn-over, then the manufacturer/supplier of the POC device can present a financial case to the managers of the emergency department. This 'financial case' is considered more and more important in healthcare. The business case ideally is adjusted and created towards the party that needs to finance the investment in POC, and this is dependent on the type of health care system.

As to *who* should perform the tests in secondary care, opinions vary. On one hand scientists advocate that POC tests can be performed by staff which do not need to be trained and registered healthcare scientists, which can save valuable time from specialists (Pearsons, 2006). Others point out the fact that interpreting the results is an important part of the complex diagnostic process, and all other medical factors should be taken into account for a diagnosis (Baerheim, 2001). This is also an argument against home-testing devices. However, there is a broad variety in complexity and impact of a diagnostic test. Some tests should rather be interpreted by specialists, for other tests it might be appropriate and more efficient to delegate it to others than medical specialists.

4.2.3. Home POC Diagnostics

A third area of application of POC diagnostics is over-the-counter or home care. POC diagnostic tests applicable for self-monitoring are commercially available at the local pharmacy, but glucose meters are the only devices that has developed quite far. This is because the target group of diabetes 2 patients is already rather acquinted with self-managing their condition (Walhout, 2011)
Home POC testing enables closer and direct therapeutic self-management. It is expected that screening tests on risk factors will develop strongly in over-the-counter POC diagnostics. The other trend that is expected in home care is the development of gadget-type applications; commercial genemapping or diagnostic apps for smartphones. (A.Menarini Diagnostics, 2009).
Self-management and home care solutions are broadly supported, as developments in this field may play a role in addressing an increasing need for health services. Preferably the elderly remain independent as long as possible, and automatic POC monitors keep track of their health status. Social scientists advocate that for these devices the target groups should really be involved in developing the application, so that factors as design, training, but also the possible risk of social isolation due to technology are taken into account. (Walhout, 2011) An important note to these developments it that home care requires a health manager or GP to be responsible for monitoring, coordinating and safeguarding the patients health as supervisor (Prakken W., 2011). It is expected that the adoption of home POC diagnostics will require consumers to become familiar with the use and quality of biosensor devices in professional POC settings, in both GP as hospital settings (Van Hoof, 2010).

Overall the characteristics of biosensor technology that are important in terms of value can be structured according to the following dimensions:

- Analytical accuracy
- Diagnostic accuracy
- Clinical utility (*physical & mental impact*)
- Impact on (post-) diagnostic care path *(indirect utility)*
- Cost-effectiveness (financial case, supersession)

To illustrate how the characteristics of the diagnostic device described in 4.1. and 4.2. influence delivering value with POC diagnostics in practice, this paragraph ends with three illustrative examples. These examples, which are given in three separate information boxes, provide a more profound understanding of the possibilities of POC diagnostics.
Following sections 4.1. and 4.2. that explain the characteristics of biosensor technology in terms of value, chapter 4.3. explains *how* this value is created/delivered in the value chain. Section 4.3. will follow the information boxes, and explain which parties are involved in the value chain and what activities are required to create value.

Box 4.3. Applications for Point-of-care Diagnostics

Acute Coronary Syndrome (ACS): primary or secondary care?

Patients may consult a GP or visit an emergency care unit with chest pain, nausea and shortness of breath. These symptoms can indicate acute coronary syndrome (ACS), angina, but are also related to non-heart related conditions. ACS occurs when a sudden blockage in a coronary artery greatly reduces the blood supply to an area of the heart muscle. This may cause heart tissue to die, with a chance to result in a heart attack (Merckmanuals, 2011). In this situation, rapid diagnoses and complementary appropriate treatment is urgent and necessary, and ideally takes place directly at the point of care.

To diagnose acute coronary syndrome often an electrocardiogram (ECG) and cardiac biomarker test are used (Merckmanuals, 2011). Cardiac Biomarkers are biomolecules that are released into the blood when the heart is damaged (Ming-Hing Lee, 2008). Cardiac biomarkers that are used most commonly are creatine kinase (CK), Troponin I, and Myoglobin. A higher concentration of CK in blood indicates muscle damage, and can be used to detect a heart attack (NtgG, 2011) Troponin is a complex of regulatory proteins specific for skeletal and cardiac muscle contraction. This marker indicates symptoms of a heart attack, or an injury to the heart muscle. Myoglobin releases oxygen in the heart muscle, and blood levels of myoglobin rise quickly when a muscle is damaged (Merckmanuals, 2011). There are markers to determine a 'risk' for cardiac events, for example brain natriuretic peptides (BNP) to help diagnose the presence and severity of heart failure. For screening people for the risk on cardiac events, other indicators are used. These indicators are lifestyle related indictors, for example smoking, high blood pressure, high blood cholesterol, diabetes, being overweight and physical inactivity (American Heart Association, 2011).

Currently the testing for ACS primarily takes place in secondary care (emergency care). The National Academy Clinical Guidelines (2009) recommend that in this setting point-of-care diagnostic devices for cardiac markers should be implemented if the central/hospital laboratory cannot provide a turnaround time of 1 hour or less (Melanson, 2009). Some hospitals have realized very quick turnaround times (10 to 20 minutes) in delivering results from the central laboratory (Groot, 2011). Others recommend that POC testing enables a transfer of the testing activities for ACS from emergency settings to a GP's office. A GP would need POC diagnostic testing device and a ECG, but this would reduce the number of people that visit the emergency department, without a need for acute (and more expensive) emergency care (Sutcliff, 2011). In this way the diagnostic device does not only add value in delivering quicker results, but also has (an efficiency) impact on the process. This shift from secondary to primary care would require the parties involved – GP, emergency physician, manufacturer, third party payer – to agree on new reimbursement arrangements (Geertsma, 2011).

Box 4.4. Applications for Point-of-care Diagnostics

Prostate Cancer Screening

In cancer treatment early detection remains one of the most important issues (Li et al 2002; Chade et al, 2009). This means that for some indications it is worthwhile to implement routine screening of high-risk groups. Prostate Specific Antigen or PSA is considered the most important biomarker for detecting, staging and monitoring cancer of the prostate in its early stage (Madu and Lu, 2010). PSA is produced (mainly) by the prostatic epithelial cells, and participates in the dissolution of seminal fluid coagulum and plays an important role in fertility (Campbell and Reece, 2005). The PSA level tends to rise in case of cancer of the prostate, or benign conditions as prostatic hyperplasia or acute bacterial prostatitis. The most valuable measurement of PSA is its change over time rather than the actual serum level. Generally doctors base their diagnose on a PSA test, in combination with a digital rectal exam (DRE). Besides PSA, other factors are related to the risk of developing prostate cancer, which are age, family history, race and possibly diet (National Cancer Institute, 2009).

Although it is undisputed that early detection is the most important aspect in cancer treatment, opinions strongly vary on whether there should be a PSA routine screening test for all men at a certain age (Andriole, 2010; National Cancer Institute, 2009). Many European countries do not offer routine PSA screening. The difficulty with routine screening is that false positives or false negatives occur, which leads to over- or under-diagnoses and treatment. This is because PSA based screening detects all types of prostate cancer: indolent (inactive) small tumors as well as aggressive lesions (Andriole, 2010). In their research Djulbegovic et al (2010) analysed six randomised controlled trials and found that screening increased the probability of being diagnosed with prostate cancer, but had no significant effect on mortality from prostate cancer or overall mortality. This

means there is no clinical impact. In addition, the human and economic costs associated with PSA screening are substantial: for a high percentage of the men who test positive later tests establish that is no case of prostate cancer, causing unnecessary but substantial stress; for about 50% of the men that are diagnosed and treated for prostate cancer through PSA screening the cancer would have remained asymptomatic and they would not have found out otherwise leading to overtreatment. Finally, the current available therapy for prostate cancer is considered very painful and has a substantial risk of causing impotence and incontinence. These indirect aspects are the reason that routine PSA screening, with *current* methods, is often not supported by many experts.

For widespread support for (routine) screening tests for cancer of the prostate, biomarkers need to be improved in terms of specificity and accuracy (Kristiansen et al, 2008). Current advancements in biotechnologies have increased the pace at which biomarkers are being discovered and improved (Andriole, 2010). New biomarkers with great potential have been reported, which are currently undergoing further investigation and validation. Other research focuses on monitoring PSA levels over time, or analyses the relation between the presence and combination of multiple biomarkers with prostate cancer (Laxman et al, 2008). "*Combining markers is thought to be the next best thing to improve the accuracy of diagnosing, treating, and surveillance of recurrence of prostate cancer*" (Madu and Lu, 2010, p. 169). Biosensor technology may play a significant role in these new developments in "surveillance" of cancer. Multiplex biomarker analysis can increase the specificity and accuracy of the test, which is considered the most important barrier for routine cancer screening (Kristianson et al, 2008). To make monitoring and screening biomarker levels over time valuable for patients, this requires a accurate, user-friendly, inexpensive, point-of-care test device that stores and communicates patient-specific data over time (Andriole, 2010; Madu and Lu, 2010).

Box 4.5. Applications for Point-of-care Diagnostics

Infectious Diseases & HIV testing @ home

Infectious diseases are one of the leading causes of death and disability worldwide (Yang et al, 2008). Infectious diseases that appear suddenly or that suddenly come to attention are referred to as emerging viruses. HIV, the AIDS virus is a classic example, which appeared in San Francisco in the 1980s, seemingly out of nowhere. A more recent example is severe acute respiratory syndrome (SARS), which first appeared in southern China in November 2002, and in 8 months around 8000 people were infected (Campbell and Reece, 2005). The most important factors in infectious disease management are surveillance and early response. The value of biomarkers in infectious diseases lies in their capacity to provide early detection, establish highly specific diagnoses, determine prognoses, molecular-based therapy and monitor disease progression.

An example of a bacterium causing infectious diseases is the *Streptococcus Pneumonia,* which is responsible for several infections as ear infections, lung infections, and meningitis (hersenvliesontsteking) (Hermans, 2009). Often the immune system of the host is well capable of cleaning up these bacteria, but especially in case of an invasive infection of the lungs, blood or central nerves system the infection can get severe. The estimated amount of children dying of this bacterium is over a million a year. The complexity of this infection is that it is very hard to predict the course of the disease in terms of severity. Pioneering research in the field of infectious diseases studies the relation between the gen expression profile of the host and the severity of the disease and the disease path in case of an infection. This leads to increasing information for developing tailored diagnostic strategies. Currently tests take a long time, and cannot be performed at the bedside yet. But this is a field in which advanced multiplexing point-of-care diagnostic devices might play a role in the future. (Hermans, 2009)

The biomarkers used for infectious disease are often antibodies to the virus that the body creates in an attempt to fight the virus. The primary tests for diagnosing HIV and AIDs is ELISA - enzyme-linked immunosorbent assay. This test is quite sensitive in chronic HIV infection, but because antibodies aren't produced immediately upon infection, you may test negative during a window of a few weeks to a few months after being infected. (UCSF, 2011). Currently most HIV testing takes place in primary care settings, and tests are sent to central laboratories (Kricka and Price, 2009).
In addition to the clinical effectiveness, POC diagnostics for HIV testing also can have a socio-economic or indirect clinical impact. Research on POC HIV testing in homeless shelters in Los Angeles describes a training model where 'paraprofessionals' without health care experience can counsel the homeless, and perform rapid testing. In these socio-economic situations, there is less access to healthcare. In this case POC diagnostics provide a solution for a lack of health resources and infrastructure. Another example of indirect impact is that high-risk groups in UK would get tested for HIV using POC home testing devices (51%) as supposed to central laboratory testing (19%). In this situation the POC diagnostic testing device creates value in terms of privacy and reduces stress, and has a health impact in the long run. (Melanson, 2009; Kricka and Price, 2009).

4.3. The Value Chain of POC Diagnostics

This section explains how this value is created, which parties are involved, and what activities are required to create value in the value chain of POC diagnostics, and how to deliver it to the end-user. For this the theoretical model of the value chain is used (figure 4.2). The POC value chain is defined in this research as *a virtual network that facilitates the movement of POC diagnostics from its earliest point of production, through packaging and distribution to the point of care/use*.
As illustrated in the previous sections, it is important to take into account the different dimensions of value through POC diagnostics. In addition, the end-consumer or end-user may be different dependent on an application in primary, secondary or home-care settings. Another point is that specific roles as the payers or insurer are country dependent. Therefore, the actors and activities in the value-chain are described in general terms. This might cost some specificity in determining which activities add value, but at the same time provides the advantage that the overall model remains broader applicable. The value chain is described according to the actors involved, and activities regarding the creation of value, trying to separate each step of adding value to the concept, while keeping in mind the end-consumer demand. Important application-dependent differences will be pointed out.

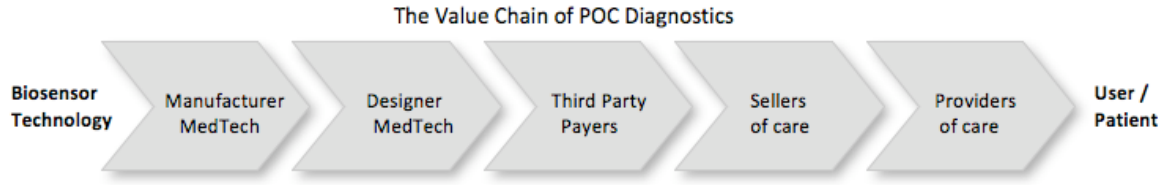


Figure 4.2 - value chain of POC diagnostics

4.4.1. Step 1: Manufacturer Medical Technology

The first box 'manufacturer' covers the companies and organisations that are involved in the research and development, leading to, and starting from the earliest point of production of biosensor technology. The earliest point of production was defined as the combination of the biochemical knowledge with the measuring component that delivers a signal. This can be the R&D division of one single company, or a research consortium for example with a university or academic medical centre. (Brunel, 2011) Companies from all sorts of backgrounds and expertise are observed to have interest in diagnostics, probably because the technologies used in biosensor technology can be optical, electrical, acoustic, etc. The advantage could be that these players bring in new knowledge into the health care sector, provided that they succeed in delivering added value. Also new companies enter the field of Point-of-care diagnostics (Brunel, 2011).
Probably the most important activity that takes place in this box is proving the scientific claims of the new application (A. Faulkner, 2011; N. Crabb, 2011): the biosensor measures biomarkers X and Y generating accurate and valid results, and the biomarkers are reliable markers to diagnose health condition Z. Methods to establish this proof is to let the technology and the results be tested and reproduced by an independent research organisation. (Derksen, 2011) Entities may choose to publish results in scientific journals, or publish via the university. Besides the fact that the claims need to be established, publication are important to generate attention to the new activities, and to start build interest in the professional network. Another essential activity in this phase is to build strong partnerships for the future value chain. It is considered important that a partner company is strong in building expectations and agenda for POC diagnostics (G. Lushai, 2011, Gimbrère, 2011).

The added value in this phase is the creation of a *diagnostics and analytical claim*: the diagnostic and analytical validity of the diagnostic test should be established.

4.4.2. Step 2: Designer Medical Technology

Dependent on the analytical possibilities of the technology, market research, and the resource capacities of the organization, a decision will be made regarding the segment/application of the technology. In this stage of the value-chain, the device requires a good medical devices designer, and a manufacturer that has capabilities to increase scale. The medical devices designer has the important task to implement health professionals' perspectives, and to actively involve users in testing of the prototypes. Companies that are successful in this area stand out by winning design awards. This not only makes the company visible, it also highlights the product (IDC, 2011).
An essential activity in this stage in the value is to involve a *practicing* health professional. There are two reasons why this is so important. First, in POC diagnostics, one of the most important factors to determine whether a product will be adopted or not, is the establishment of a clinical case. A test may be technically and analytically valid, deliver results within 2 minutes, but have zero impact on the treatment. To gain knowledge on this practical part of the POC diagnostic device, you need a health professional (Grimbrere, 2011; Lushai, 2011). The second reason is integration. There are examples that a technology is introduced into the market after 15 years of research, without ever seeing 'daylight'. When there is no match between technology and practical and clinical utility, the product has very little chance of success (Crabb, DAP, 2011). The knowledge and experience built up in the value chain so far, based on user insights, clinical utility, market dynamics, the technological knowledge, and the network built so far, should give insight in the diagnostic process and the post-diagnostic care pathway of a specific application. This should provide the possibility to identify how the POC device can add value indirectly. These insights determine the impact on the post-diagnostic care pathway.
In vitro diagnostic medical devices in Europe are regulated under EU directive 98/79/EC, and require CE marking, which is seen as a declaration that the product meets all the appropriate provisions of the relevant legislation, including those relating to safety. With CE marking the product can be freely marketed anywhere in the EU without further control. Custom-made devices, devices undergoing a clinical investigation, and IVDs for performance evaluation are exempt from the CE mark. (CE Mark, MHRA, 2011). Depending on the complexity and application of the product in primary, secondary or home care, distinction has to be made here. The non-complex home-use products, as diabetes monitoring tests and pregnancy tests, that are CE-marked may be sold directly via channels as the pharmacy, supermarkets, or online for example. These products go from box 2 straight to the user. Biosensor-based POC diagnostics that aim for secondary or primary care applications, are often more complex, and their development requires involvement of other parties in the value chain.

The added value in this phase is the creation of a *clinical claim*, and the value in *impact on the (post-) diagnostic care pathway (indirect utility)*.

4.4.3. Step 3: Third Party Payers

This third box requires the involvement of third payers. These can be the government or insurance companies for example, that bare the overall financial risk. It is advisable for manufacturers of medical technologies to involve the third party payer as early as possible. The further the product is developed, the lesser the chance becomes that third party payers can integrate the concept in reimbursement schemes, and the lesser will the chance become that the product will be used (Geertsma, 2011).
TTPs can play a very active role in the creation of value through POC diagnostics in the way that they benefit from more effective quality care, and have funds and research subsidies available, so that manufacturers are able to do clinical research and establish a clinical case. They can also publish guidance on whether to use the device or not.
The way the third party payers add value in the value-chain is two-fold. First, if a company has a product that is really promising, they will have good reasons to share knowledge on financing structures and regulation, to help the product the next level. The other dimension is that third party payers have a big responsibility to manage the public's budget in a way that they arrange the best possible care, at an acceptable price/insurance fee/tax. This means they have a watchdog function for *good* care. Implying this actor in the value-chain, prevents supplier induced demand, demand push, hyping, and excess use

of care, leading to increased costs. Having these diverse actors implied in the value chain of POC diagnostics, also with the focus to deliver value, makes the system more sustainable.

4.4.4. Box 4: Sellers of Care

This box is about the involvement of sellers or 'retailers' of care. In case of delivering value with POC diagnostics in secondary care, the sellers of care will be the hospital boards, trusts, or other managing parties that also negotiate prices with the third party payers. When delivering value with POC diagnostics in primary care, the general practitioner will be the seller of care, or in case of a health management centre, a general manager could be responsible. The seller of care in the value chain of POC care diagnostics (in secondary or primary care) is the party that buys the device from the manufacturer of care and sells it to the patient. The payment to the sellers of care for the health service they provide comes from third party payers or individuals. It depends on the application of the POC device, whether and how the third party payer's requirements need to be taken into account in the decision of the seller.
Three main channels can be used to bring the POC diagnostic device under the attention of the sellers of care. The first is via scientific and professional journals, or congresses. The particular physician interested in the application will look into the articles and information, and try to convince the management of the hospital for example to consider buying/acquiring the application (Groot, 2011). Another way is through published guidance. If the national independent advisory committee on POC diagnostics advices the use of this application, to improve quality, save costs, or improve efficiency in the diagnostic process, this is a very good starting point (Melanson, 2009). A third method is that the manufacturers will try to convince the management directly, who will need to introduce the device top-down. These three ways of entrance are not mutually exclusive, and a combination of the three might be strongest. The added value of the hospital or care-center management is that they will have to negotiate high-value contracts. Here lies an important role for the sellers of care, to take the opportunities to negotiate prices, education, training, arrange secondary benefits, long term contracts, new pilots, and much more is possible (Vusse, 2011). There is plenty of space in this area for stronger negotiating, more business minded approaches, and financial innovation (Linden, 2011). This will add up to a long-term financing plan and a solid business case.
The added value is *the cost-effectiveness or financial case*, stimulating financial innovation & service level improvements.

4.4.5. Box 5: Provider of Care

The last box concerns the involvement of the provider of care, which can be the GP or the specialist that will work with the diagnostic device. The provider of care has an important role throughout the value chain for delivering the value to the end-user (N. Crabb, 2011). Also when people will use home POC tests, the GP will have to adjust his processes too to adapt to these new developments. He will have to be able to receive the data, and answer questions about the results.
The most important role of the provider of care in the final phase of development is to implement the device into the diagnostic process as it was intended. Here remains also a role for the developers: there are still examples that show that even in the last phase of development and implementation, the product will eventually not add value because the device is not used as intended (Geertsma, 2011).
The provider of care will read medical journals, or visit the conferences and will keep learning in his field about new possibilities. A group of specialists can be a strong agenda builder for the acquisition/use of a new technology. For that reason the physician should be involved in the value chain. Another reason is because this anticipation enables a strong feedback relation about experience with the device, suggestions for new applications, and monitoring how patients experience the device. Involvement of this last group into the value chain, enables a long-term innovating sustainable value-chain.

The added value here is the professional use of POC diagnostics, making sure that value is actually delivered. The second attribute is continuous feedback from provider and patient, which is input for incremental innovation and keeps the value chain sustainable.

4.4.6. The POC value chain: an overview

This chapter aims to answers the second sub-question "*Which characteristics of biosensor technology are important in terms of value and how is value created in the value chain of POC diagnostics?*

Biosensor-based POC diagnostics have the potential to deliver value in the health care system in diverse applications. They can play a role in infectious diseases, hematology, coagulation, diabetes (glucose), and cholesterol for example. The test can be developed for critical care, for primary care and for home care, for reasons of monitoring, screening, diagnosing, data management, privacy or comfort. However, this study has indicated that every different type of POC application requires highly specific and specialized insights in technology, microbiology, medicine, and the health care system it should fit in, in order to develop any product that will deliver value. In addition, different points of application (primary, secondary, and home care) are related to different end-users, different regulation, and a different process to deliver value. Value in POC diagnostics can be structured according to **analytical accuracy, diagnostic accuracy, clinical utility, impact on (post-) diagnostic care path, and the cost-effectiveness/financial case.**

Important actors involved in the creation of value are manufacturers and designers of medical technology, third party payers, sellers of care, and providers of care. In line with theory, a number of activities are important for the success of a value chain. The first is *integration*: this means building a value chain through strong partnerships with suitable and valuable candidates, but also to develop a product with the end-user and context already in mind. The second is to start the chain with *user-needs* in mind: involve an experienced *practicing* physician as early as possible in the development of (POC) diagnostics as this person is the most suitable person to assess clinical utility. The third activity is *communication*: transparency throughout the value chain and working with a shared set of values to connect the parties. Communication refers also to the publishing of results: an essential requirement for developing a POC device is that there needs to be sound objective evidence on the different dimensions of value. A fourth important role that needs to be taken care of is the *coordination and direction of the value chain*. Research has supported that the use of a partnership or value chain approach requires a party that coordinates and manages the value chain (Lushai, 2011).

With regard to the creation of value through POC diagnostics, value is not created in linear or cumulative steps, but an interactive dynamic process with feedback loops. Some applications may deliver value by only being more accurate than the alternative. Some devices might have to add value in all five dimensions in order to be acquired. Especially the latter type of innovations will require strong integration: a good network and involvement of the parties. The value created in the value chain is not necessarily directed at the end-user, but may also be directed to other parties in the VC. A financial case in terms of cost-efficiency of the medical device may add value to the user at the end, but also to the hospital management or the third party payers. Home care POC diagnostics may seem to deliver only value in terms of comfort and time-savings, but may have overall impact in peoples' health status, which adds value to third party payers.

On the following page the results are summarized in a table. The aim of the table is provide a quick overview on the process of creating value in the value chain of point-of-care diagnostics, and how value can be delivered in several dimensions. Different actors can be related to different processes. In addition the table aims to roughly illustrate that the process of creating value depends on the type of application and the point of application.

Home POC	**Analytical & diagnostic claim** -Build/Search Partnerships	**Clinical Claim** - CE Mark - Design		(Pharmacy)	Keep involved & up to date	Consumer& Patient *(GP as health manager)*
Primary care POC	**Analytical & diagnostic claim** - Publish results - Build/Search partnerships	**Clinical Claim Diagnostic - Care Path** - CE Mark - Design - Physician Involvement	- Financial & - Regulatory advice - Financial balance	**Cost-effectiveness** - Build agenda - Guidance - Negotiate Contract - Financial Innovation	**Sustain** - Deliver value - Monitoring - Feedback - Incremental innovations	General Practitioner
2ndary care POC	**Analytical & diagnostic claim** - Publish results - Build/Search Partnerships	**Clinical Claim Diagnostic - Care Path** - CE Mark - Design - Physician Involvement	- Financial & - Regulatory Advice - Financial Balance	**Cost-effectiveness** - Build agenda - Guidance - Negotiate Contract - Financial Innovation	**Sustain** - Deliver value - Monitoring - Feedback - Incremental innovations	Specialist

Table 4.1 - Overview of the process of creating/delivering value through POC diagnostics (source: author)

5. The British Health Care System

Figure 5.1 – London Eye
Source: author, 2011

Chapter 5 aims to answer the third sub-question: *What is influence of the key components in the British health care system in relation to Point-of-Care diagnostics?*
Section 5.1. gives a brief overview of POC diagnostics in the UK to provide insight in the creation of value through POC diagnostics in the British health care system, as a qualitative 'output' factor of the value chain. Section 5.2. describes the British health care system. The major institutions and organizations involved are described in terms of their main role and activities in relation to POC diagnostics. Section 5.3. provides a summary of the results in the form of a map of the health care system. The results in this chapter are based on observations, governmental publications, a conference, and interviews with a number of experts in POC diagnostics from the United Kingdom.

5.1. POC Diagnostics in the UK

Worldwide, the market of In Vitro Diagnostic (IVD) tests is growing with 10% annually, and in 2007 about 30% of these tests were point-of-care devices (Rajan and Glorikian, 2009). The market growth of IVD testing in the United Kingdom between 2008 and 2009 was 9,1%, in comparison to 3,3% average growth of the EU-15 countries. The United Kingdom spend around 0,5% of their total annual health expenditures (THE) on IVD testing in 2009, which was 702 million Euro. The average % spent on IVD testing of the THE in Europe (for EU-15 and EU-27) is 0,8%. The UK is among the countries that spend the least % on IVD testing, but there is not that much variation in the EU-15 (0,5-1,6%). (OECD, 2009)
Point of care testing is being used for various applications in British hospitals, for example for blood gases, cardiac biomarkers, and glucose meters (Fitzgibbon et al, 2010). These are often devices that add value in time-savings or clinical impact. The responsibility for keeping these tests accurate and how they should be used is often in the hands of a special POCT coordinator (Faulkner, 2011). This person in fact often works in the central hospital laboratory. This shows that in British hospitals, POC devices are applied in a manner they deliver value compared to a centralized lab. In primary care POC diagnostic devices are used, mostly for urinealysis and measuring hemoglobine and glucose. GP's in the UK are actively stimulated to train themselves additionally in a manner they can take over secondary health procedures. Also increasingly GP practices become part of health management centres. Physicians in such larger organisations are interested in ways they can deliver value with POC diagnostic devices (Sutcliff, 2011). In the local pharmacies a number of OTC POC diagnostic devices are available. These devices are mainly glucose meters, pregnancy tests, and blood pressure devices. These devices are broadly accepted, which could be related to the number of years these tests are being used already, and the complexity of the technology. The British authority on medical safety and quality, called NICE, has founded a new department specifically to investigate the possible value of diagnostic technologies: the Diagnostics Assessment Program (Faulkner, 2011).

It is difficult to assess the way the UK is able to deliver value in POC testing in comparison to other (European) countries. The US is currently the largest and most developed market for IVD and POC testing, but also spends the largest amount of money on health care in general (Folland et al, 2010). Experts point out the differences between western markets and developing economies, which also makes it difficult to assess who is leading. Point-of-care devices in western markets are "expensive, high-end products at a doctor's desk or in secondary care for quick decisions". Point-of-care tests in developing countries are affordable tests that take place when there is lack of medical infrastructure. The product then delivers value in terms of affordability, replacement of inadequate medical infrastructure, and shortage of medical staff. However, this research will try to make a qualitative comparison between the Dutch and the UK health system and the way value is created through POC diagnostics. But first both health care systems will be discussed in chapter 5 and 6.

5.2. The British Health Care System

To describe those elements in the British health care system that are relevant to POC diagnostics, the innovation system approach is used as a framework in this chapter. The health care system is defined as *the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse point-of-care diagnostics*. The model below, adjusted from Kuhlmann and Arnold (2002), is used to map out the relevant parties in the British health care system. Before the different components will be described, first a short introduction and history of the British health system is provided to give insight into how the different organizations and institutions are related.

1. **Framework Conditions**
2. **Political System**
3. **Education & Research**
4. **Intermediaries**
5. **Third Party Payers**
6. **Industrial System**
7. **Infrastructure**
8. **Demand**

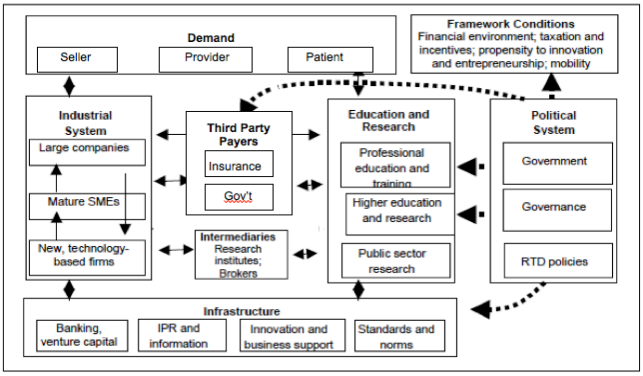


Figure 5.2 – Map of a National Health Care System, adjusted from Kuhlmann and Arnold, 2002.

Introduction

Health care in the United Kingdom is provided by the National Health Service (NHS), and financed through general taxation (Gaynor et al, 2010). All primary care and almost all secondary care, with exception of some prescriptions and optical and dental services, are free at the point of use and provided for anyone who is resident in the UK (over 61 million in 2009) (Gaynor et al, 2010; NHS Choices, 2011). Primary care is provided by general practitioners who act as 'gatekeepers' for hospital based care. Secondary care is provided in public (NHS) hospitals. There is also a small private health sector, which functions parallel to the NHS. Around 15% of the population have complementary private health insurance or use "self-pay-treatments" as health checks. The NHS was launched in 1948 and has become the world's largest publicly funded health service (NHS Choices, 2011). The principle the system is founded on is accessibility; free at the point of use and available to everyone based on need, not ability to pay (White paper *Equity & Excellence*, 2010).

There have been several step-wise reforms in the NHS the past few years. From 1991 on the role of buyer and seller of hospital-based care was separated hoping to promote competition between public hospitals. The local or regional health authorities were given the responsibility of buying hospital-based care for their community. The hospitals became 'sellers' of secondary care and were transformed in free-standing public organizations: *NHS trusts*. The purpose of these market-oriented health care reforms is to make resource allocation in health care more efficient, more innovative, and more responsive to consumers' preferences while maintaining equity (Ven, 1999). In 2002 the government initiated another market-oriented reform package. The essential new elements, which were introduced in 2006 is more patient choice and a change in hospital payments. Patient choice was introduced to encourage movement of patients and stimulate active selection of quality care. The change in hospital payments was to stimulate paying for positive results. Both reforms aim to create an incentive for sellers of care to improve performance and compete on quality (Folland et al, 2010).

In 2010 the Department of Health has published a paper on new reforms in the NHS, called "Equity and Excellence: liberating the NHS" in which again a number of market-oriented elements are introduced. By means of a number of fundamental changes, the overall aim is to empower patient and public choice towards patient-centred care, to improve transparency and insights in results stimulating high quality care, and to increase autonomy (and responsibility) of health care professionals and providers (White Paper Equity & Excellence, 2010). Although it is too early to assess the impact of the 2010 reforms on the NHS, it is good to take into account that system-wide changes with regard to competition and financing will be introduced in the British health care system.

In the following paragraphs 5.2.1 until 5.2.8. the British health care system will be discussed. The different paragraphs start with a general description of the components that are described within the British health care system, followed by the subsequent influence of the specific component on Point-of-care diagnostics specifically. The second part of the description of the influence on POC diagnostics is written in italic so that it can be distinguished.

5.2.1. Framework Conditions

The framework conditions in an innovation system cover the financial and economic environment of the innovation. From the NHS reforms and the communication from the Department of Health some general signals can be identified. There are (political) drivers to improve health outcomes, and stimulate the British health system to become leading and world-class. The motto "Equity & Excellence" of the NHS reforms refers to excellent, high quality care, which remains financially accessible to all, through competitive elements. Patient empowerment should enforce competition on quality and value between health care providers. The UK has a challenging financial position, as many countries throughout Europe (DH, 2010). In addition, through ageing of the population and chronic diseases, there is pressure to increase efficiency, quality and maintain affordability in health services. At the moment there is a vivid public debate in the UK on how the health reforms should be rolled out, whether the DH should invest on competition or in integration between services (BMA, 2011; BBC, 2011; DH, 2011). Amendments and concessions are still made, and it is too early to assess the impact of the NHS reforms. However, in the light of the adoption of POC diagnostics in the British health system a few drivers stand out; the need for more efficiency, integration and quality (BMA 2010).

The framework conditions in the British health system influence the value chain of POC diagnostics in the direction of more efficiency in diagnostic processes, patient centred care and self-management. Point-of-care diagnostics can be developed to address a need for more integration between services and more efficiency if developed specifically for this aim. On this moment everyone – provider, patient, manufacturer, university, hospital and government - is lacking financial resources. Framework conditions drive POC diagnostic devices that deliver value in the sense of efficiency or have a strong business case (Lushai, 2011). There is a general trend to empower patients, and to put patients at the centre of the health management cycle. There are high expectations of technological innovation be an important enabler in this process (QIPP, 2011). Specific for POC diagnostics this could mean that self-management care, as POC home devices are high on the agenda.

5.2.2 The Political System

The political system in a national innovation system refers to the organizations that cover government, governance, guidance and research and technological development (RTD) policies. In the political system in the UK around POC diagnostics a number of organizations can be identified, being the Department of Health, the Medicine and Healthcare Products Regulatory Agency (MHRA) and the QIPP program. Semi-governmental or independent organizations that actively stimulate the development and adoption of innovation in health care are described under section 5.2.5: Intermediaries. A short description of each of the organizations/stakeholders in the political system, specific for POC diagnostics is provided.

The Department of Health (DH)

The British Department of Health (DH) controls the NHS, and is responsible for the budget, policy, guidance, and publications for NHS and social care professionals. The DH reports to Parliament Select Committees (DH, 2011; Zee and Kroneman, 2007). The DH is responsible for standards of health care in the UK, including the NHS, adult care and social care. They set direction on promoting and protecting public health, which encompasses infectious diseases, health promotion and education, safety and environmental hazards. The DH performs tasks by means of strategy, policy, regulation and legislation, performance monitoring and evaluation, building capacity and ensuring transparency. (DH, 2011)
The role of the DH in innovation is formulated in the DH innovation strategy in 2002: encouraging

innovation, sponsoring healthcare industries, contributing for and investing in medical research, and helping to translate research into practice and practical application for example (DH, 2002). Specific for POC diagnostics these activities are translated in RTD policies, such as the Medicines and Healthcare Products Regulatory Agency (MHRA), the Quality, Innovation, Productivity and Prevention program (QIPP) and the founding of the National Institute of Excellence (NICE) for example. Because NICE can be considered an independent intermediary organization, this organization is discussed in section 5.2.5.

The Medicines and Healthcare Products Regulatory Agency (MHRA)

The MHRA is an executive agency of the Department of Health, and responsible for ensuring that medicines and medical devices "work and are acceptably safe". They protect public health through regulation and information on risk-benefit profiles. Concerning medical devices as POC diagnostics, the MHRA oversees the UK notified bodies that audit manufacturers. They regulate medical devices through implementation of the EC Medical Devices Directives into UK law by MHRA regulations. They place obligations on manufacturers to ensure that devices are safe and appropriate for the intended purpose before they are CE marked and placed on the market in any EC member state (Faulkner, 2011).

Quality, Innovation, Productivity and Prevention (QIPP)

"QIPP is the umbrella term used to describe the approach the NHS is taking at local, regional, and national levels to reform its operations and redesign services in light of the economic climate" (BMA 2010, *An NHS beyond the market).* The Department of Health has set up work streams to help manage the delivery of QIPP in the NHS: the program is designed to address the financial challenges in healthcare, while keeping up the importance of quality. (BMA Briefing Note; 2010) In practice, and in the light of diagnostics, the QIPP workstreams may help implement and inform the NHS when a specific POC device is more cost-effective, or reduces steps in procedures (Crabb, 2011).

With regard to the influence of the political system on point-of-care diagnostics, the Department of Health, the MHRA and QIPP seem to actively stimulate promising medical innovations as POC diagnostics. As the DH is responsible for the NHS budget and the public health, they appear to have direct incentive to stimulate innovations that improve quality, efficacy, or (cost-)effectiveness, but also innovations that may improve public health in the longer run. RTD policies as NICE and QIPP have as main goal to assure that those innovations can have ***quick*** *entrance into the health system. In addition, a number of policies have been set out to stimulate quality, and drive value in the health system. This can be observed in the new programs as the Diagnostics Assessment Program, the Quality Innovation Productivity and Prevention Program (QIPP Program). Subsidies and awards are made available for hospitals and trusts that out-perform (Crabb, 2011). Also physicians are rewarded in salary if they develop themselves in a way that improves efficiency in the NHS. These initiatives eventually are financed by the budget of the Department of Health (DH, 2011).*

5.2.3. Education & Research

The organizations that can be identified to play an important role in education and research about point-of-care diagnostics are universities, research consortia, independent and professional organizations and international organizations as the World Health Organization and the European Union. A lot of research on the possibilities of biosensor technology for Point-of-care applications is conducted in universities and research consortia (Brunell, 2011). Universities and university research in The United Kingdom has a strong culture of prestige and delivering excellence. There is transparent information on the overall ranking per university each year, as there are leagues specifically for medicine. These leagues affect the impact (validity, and reliability) of published claims (Crabb, 2011).
The role of independent organizations as NICE and professional organizations as the British Medical Association (BMA) is to publish and deliver guidance. These organizations play an important role in the spreading of knowledge, experience, and professional medical opinions in POC diagnostics.

The WHO recently has introduced new guidance on the technology assessment of diagnostic devices. The European Union has yearly calls for funding for medical technology research and clinical trials for international research consortia, in their FP7 framework program.

In light of the development of point-of-care diagnostics, and sharing of experience and knowledge, research and education in the United Kingdom can be an asset. Excellence in research is important driver in the UK. Organizations as NICE and the British Medical Association have built quite a strong (international) reputation in their opinion and advice, because of very thorough independent assessments and research. When a point-of-care device is considered for medical technology assessment, and independent high-level research on analytical and diagnostic accuracy and clinical utility has been carried out, this is valued highly by the assessing committee (Crabb, 2011). It may have a positive impact to involve a 'league' university as a partner into the value-chain of POC diagnostics. This gives access to personal capital for setting up high standard research to build a strong scientific, clinical and business case, which are very important in building and proving the value of POC diagnostics.

5.2.4. Intermediaries

The main role of intermediaries is the information scanning and gathering, and communication of that information, often referred to as the 'bridge' function (Howells, 2006). The role of intermediaries is also related to expert knowledge on a specific technology, in which they have insight and foresight and can advice stakeholders in the system. For point-of-care diagnostics, important intermediaries in the United Kingdom are the National Institute of Clinical Excellence (NICE), The Medical Technologies Evaluation Program (MTEP) and the Diagnostics Assessment Program (DAP).

National Institute of Clinical Excellence (NICE)

NICE is an independent organization providing guidance, quality standards and managing a national database to improve public health. The focus of the organization is to enable quick adoption and implementation of good and efficient medical services. The role of NICE is to spread knowledge and guidance on how to improve and standardise health service and practice (Crabb, 2011).
NICE makes recommendations to the NHS on medicines, treatments and procedures, care-paths for specific conditions, preventive measures, and how to improve cost-effectiveness with current methods. Decisions are made in a transparent way, based on the best available evidence and including interdisciplinary input (Hill, Bullock, and Alderson, 2011). NICE has become rather successful in this role, and has extended services to provide scientific advice consultancy services to pharmaceutical companies and medical device manufacturers. Because of their sound reputation NICE' international division provides advice to other countries on effectiveness and cost-effectiveness of health practices.
As advice and guidance on POC diagnostics, NICE has two important programmes called the Medical Technologies Evaluation Program (MTEP) and the Diagnostics Assessment Program (DAP), which are closely linked. This is because often the meaningful assessment of diagnostic technologies requires detailed knowledge of the post diagnosis care pathways, resulting in considerable complexity of the technology assessment. (Faulkner, 2011; Crabb, 2011; NICE Website, 2011; Hill et al, 2011)

The Medical Technologies Evaluation Program (MTEP)

MTEP focuses specifically on the selection and evaluation of new or innovative medical technologies, including devices and diagnostics. Although NICE still evaluates biotechnology products, MTEP is specifically designed to help the NHS adopt effective and cost-effective technological applications more quickly. They have a quick and thorough assessment program, and selection of topics is only technology based: MTEP only assesses 'cost effectiveness' and 'clinical effectiveness'. The devices in this stage are often still in development, and the assessment is 'claims-based'. In case of truly complex diagnostic devices that are very 'promising' the technology will be forwarded to the DAP. This happens when the assessment of the diagnostic device requires evaluation of the complete diagnostic care-path, or when a group of diagnostics can be assessed in parallel. (Crabb, 2011; NICE Website, 2011)

Diagnostics Assessment Program (DAP)

DAP provides specialist capacity for undertaking complex assessments of diagnostic technologies, which are referred to the DAP from the MTEP program. DAP was founded from the insight that a technology assessment on (POC) diagnostics quickly is higly specific, complex and specialized. For each application a new assessment is required. The Diagnostics Assessment Program is a very new program, and is just up and running. DAP is not intended as a gatekeeper program, as NICE for pharmaceuticals for example. Many often not too complex devices already have free entrance into the health system once considered 'safe'. The DAP assesses complex diagnostic devices, and provides guidance to the NHS. Notifications to the program are driven by manufacturers or sponsors. There is a procedure for public consultation. Technology assessments are undertaken by independent external assessment groups (EAGs). There is a strong commitment to express the advice built from technology assessments in cost/QALY (quality adjusted life year). The advantage of using this method is that difficult decisions regarding the allocation of resources can be made transparent and explicit (Buxton & Chambers, 2011). For the assessment process the NICE standard Multiple Technology Appraisal (MTA) process is used as starting point. The intention of using MTA and expressing value in cost/QALY is to make the decision making process regarding the allocation of resources in healthcare as transparent and as rational as possible. The aim of the Diagnosics Assessment Program is that the NHS will regard the DAP guidance, and manufacturers will consult the program as to how their product can generate most value in the health system. (NICE, 2011; DAP, 2011; Crabb, 2011)

Regarding the Influence on point-of-care diagnostics, intermediaries as NICE, MTEP and DAP have a facilitating role in the delivering patient-value through biosensor technology, and during the value-chain of POC diagnostics. First, for agenda building, it is useful to ask MTEP or DAP to take a look at a POC test. The process they will go into consists of assessing the scientific literature and assessing the possible clinical impact. In this process interdisciplinary expert teams are brought together to assess the technology, and brainstorm with the manufacturer and DAP to see whether a valuable business case can be developed. (Crabb, 2011; Faulkner 2011) All persons in the expert team will be introduced to the new application, which may build expectations and set agenda in the professional sector. In addition, these teams bring in cross-disciplinary knowledge and new insights to the manufacturer on how the product may add value, or what may should be adjusted, and where barriers may be (Crabb, 2011).
In the best case guidance is developed on how to use the POC device in way that it will deliver additional value in the diagnostic process. As described before NICE guidance is highly valued by NHS trusts, and medical professionals. The Diagnostics Assessment Program is fairly new, and may not yet have a similar reputation as NICE guidance on pharmaceuticals for example (Crabb, 2011). However, as DAP is one of the first initiatives worldwide to focus on high-tech diagnostics assessments only, and they are supported by NICE, there work is very interesting.

5.2.5. Third party payers

In the British health care system the role of the third party payer is fulfilled mainly by the National Health Service (NHS) and for a small part by private health insurance companies.

The National Health Service (NHS)

In the UK healthcare is financed through general taxation, in a public health service called the NHS. The NHS, launched in 1948, was based on the principle of solidarity, and the ideal that good healthcare should be available to all, regardless of wealth, which principle still remains at its core (Gaynor et al, 2010; NHS Website, 2011). Directly under the responsible Department of Health, ten regional Strategic Health Authorities (SHAs) are responsible for enacting the directives and implementing fiscal policy. Under those SHAs, healthcare is managed through NHS trusts. The NHS trusts may provide primary, secondary or other types of care. Figure 5.2 shows the structure of NHS covered care.

Strategic Health Authorities (SHA)

The ten Strategic Health Authorities across England form an important bridge between the Department of Health and front line NHS organisations (BMA, 2010). Each SHA is responsible for enacting the directives and implementing fiscal policy from the DH at a regional level. In turn each SHA area contains various NHS trusts, which take responsibility for running or commissioning local NHS services. The SHA is responsible for strategic supervision of these local NHS services, meaning they have to develop plans for improving health services, make sure local health services are of a high quality and are performing well, and increasing the capacity of local health services so they can provide more services. They also have to make sure national priorities are integrated into local health service plans (BMA, 2010; NHS website, 2011).

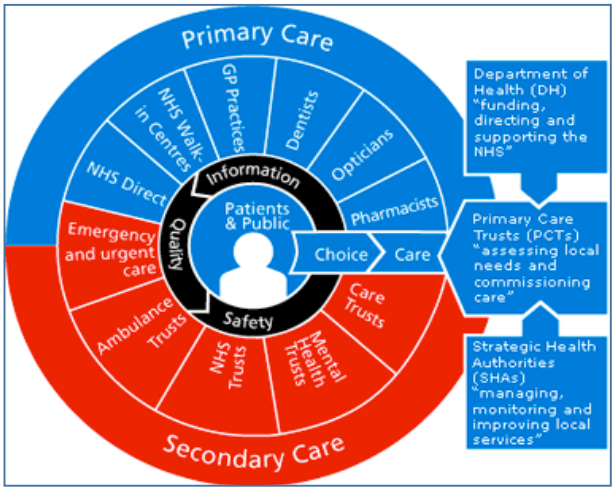


Figure 5.3. - NHS Structure (Source: NHS Choices)

NHS Care Trusts

As explained, as a result of the 1991 reforms NHS hospitals and practices became 'sellers' of health care services, while the DH Department of Health and its strategic health authorities became the 'prudent' buyers or third party payers (Gaynor et al, 2010; Ven, Schut en Rutten, 1994). The local or regional health authorities were given the responsibility of buying care for their community and were transformed in free standing public organiza-tions: *NHS trusts*. A trust is a generic term for a legal entity/organisation providing health and social care services within the NHS (NHS Choice, 2011). Several types of NHS trusts exist. Hospitals are managed by acute trusts, which function as the 'board' or direction of the hospital, university medical centre, or specialized care centre. Primary care services are managed by local primary care trust (PCT). There are currently 151 primary care trusts in the United Kingdom, controlling 80% of the NHS budget, which makes them the centre of the National Health Service.

Private health insurers

In addition to the NHS, people can get private health insurance, which is often complementary to the services provided by the NHS. About 15% of the UK residents have additional private health insurance. Private health care is mostly focused on non-acute services for which there are long waiting lines. (Gaynor et al, 2010) Some insurers are more pro-active in the way they deliver services, for example they provide self-pay treatments, health checks, insurance, and distinguish themselves by focusing on the self-management and prevention. With regard to POC diagnostics, private health insurers often only provide primary, non-acute services, or services with long waiting lines in the NHS (Gaynor et al, 2010).

The way the third party payer role in the United Kingdom is historically shaped is one of the main reasons for constant reforms. The National Health Service is a large, complex, hierarchical and some say bureaucratic system, of which fragmentation of expertise and services is often as result. And there is room for improvement in terms of quality and efficiency would many agree. There is however a vivid discussion as to whether improvements should be sought in more competition, through more patient choice and provider liability, or that big improvements can be made through integration. Former Health Secretary Stephen Dorrell replied in an interview about the role of integration as a solution in healthcare: "look at alternative ways of delivering care, that address some of the fragmentation which is part of the history of the NHS health service that needs to be improved upon." (BBC, 2011) Point-of-care diagnostics could play a (facilitating) role in the trend towards patient centred and integrated services care, so reforms in the system are not a barrier per definition. In line with reforms there are for example initiatives to strengthen the 'entrepreneurial' role of GPs, supporting them to take over activities that take place in secondary care for instance. This is especially interesting in case of POC diagnostics.

5.2.6. Industrial System

The most important actors in the industrial system around Point-of-care diagnostics in the UK are manufacturers and designers of biosensor technology, clinical research laboratories, (large) pharmaceutical companies, and new entrants to market. These can be start-ups or companies from other markets. Some examples of manufacturers in the global POC diagnostics market currently are Abott Diabetes Care, with the FreeStyle for home or clinical glucose testing and Abott Diagnostics with the iStatt for critical care. Roche Diabetes has developed a complementary line of diabetes POC applications with the ACCU-CHEK. GE-healthcare's has developed the QuietCare system for elderly home care applications, and also microbiology (clinical lab) expert Biomerieux has started a long term alliance with Quidel to start developing new rapid testing devices. The main focus of the POC diagnostic market currently is diabetes, cardiac markers, critical care, hematology, and immunoassays. (Kalorama, 2010) The development of these markets is related to the fact that diagnostics in these fields of medicine have developed quite far, and especially diabetes is a field in which self-management and home care already plays an important role for some time (Walhout, 2011; Frederix, 2011). Possible new entrants in the market of POC diagnostics are Philips Handheld Immunoassays, NXP Semiconductors, but also large telecommunication parties that cooperate with existing smaller IVD diagnostic companies. It is also expected that real new entrants will enter the field of diagnostics: experts in optical and magnetic electronics as Fujifilm and Canon might enter the field of POC diagnostics as they have the capabilities to develop magnetic/optical biosensors (Brunel, 2011). In general a large increase in competitors is expected in the field of IVD testing and POC diagnostic devices (Brunel, 2011; Kalorama, 2010).
Medical devices designers (industrial designers) play an important role in developing and designing POC diagnostic devices by connecting medical and technological knowledge with user input and ergonomics. When looking at international awards for POC diagnostic devices, leading designers can be found in Denmark, Sweden, the US and UK, and Austria for a large part. International industrial designers involved in POC diagnostics are for example Masimo Labs (US) who won the Medical Design Excellence Awards in 2011 with their handheld noninvasive hemoglobin spot-check testing device, and IDEO (US) that designed the Contour USB blood glucose monitor in collaboration with Bayer Diabetes Care and won an MDEA in 2010. Other (European) designers are Kinneir Dufort (UK) that developed the Accu-Check Inform blood glucose meter in collaboration with Roche Diagnostics, and Althofen Electronics (A) that developed the ClearPlan Easy Fertility monitor in collaboration with Cambridge Consultants (UK) and Unipath Diagnosics (India, US). The Medical Design Excellence Awards (MDEA) competition is a premier awards program for the medical technology community, which recognizes the achievements of medical product manufacturers, engineers, scientists, designers, and clinicians. (MDEA, 2011)

POC diagnostics in hospital settings often are used under supervision of the clinical hospital laboratories, under the POCT coordinators, who are responsible for the processes to maintain quality (FitzGibbon et al, 2010). In addition there a number of medical laboratory companies, that have (private) laboratory testing services. Clinical laboratories will not be a stimulating factor in the adoption of POC diagnostics, because this would mean that their current activities and procedures will change or decrease (Faulkner, 2011; Lushai, 2011). It is wise to assess whether every diagnostic test should become POC available and replace clinical lab tests, because sometimes clinical lab test deliver more value, and results are not needed immediately (Lushai, 2011). That is why it is very important to define which diagnostic test will add patient value in its application in POC diagnostics and how.
In line this with this view, it is important for POC diagnostics manufacturers and designers to define which diagnostic test will add patient value in its application and how. This is how companies distinguish themselves from competitors, but also do not directly have to compete with an existing high performing market of clinical laboratory testing (Kooij, 2011). Companies can have an active role in delivering value with POC diagnostics, provided that they have a distinct case, and the company has potential to add value or knowledge or expertise to the value chain.
A handicap of many new entrants is that they prefer delivering a complete product, because it is easier to build internal or external agenda for investments, or the company has developed processes and routines in a specific area. However, companies may be more competitive if they investigate how the companies' specific skills adds value to current processes in health care diagnostics. (Lushai, 2011) This

could mean that a company provides a supporting device that is capable of communicating with all POC diagnostic devices in the hospital, and combines data for smart patient records (Brunel, 2011). Or deliver only knowledge or services to current processes. If a company cannot diverge from existing patterns and routines, the organisation itself can be a barrier for successful innovation, and delivering value in the health system with POC diagnostics (Lushai, 2011).

5.2.7. Infrastructure

Infrastructure refers to non-natural resources that are collectively used, including energy supply systems, water supply, transport systems, but also non-physical components as technical standards, educational provision and legal systems. What is interesting for the development of POC diagnostics, is the infrastructure specifically designed for the use of POC diagnostic devices in hospitals, primary care, and home care in terms of regulation, IT infrastructure, electronic patient files, and trained staff.
The UK has rather developed infrastructure with regard to POC diagnostic devices. As an answer to the development in POC testing (POCT) a new function is created called POCT coordinator. This person is responsible that the tests are being conducted as intended, the test is calibrated, and quality is monitored. This means there is knowledge and experience on how to use the device, and there is someone responsible that the device is checked regularly.
Legislation with regard to POC devices is quite clear so far, and in full development. POC diagnostic devices in the UK require a CE-mark that ensures safety in line with EU regulation. There is guidance available for users and POCT coordinators how to best use the devices. Reimbursement policies are an important driver of developments in the POC diagnostic devices (Burnell, 2008). For manufacturers it is important to understand whether, and if so how, hospital and primary care based POC devices are reimbursed. Within acute care, reimbursement of point-of-care diagnostic devices is often incorporated into inpatient and day case tariffs. Some POC applications have separate tariffs. The main NHS financing structure for pathology (central lab) services is based on payment by results (FitzGibbon et al, 2010). The introduction of POC in the UK is largely driven by the NHS bodies, in special the NHS pathology service, and a large network of POC testing coordinator staff. Currently there are a number of reforms in the NHS pathology services that would eventually lead to a situation where manufacturers can influence the setting of the price of the test. These reforms have been delayed until 2012, and it is uncertain what role POC diagnostic devices will get in the new tariff plans (FitzGibbon et al, 2010).

Quality and accuracy are important considerations in the adoption of POC devices in professional care settings (Kooij, 2011). Therefore the development of the educational infrastructure in the form of a new function as POCT coordinator is a positive influence on the development of POC diagnostic device.
Regarding regulatory infrastructure the developments in reimbursement policies are important. The fact that currently POC testing falls within set tariffs mean it is difficult to get reimbursement per test. However, set prices are an incentive for providers of care to improve efficiency (Folland et al, 2010). If the POC test has a cost-saving or time-saving case, compared to current methods this would still add value to the NHS trust. However the discussion on POC testing reimbursement policies are postponed to 2012, and uncertainty in reimbursement policies are certainly not a positive influence for manufacturers. Reforms proposed by the DH, will also affect the health regulatory framework, and may add up to uncertainty for companies for long-term investments.

5.2.8. Demand

The demand side or end user in the innovation system of point-of-care diagnostics can be divided in three major groups; 1) the sellers of care, the directors/boards of hospitals and health management centres, 2) the providers of care, which are the health professionals and the general practitioner, nurses and specialists, 3) the consumer and patient, who may buy the device in a local pharmacy.

Sellers of care
With regard to the decision to acquire a new medical device as POC diagnostics, the NHS acute trust also has a specialized committee to assess the new technology. The hospital board or health management board will decide eventually on acquisition of a new medical device. They use published guidance on the topic, and take into account specialist's opinion. (Crabb, 2011)

Providers of care
When a POC device will be used in primary or secondary care settings, the user is a specialized physician, or GP. The physician or GP is an important agenda builder for the acquisition of a new medical technology to the hospital or health management centre. They attend congresses and read on the subject in professional medical journals. In the external assessment groups (EAGs) of DAP, physicians are a very important stakeholders and source of experience (DAP, 2011). General Practitioners in the UK often work in (primary care) health management centres, together with nurses, dentists and physiotherapists for example. GP's are actively stimulated to take on training to be able to take over some activities from secondary or acute care. When a GP would perform activities that a patient would normally have to go to the hospital for, but the GP can do as troponin testing for example, the GP is financially rewarded from the NHS. (Sutcliff, 2011; Bates, 2011)

Consumers of care
The other category of final demand are the consumers that use POC testing for home applications, and pharmacies that are the retailers of these applications. What can be seen is that already a reasonable assortment of POC diagnostic devices is available in local pharmacies. In addition, the pharmacy is increasingly becoming a place where consumers can come consult trained professionals on health issues, and do health checks. For example Boots Pharmacy in the UK facilitates an NHS walk-in service in several large stores. Consumers can get advise, prescriptions, and over the counter care as well. In these stores a number of POC diagnostics devices are sold over the counter. The advantage of selling POC in combination with a walk-in centre is that people can ask advise on the people working for the NHS.
A small survey in the US and the UK on the use of point-of-care (self-)testing by Kricka and Price (2009) highlighted that consumers are highly familiar with the tests available in pharmacies, and less aware of tests available in supermarkets or online. More people had been using POC tests in primary care settings, getting advice and feedback about the results, than they performed the tests themselves at home. The fact that the test results were delivered quickly was seen as a principal benefit, and consumers were willing to pay for this. In addition the privacy and convenience of home-testing was seen as an important benefit as well, and this was related to an interest of keeping medical records of themselves and family. Kricka and Price (2009) point out that the concept of patient choice for the use of POC diagnostic devices carries with it important associated expectations: tests need to be reliable, there needs to be evidence to support the use of test (diagnostic accuracy and clinical utility) and results should contribute to health issues, prevention for example.

Figure 5.4 - OTC POC diagnostics in the UK
Source: author, 2011

Figure 5.5 - NHS Health Centre & walk-in service
Source: author, 2011

The actors representing the (final) demand side in the UK health care system are quite influential for the creation of value through POC diagnostics. The decision for adopting POC in primary and secondary care is largely coordinated through acute and primary care trusts (Crabb, 2011). For this decision, physicians, specialists and GP are in important source of expertise and building agenda for new developments in the field of POC. The opinion of physicians is also highly valued in technology assessment. So far consumers are more comfortable using POC diagnostics when the results are accompanied by a health professional's advice and explanation. The concept of POC home diagnostics is rather well-known, only not for all applications (Kricka and Price, 2009). Overall, specialists are important source of knowledge on where and how POC can deliver value, but they also have an important position for building trust and building interest in the results.

5.3. Map of the British Health Care System

The following map shows an overview of the British the system of organizations and institutions around POC diagnostics. The relation *between* the various components was not a topic of study in this research. The arrows in figure 5.3. represent the general relations between the different organizations and institutions in an innovation system, as they are discerned in theory (Kuhlmann and Arnold, 2002; Edquist, 1997).

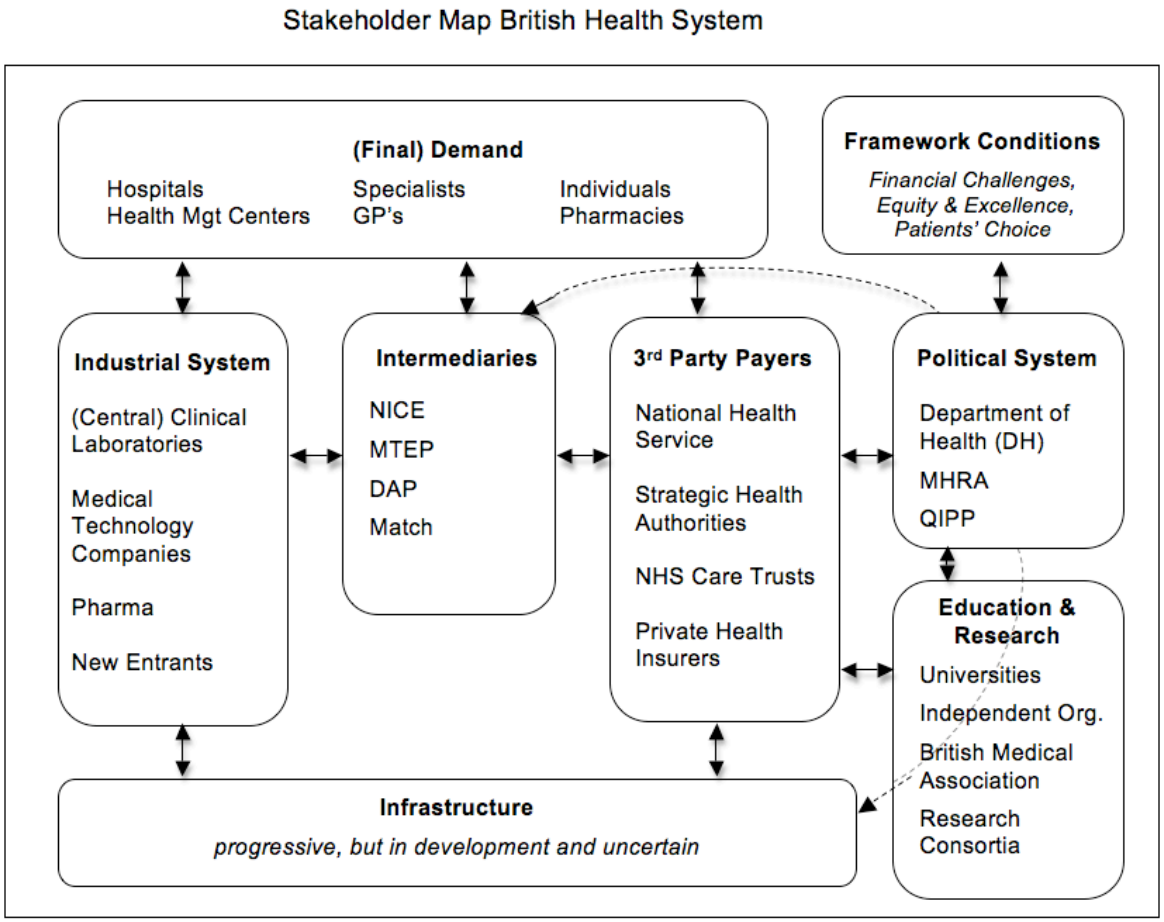


Figure 5.5 – The British Health care System (adjusted from Kuhlmann and Arnold, 2002)

This chapter aims to identify the possible influence of the various actors in the UK health care system on the value chain of point-of-care diagnostics, by answering the question: *What is the influence of the key components in the British health care system in relation to the value chain of Point-of-Care diagnostics?*
Some specific observations are pointed out here:
Patient choice and self-management are high on the agenda in UK, seemingly due to framework conditions and the political system. Point-of-care diagnostics for at home care are rather well known, which seems to be related to a broad availability of the devices and the spread concept of self-management. Point of care diagnostics are also rather broadly used in primary and secondary care, and physicians have an important influence in the decision making process. The industrial system has a lot of new entrants and new initiatives in diagnostics, but may form a barrier if they do not adjust their business model to needs of the health care system. Intermediary organizations perform well in supporting quick adoption of the technology in the health system, by formalizing the role of the POC coordinator, and writing guidance on how to use the POC device in primary and secondary care. Intermediaries also actively stimulate GP's to take over activities from secondary care, as diagnostic testing procedures, which can benefit the development of POC diagnostics.

6. The Dutch Health Care System

Chapter 6 aims to answer the fourth sub-question: *What is the influence of the key components in the Dutch health care system in relation to Point-of-Care diagnostics?*
Section 6.1. provides a brief overview of the current state of POC diagnostics in the Netherlands, to provide insight in the creation of value through POC diagnostics currently, as an 'output' factor of the value chain. Section 6.2. provides an overview of the role and activities of the main entities and organizations in relation to POC diagnostics. Section 6.3. provides an overview the form of schematic map of the Dutch health care system.
The results are based on scientific literature research, governmental publications, conferences, and interviews with experts on the topic in the Netherlands. The depth of the knowledge is more profound on the Dutch health care system compared to the UK health system, because resources and time enabled a more thorough research in the Netherlands.

Figure 6.4 – University Medical Centre Utrecht
Source: umcutrecht.nl

6.1. POC Diagnostics in the Netherlands

Worldwide, the market of In Vitro Diagnostic tests (IVD tests) is growing with 10% annually, and in 2007 about 30% of these tests were Point-of-care (Rajan and Glorikian, 2009). The market growth of IVD testing in the Netherlands between 2008 and 2009 was 3,7%, in comparison to 3,3% average growth of the EU-15 countries. The Netherlands spend 0,5% of their total health expenditures on IVD testing, which was 309 million Euro in 2009 (OECD, 2009; EDMA, 2011).
In secondary care point-of-care diagnostic devices are being used for number of applications, but mainly for bloodgases, cardiac markers and glucose monitoring. Clinical hospital laboratories in hospitals have optimized the collecting and deliverance of diagnostic tests, which enables the physician to retrieve the results of a test for example of cardiac markers within 15 minutes if necessary (Groot, 2011). Physicians are interested in new point-of-care devices, but strongly point out that safety, accuracy and quality need to be guaranteed over time, and there should be clinical impact and/or efficiency gains (ZorgOplossing, 2011; Prakken, F. 2011). Physicians and clinical chemists suggest that a person from the hospital clinical lab may be the best person to be responsible for the quality-management of the device (Meerkerk and Wulkan, 2011; Groot, 2011). In addition to direct impact on the diagnostic care path, some physicians think the concept of point-of-care can play a role in a shift towards patient-centred integrated care-paths. In these care paths, primary, secondary and self-care are to be integrated around a medical condition as Parkinson or CVD Risk Management for example (Cardiovascular Disease) (Bloem, 2011). This in contrast to hospital divisions which are currently structured around a medical expertise.
Almost everywhere in primary care, point-of-care urineanalysers and tests for measuring hemoglobine and glucose are used. Also in primary care there is an increasing demand for POC testing. Increasing availability and diversity of tests has lead to a need for data- and quality-management for POC devices in primary care as well. The clinical lab of the Atrium Medical Centre in Heerlen has run a pilot for 2 primary care (GP) practices for a new data-managament system that could monitor and support the primary care practice from the clinical lab in the hospital, and matched the data-systems of the different labs, for the GP and hospital specialists in the EPD. (Kleinveld et al, 2011)
Home care POC testing devices in the Netherlands are not broadly accepted. In normal pharmacies, perhaps a glucose meter and some pregnancy test are available. Plenty of tests are available online, but people remain very cautious as to the quality of the result. Often people perceive home tests as being 'just a little better than a wild guess' (Derksen, 2011). This scepticism is related to the fact that currently diagnostic home-test are only regulated by (EU) law with CE-certification. The CE certification is only meant as safety regulation, and does not require analytical or diagnostic accuracy.

6.2 The Dutch Health Care System

The health care system from an innovation's point of view is defined as *the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse point-of-care diagnostics*. The model below, adjusted from Kuhlmann and Arnold (2002), is used to map out the relevant parties in the Dutch health care system. Before the organizations and institutions will be described, first a short introduction and history of the Dutch health system is provided to give insight into how the different components in the system are related.

1. **Framework Conditions**
2. **Political System**
3. **Education & Research**
4. **Intermediaries**
5. **3rd Party Payers**
6. **Industrial System**
7. **Infrastructure**
8. **Demand**

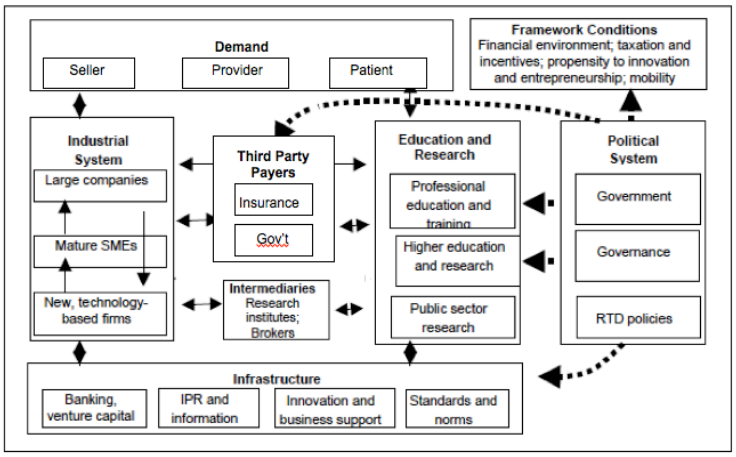


Figure 6.2 – Map of the Health care system (Kuhlmann and Arnold, 2002)

Introduction

In the Netherlands there is a social security based health system, where everyone has mandatory 'private social health insurance', based on principles of equal access and solidarity (Muiser, 2007; Exter, 2004). Health insurers are regulated under government regulation. Health care providers are private parties, self-employed in care practices, or employed by hospitals, which are non-profit by law.

The Dutch health care system, historically, has been characterized by much private initiative in both funding – local insurance parties - as in provision of care. Until 1941 there was no government involvement in the heath system. Between 1940 and 2011 three important waves of reforms took place. Between 1940 and 1970, the main goal of the reforms were to promote public health, regulate professional licensure to ensure a level of quality, and ensure universal access (for everyone, everywhere, with every income) (Ven and Schut, 2008; Exter, 2004). Between 1970 and 2000, the reforms were largely directed at cost-containment, as they already saw health-care costs rising uncontrollably. Strict budgeting systems were implemented, and fee-for-service payments were largely eradicated from the system. From 2000 onwards the budgeting policies were subject to growing criticism as there were no drivers for efficiency, quality and innovation. A new adequate governance structure was required that enable effective competition, and drive value, effectiveness and quality in the system. This finally paved the way for the 2006 Health Act, which enabled national mandatory health insurance, based on managed competition in the private (insurance) sector. Every person in the Netherlands is obliged to have a basic health insurance. The basic health package covers basic necessary care, as primary and secondary care, dental care under 18, pregnancy care and other. The general practitioner functions as gatekeeper for specialized care. The specific content of the basic health insurance package is determined by the College voor Zorgverzekeringen (CVZ) (Derksen, 2011).

In the current health care system, all Dutch individuals have to pay an income-related contribution to the tax collector, who transfers this amount to a Risk Equalization Fund (REF). In addition, all adults have to pay an insurance premium directly to the chosen insurer. Each insurer may set their premium, but this premium is an important source of competition. In case the insurers have a client with high health related risk profile, insurers receive a high risk-adjusted equalization payment from the REF. In case of clients with a low health related risk profile, insurers have to pay an equalization payment to the REF. People are free to buy voluntary supplementary health insurance for benefits that are not included in the mandatory basic insurance. More than 90 percent of the population buys supplementary health insurance, almost always from the same insurer that provides their basic coverage. The complete health

system is primarily financed through two mandatory universal schemes: a scheme for curative health care services (Health Insurance Act) and a scheme for long-term care services which is meant for people in need for "uninsurable care"; chronic or congenital diseases for instance (Exceptional Medical Expenses Act/Algemene Wet Bijzondere Ziektekosten, AWBZ). (Ven and Schut, 2008)
The difficulty of this very advanced system of risk equalization is that it requires a high component of control and legislation, which can be problematic for innovation. For example if a certain type of diagnostic test can take place in primary care, and saves time and costs in emergency care, the current reimbursement structures make it very difficult for the insurer to reward the GP, and reimburse less to the emergency department (Geertsma, 2011). Another point is that the risk equalization scheme makes sure that insurers will not discriminate and select between high-risk or low-risk clients. The adverse effect of this equalization system is that it gives insurers little incentive to invest in innovations that focus on decreasing the risk-levels of clients, and thus do not directly have an incentive to invest in public health. (NZA, 2010)

In the following paragraphs 6.2.1 untill 6.2.8. the Dutch health care system will be discussed. The different paragraphs start with a general description of the components that are described within the Dutch health care system, followed by the subsequent influence of the specific component on Point-of-care diagnostics specifically. The second part of the description of the influence on POC diagnostics is written in italic so that it can be distinguished from the first.

6.2.1. Framework Conditions

The framework conditions in an innovation system cover the financial and economic environment of the innovation. In addition it covers taxation, incentives, and entrepreneurship in the sector (Kuhlmann and Arnold, 2001). As in many European countries, the Netherlands has a challenging financial position. This means that the budget for investments in public services as healthcare is very tight (Vossenaar, 2011). In addition the Dutch government has to cope with an increasingly expensive health system: the total health expenditures in 2009 is estimated at 12,0 % of total GDP, compared to 8,3% in 2001 (OECD stats, 2011). The accessibility and quality of health services in the Netherlands is among the highest in the world (RIVM, 2011). The main cause of the increase in health care expenditures is an increase in volume, mainly caused by ageing of the population, which is related to a need for different and more complex health services, and an 'explosive' increase in chronic diseases (RIVM, 2010). In addition, ageing of the population in relation to health care means that the group paying for the health care system will become smaller relatively to an increasing population of elderly and chronic patients. This will eventually put pressure on the financeability of the health system and the principle of solidarity (Vossenaar, 2011). There are high expectations that (technological) Innovation in health care could be an important part of the solution to keep the health care system sustainable, but only if a balance can be found between a reduction in expenditures and new technologies (RIVM, 2010). A number of insights are gained the past few years in the field management and policy in the Dutch health care system. First the statement 'higher costs = higher quality" was extensively proven to be wrong, not at least because low quality is related to substantial costs. People are more aware that it could be helpful in healthcare that competition would be based on quality and value, which requires transparency and measurable concepts (Rijn, 2011). Developing measurable quality indicators has shown to be very difficult, and especially physicians seem to be aware that they have to take responsibility for designing the standards, than wait for policy. A third trend is the growing awareness that a tighter outcome-based health policy, is related to much more specialisation and integration, which will impact the way health professionals and others connected in the system will have to organise (Rijn, 2011).

In the light of POC diagnostics, (governmental) policy will strongly focus on supporting innovations regarding efficacy gains (NL: doelmatigheid) and labour-saving solutions. Besides the investments in innovation, maintaining the current level of the quality while realizing some cost-savings in the health care system will be high on the agenda (Vossenaar, 2011; Gruijters, 2011). There is an important influence from the current framework conditions, on the possibilities and opportunities in health care innovation and with regard to POC diagnostics. In line with innovation theory, several experts in the field

of health care policy and technology point out that the current focus on cost-saving and 'smarter' innovations does not necessarily have to be a barrier for the development of POC diagnostics (Vossenaar, 2011, Linden, 2011, Porter, 1998). If accompanied with a good business case, and if adjusted to a specific need for more efficiency in terms of time, or in the diagnostic process, this focus can be used a driver or seen as an opportunity as well. It is interesting to notice that concerning the innovative possibilities of POC diagnostics, other countries as the US and the UK focus on screening and early diagnosis as source of possible value from POC diagnostics, to put some more weight and value in prevention and lifestyle as part of the health cycle. The perception on screening and the related health gains can be considered sceptic in the Netherlands (Derksen, 2011). In the Netherlands the political and economic agenda focuses more on developments in POC diagnostics that add value in terms of process-improvement, time-savings, labour-savings, and cost-savings (Vossenaar, 2011).

6.2.2. The Political System

The political system in a national innovation system refers to the organizations that cover government, governance, guidance and policy. In the Dutch political system, the government "steers on headlines and safeguards public interests (quality, accessibility, affordability of care)" (Muiser, 2007, p. 12). With regard to POC diagnostics a number of organizations can be identified: the Dutch Ministry of Health (VWS), de Nederlandse Zorg Autoriteit (NZA), and DBC Onderhoud. This paragraph provides short description of these organizations and finishes with the role of the political system for the development of POC diagnostics.

Ministerie van Volksgezondheid, Welzijn en Sport (VWS)

The Dutch ministry of health, wellbeing and sports (VWS) is responsible for the enablers and circumstance for good care and stimulating innovation. They are responsible for informing the parties involved about available subsidies and regulation, more transparent procedures for developers and implementators of innovative care (Vossenaar, 2011). However due to current financial challenges in the Netherlands, little extra funding is available for innovation in health care. VWS stimulates people to develop healthy behaviour and lifestyle, by information and education. Finally VWS is responsible for guaranteeing the right to basic care. With regard to the development and implementation of POC diagnostics, the ministry of health in the Netherlands only has an enabling role, the active role lies with the sector itself, the developers, and the insurers. A few goals of VWS are relevant for the development of POC, which are that the innovation process needs to become quicker and more effective, to make it possible that valuable technologies can be implemented much sooner. The requirement for manufacturers to show at least 3 years of clinical studies before the product can be assessed for basic insurance, is postponed in some cases. This evidence building may than take place as the product is being used, in a controlled and measurable setting (Grimbrere, 2011; Vossenaar, 2011). According to VWS real opportunities for innovation in health care and for point-of-care diagnostics will be E-health, health 2.0., self-management, and labour-saving innovation. However the active role for the development of innovations in this area are in the hands of the industry, the medical profession, and the insurers. (De Groot, J. 2011)

Box 6.1. Health 2.0
Webpower, Xenias 2009

Although some physicians would like to turn back time, the well-informed self-managing patient that googles medical information before going to the medical expert, receives increasing support.
Health 2.0. refers to 'participatory' health, patients that become expert in their own health matters, become self-managing, are active in communities as Google Health and PatientsLikeMe. In these communities knowledge, personal experiences, and data is shared and exchanged. Patients build informal valuable networks. The condition specific online communities meanwhile build highly valuable statistics on medication and adverse reactions – and often quicker than in clinical trials.

De Nederlandse Zorg Autoriteit (NZA)

The market of health care often is described as a triangle between the consumer, the third party payer, which is the insurer in the Netherlands, and the seller/provider of care. Three smaller sub-markets can be distinguished, being the health insurance market - between consumer and insurer, the purchasing

market - between buyer and seller of care, and the provider market, between consumer and provider. The Nederlandse Zorg Autoriteit (NZA) is market regulator in these three markets. The consumer's interest is central to the activities by the NZA, to ensure efficiency, market transparency, choice, access and quality. The main tasks of the NZA are to analyze information, intervene, and create and exercise regulation, and advice VWS. Technological innovation in healthcare is often more difficult, partly because it is more difficult for manufacturers and care providers to earn back their investments, and due to the payment structure, insurers in the Netherlands do not have much incentive to invest in innovation. This makes it even more difficult to find the capital for clinical effectiveness studies. (Vliet, 2011; NZA, 2011) The NZA has a number of innovation policy documents that make it possible to apply for subsidies for 'short' term experiments. To file the application, a contract must be provided to the NZA, signed by both the provider of care as the insurance company, containing the plan, the goal of the experiment, how the 'achievement' will be financed eventually. (Veltink, 2011; Grimbrere, 2011).
In terms of the development of POC diagnostics, the NZA finds continuous innovation in healthcare an essential way to keep the Dutch health system affordable and high-quality. Within the market of health care the insurance parties have a crucial role as prudent buyer of care. Empowering this role is of central importance to the NZA. The NZA is stimulating the use of Good Contracting Practices' to take away some barriers in the often very difficult and long lasting negotiations between insurers and sellers/providers of care. (NZA, 2011; Vliet, 2011)

DBC Onderhoud

DBC-Onderhoud is an organisation that is responsible for the functioning of the DBC-financing structure in the Netherlands (Dijke, 2011). DBC is the term for a diagnose-treatment combination, and this term is used in relation to a set amount of money that health professionals receive from the insurance party for the treatment, the reimbursement (NL: Diagnose-Behandel Combinatie). There are a few advantages in the reimbursement of a complete diagnose and treatment plan, as supposed to set prices per procedure. Firstly physicians receive a set amount of money for each patient, so they will have a financial incentive to help the patient as efficiently as possible. Also, there will be less supplier-induced demand (Folland et al, 2011). Second, the hospital or physician themselves are responsible for what the treatment will consist off. So if a POC troponin test falls within the criteria of a cardiac arrest DBC, than the hospital is free to acquire/buy the new POC diagnostic device. The system in which medical technology/medicines may 'freely move' without assessment from the insurance authorities is called the free inflow and outflow system (Geertsma, 2011). There are also disadvantages, when a medical device does not fall within an existing DBC, or when no 'outflow' occurs (ZonMW, 2011; Grimbrere, 2011). DBC Onderhoud is an independent advising commission, but in the light of their actitivies and function, the organisation is considered part of the 'political system' in this research.

With regard to the development of POC diagnostics in the Netherlands, some specific directions are underlined and supported by the political system. These are for example POC diagnostics that fill a need for process improvements through delivery of quick results, or more efficient wireless data saving and communication, but also labour saving innovations. The latter type of innovations realize more independency and self-management of the patient (at home), or enable a partial transfer of a complex medical procedure from a specialist to less specialized (cheaper) medical staff. With regard to the nature of the influence of the political system in the Netherlands on the value chain of POC, this is merely facilitating. The Dutch health care system historically has a lot of private initiative and actors (Ven and Schut, 2008), and still the role of the Ministry of VWS, the NZA, and DBC-onderhoud, is mainly to make sure that the conditions/prerequisites are in place to enable (managed) competition, patient choice, competition between insurers, sellers of care, and that consumers have choice. Also the conditions are set in a way that this competition in health care will drive innovation and efficient allocation of resources (Ven and Schut, 2008). The goal of VWS to streamline the different institutions that are involved in regulation, health technology assessment, subsidies and research, in order to decrease the time-to-market of technology in health care, is an example of this facilitating role.
A positive development in the Dutch political system, is that the current pressure on more effective allocation of resources – same amount of resources, increasing number of patients – has lead to a more critical point of view in health technology assessment. Institutions as CVZ and DBC-onderhoud that are

responsible for determining 'basic healthcare' and what should be reimbursed, have complemented their assessment activities of new health technologies, with a critical re-assessment of existing procedures and techniques that are insured (Dijke, 2011). Also in health technology assessment, a supersession case[1] is explicitly valued in the category cost/efficiency of the treatment. These developments could improve the competitive environment in health care, as it should motivate suppliers of health technologies and medicines to keep improving their product. With regard to POC diagnostics, this would be a positive development, as the overall effect is that there would be more inflow and outflow in the health care system, which could lower the barriers to entry.

6.2.3. Education & Research

The organizations that can be identified to play an important role in education and research about point-of-care diagnostics in the Netherlands are universities, university medical centres, company fundamental research, public private partnerships (PPPs), and (semi)governmental institutions as RIVM and the Rathenau Instituut.
University Medical Centres (UMC) have specific task with regard to innovation in health care, which is described by the ministry of VWS. The UMCs have the task to develop knowledge and innovate in specialized medical care, and translation of this knowledge into concrete applications. This is to centralize the research efforts. In addition the ministry of VWS expects UMCs to think about social issues as the growing demand of health care services, patient safety, resource allocation in health care with limited resources and quicker development of innovative medical devices. (NZA, 2010). Because hospitals have to invest and take financial risk a financial component is payed to UMCs for this task. This 'academic component' is only for specialized care.
An example of a public private partnership in the health care sector at the moment is EhealthNu, a partnership between Philips, Menzis, Achmea, Rabobank, KPN en TNO, and in cooperation with the Zorginnovatieplatform[2]. This cooperation again illustrates the expectations in e-health. Also public private partnerships are initiated and supported by the Verbond van Verzekeraars, a union of private insurance parties in the Netherlands that represents 95% of the health insurance market (Geertsma, 2011). The importance of this union is that when new technologies are developed and implemented, all insurance parties need to agree on covering the procedure. A physician will have serious second thoughts before incorporating a new procedure – even though it might be very promising - when the procedure is only covered for patients with a specific insurance (Geertsma, 2011). An important example of a PPP in the field of diagnostics combined with E-health is the DiabetesStation, which is the result of a cooperation between IPT Medical Services (founded by KPN), and the Erasmus Medical Center Rotterdam. The 'station' which is already in use in the Erasmus MC, enables diabetes patients to measure and monitor weight, blood pressure, glucose and BMI themselves with help of interactive software available in eight languages. In addition, patients can access this data at home, which stimulates proactivity and involvement (DiabetesStation, 2010).

Medical devices as POC diagnostics have emerged from applied technological sciences: new solutions in health care have emerged from telecommunication, car sensors and security systems for example. New partnership networks in health care – with telecom and micro/nanochip experts - illustrate that medical research and development has entered a new field of sports. Currently there is still often a gap between fundamental medical research that takes place in UMC's and research and development and implementation of medical devices (Hermans, 2011). There is however increasing awareness on this issue, which leads to partnerships as the KPN-Erasmus MC DiabetesStation, and technology transfer centres linked to academic medical centres and research institutes in health care that focus on translating fundamental research into practical applications (utrechtvalorisationcenter, 2011). Public

[1] *Incorporating the (cost-, time-, labor-) savings of replacing the older medical procedure/process/device in the business case of the new medical technology.*
[2] *The ZorgInnovatiePlatform is an initative by ZonMW, CVZ and NZA, to to provide a single point of access to information about regulation, subsidies and support for 'innovators' and entrepreneurs in health care).*

private partnerships seem a very promising approach for the development of new health technology. The main reason for this is that in the development of the device, needs and interests of stakeholders are integrated in the solution. The design incorporates these needs and users have been involved, which lowers resistance for new developments (Geertsma, 2011). Education & Research have a facilitating function in the health care system, but the valorisation of this knowledge seems most effective when the research takes place in a corporative model.

6.2.4. Intermediaries

The main role of intermediaries is the information scanning and gathering, and communication of that information, often referred to as the 'bridge' function (Howells, 2006). The role of intermediaries is also related to expert knowledge on a specific technology, in which they can advice stakeholders in the system. For point-of-care diagnostics, important intermediaries in the Netherlands are governmental institutions that support innovation through guidance and innovation subsidies, these are for example the College voor Zorgverzekeringen (CVZ), ZonMW, and Agentschap NL.
Also active intermediaries are public private partnernetworks specifically set up for the development and implementation of technology, and to help smaller start up firms. Examples of these partnerships are the Zorginnovatieplatform, Vitavalley, Healthvalley, MedTech Partners and IZIT (ICT Connectie Zorg Twente) (VitaValley, 2011; Grimbrere, 2011). A third type of intermediaries focuses on the financing, entrepreneurial insights and business support of new promising innovations in health care. Examples of these type of intermediaries are the Innovatiefonds Zorgverzekeraars, Healthcare Finance Group (venture capitalists), and the Health Innovation Fund (Achmea, ABN AMRO and Mediq). Than finally there is a developing role for technology transfer centres or valorization centres, as explained in the paragraph on research and education. These are centres that are often (geographically) connected to a academic medical centre, or research institute, and focus on For example in the Academic Medical Centre in Amsterdam and the VU Medical Centre both have a technology transfer office in their hospitals. In Utrecht the Utrecht Valorisation Center works closely with the UMCU (utrechtvalorisationcenter, 2011). The role of College voor Zorgverzekeringen (CVZ), ZonMW, and Agentschap NL will be elaborated, as these institutions are specific for the Dutch health care system.

College voor Zorgverzekeringen (CVZ)

CVZ, the college for health insurers is an independent policy institution that advises on the specific content of the basic health package. CVZ primarily holds relations with the ministry of VWS since 2006, to support the acceptation and content of the basic health insurance package (Derksen, 2011). CVZ writes guidance on new innovations in health care and whether these should become part of the basic package, which means the process/device will be reimbursed. In their technology assessments they require that technical and clinical claims need to be proven by reliable medical-scientific studies. This sometimes means that it takes some time before pateints have access to a product, because no clinical studies are available yet. Because clinical studies are time consuming and a hampering factor, there is a new policy document that enables a temporary adoption of the product in the basic package – provided that the product fits all other requirements – so that the manufacturer can obtain clinical data and the product is reimbursed. The product at first will only be used in monitorable, safe, and small applications, to be able to collect useful data. (Grimbrere, 2011; ZIW, 2011). CVZ guidance is very important to manufacturers, as this makes it plausible that there will be demand for their device (ZIW, 2011).
Regarding POC diagnostics specifically, there are legal guidelines for technology assessments. The test is assessed according to the following three points; technical validity, analytical validity and clinical value/utitility. The first two are tested by independent research organizations as TNO for instance, and are a matter of certification. CVZ is involved primarily in the second and third traject of the technology assessment. Especially clinical utitility is a strong issue, because CVZ is manager and custodian to the basic health package, which means they are responsible to allocate the public health budget for the most effective care. In addition to clinical utility, the financial case, and other health related outcomes are taken into account. Because the clinical utitlity case of POC diagnostics is different for each application and point of use, for every different application a new assessment will be carried out (Derksen, 2011).

ZonMW

ZonMW is a subdivision of the ministry of VWS and NWO, the Dutch Organization for Scientific Research, and is the result of a fusion between Zorg Onderzoek Nederland (former ZON) and the department of medical sciences of the NWO. The main task of ZonMW is to speed up technological innovation and implementation in health care, which they do by stimulating and subsidizing research, development and implementation in health, prevention, and health care. ZonMW aims to be the bridge between research, policy and practice, stimulating knowledge- and innovation projectst which can contribute to health care in practice (ZIW, 2011). The core activities of ZonMW is to subsidize research on innovations in healthcare in all phases, from idea, concept, implementation to adoption, in which they have built a reasonable experience. However, to be considered for a subsidy traject, this requires the initiator to present a grounded plan. Therefore ZonMW might be less appropriate for less fundamental innovations as process-innovations for example (Linden, 2011).
ZonMW and CVZ actively point out the importance of supersession in a business case. In a system in which free in and outflow of medical technologies can occur, the outflow of older applications is very important for the sustainability in the system. Very often the reason that medical technological innovations lead to an increase in costs, is because there is acquisition of new products, but no supersession (Linden, 2011; Grimbrere, 2011). ZonMW and CVZ strongly advise companies to think about long-term financing of their POC diagnostic device which can be done in two ways; either the product saves time or money in itself, or buy acquiring new POC diagnostic device A, the older alternative B process can be replaced. This financial plan is often not taken into account by manufacturers (Linde, 2011; Grimbrere, 2011).

Agentschap NL

Agentschap NL is a division of the ministry of Economic Affair, Agriculture and Innovation. The organization consists of five thematic sub-divisions with a centralized supervision. The division relevant to POC diagnostics is the sub-division NL Innovation, which also has a focus on health innovation. Agentschap NL has no health care specific subsidies, but can be a source of subsidy. The strong advise that Agentschap NL has for manufacturers of medical technology is that they have to build a solid long-term structural financing plan, instead of relying too much on subsidies to survive. In the latter care the experience has shown that a large proportion of the starting businesses in healthcare fail immediately after the subsidies are stopped. (ZIW, 2011; Starremans, 2011)

With regard to the value chain of POC diagnostics, and the development of an emerging technology in healthcare, there are many intermediary organizations in the Dutch health care system that are expert in some part of the process. According to the ministry of VWS, there are still a lot of medical innovation subsidies available. Companies just have to find out where to get them (Groot, 2011). As a response there has been a persistent signal by companies that the current structure of intermediaries, and especially procedures where companies have to match different requirements at different institutions (CVZ, ZonMW, NZA, and DBC-onderhoud) is an important barrier for entrepreneurs to enter the market of health care. In addition, current procedures increase the time-to-market in such a way, that only a select group of entrepreneurs and large companies are able to take the risk (Boer, 2011, Linden, 2011). Fortunately there are initiatives currently to centralize ZonMW, CVZ, and the NZA, to have a single access point of information on subsidies, requirements and health technology assessments. This new initiative should replace the current Zorg Innovatie Wijzer[3]. Streamlining these processes would have an important facilicating effect on development of new technologies.
Summarizing, there are a number of important developments within the group of different intermediaries that can facilicate the creation of value through POC diagnostics. These are specific partnernetworks with expert knowledge and connections, and centralization of regulatory and guidance institutions (Grimbrere, 2011). There are however also still negative and bureaucratic elements presents, that hamper time-to-market, quick decision time, and flexibility.

[3] This initiative can be found at www.zorgvoorinnoveren.nl

6.2.5. Third party payers

The role of the third party payer in the Dutch health care system is fulfilled by private health insurance companies. In 2011 there are 10 insurance concerns, that cover 27 risk bearing health insurance companies in total. Five out of the ten concerns have one health insurer (NZA, marktscan 2007-2011). All Dutch citizens are required by law to register for an insurance fund. In addition, insurers are regulated to to apply open enrolment to all for the basic health care package. (Muiser, 2007)

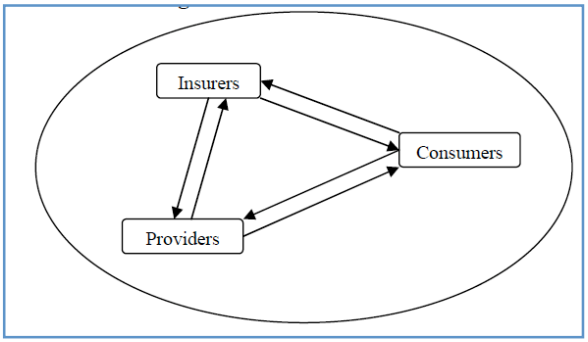


Figure 6.3. Dutch health care market: a level playing field for health market actors within the boundaries of a legal framework (Source: *Muiser, 2007*).

The main role of the third party payer is 1) to take over the consumer's financial risk of becoming ill, 2) to be a prudent and critical buyer of care and negotiate with providers of care and hospital boards, and 3) to guarantee universal non-discriminatory access to basic health care services (Ven, Schut & Rutten, 1994). The Dutch health care market is often described as a tripartite system between consumers, providers and insurers. This makes the role of the insurer in the Dutch health care market twofold. The first main role is that insurers have the responsibility to purchase good quality care, and negotiate the best care for their clients with the available resources. This negotiation takes place between the insurer and the providers of care (Muiser, 2007; Vliet, 2011). The other role is that insurers have to distinguish themselves in the health insurance market and compete for consumers. These two elements would stimulate insurers to selectively cooperate with certain high quality or specialized hospitals, which then should drive quality in hospitals and between health care providers. In addition, competition between insurers would increase efficiency in terms of transaction costs.

Health insurers are connected in the Verbond van Verzekeraars (VV) the Dutch private health insurers' professional organization. Members of the VV represent 95% of the private health insurance market (Verzekeraars, 2011). The VV has identified four main responsibilities, which is to represent the member insurance parties in political, regulatory or other dialogues. Another task is to improve and maintain the sound reputation of the health insurance branche towards the consumer and the media for instance. The third and fourth role of the VV is to create a platform, and keep up-to-date with relevant developments in the sector (Verzekeraars, 2011; Geertsma, 2011).

As explained before, the complex structure of risk equalisation decreases the incentive for insurers to invest in public health, as high risk clients are compensated. Another issue with health insurers is that if insurers can distinguish themselves by providing a new innovative type of care which they have developed in close collaboration with a manufacturer, there is a problem with the 'non-discriminative' element in healthcare. All people in the Netherlands have a right to the same level of quality. So in this case, the innovative insurer would have to tell the concept to all other health insurers. This decreases the incentive by insurers to proactively search for innovative care as a way to compete. (NZA, 2010)
However, health insurance companies do compete on premiums and these premiums are expected to go up in the following years due to increased health care expenditures. So there is a huge drive to search for innovative procedures and devices that enable the same level and quality of care, but at a better price (Geertsma, 2011). Overall, insurers are quite active in public private partnerships and research collaborations, as explained in section 6.2.3. Also, the NZA research and innovation subsidy is funded by the health insurance companies (Geertsma, 2011; Grimbrere, 2011). What is difficult is the amount of parties that the insurer has to take into account, and as explained, all insurers need to agree on financing a medical device, or the barrier for implementation will be very high for the manufacturer and the insurer. To take all the stakes into account in the development of a new product, insurance companies strongly advice the manufacturer to discuss the possible applications and financing as soon as possible. To overcome these issues, insurance companies now more often join a research collaboration with more parties or with the Verbond van Verzekeraars. (Geertsma, 2011)

6.2.6. Industrial System

The most important actors in the industrial system around Point-of-care diagnostics are manufacturers of biosensor technology, industrial designers, clinical research laboratories, (large) pharmaceutical companies, and new entrants to market. These can be start-ups or companies from other markets.
As explained in the previous chapter, manufacturers of diagnostic devices currently are Abott Diabetes Care, Roche Diabetes care, GE-healthcare, Biomerieux and many more. The main focus of the POC diagnostic market currently is diabetes, cardiac markers, critical care, hematology, and immunoassays (Kalorama, 2010). New initiatives in the market of POC diagnostics in the Netherlands are the DiabetesStation developed by KPN en Erasmus Medical Centre which is developed for diabetes patients self-management, and MediMate, a spin-off from the Technical University of Twente, which is a home care diagnostic test that measures the lithium concentration (Medimate, 2011; DiabetesStation, 2011). Medimate is developed for depressive patients, and saves the patient a visit to their GP or hospital for their periodical lithium values. Possible new entrants in the (Dutch) market of POC diagnostics are Philips Handheld Immunoassays, NXP Semiconductors, but also large telecommunication parties that cooperate with existing smaller IVD diagnostic companies. In general a large increase in competitors is expected in the field of IVD testing and POC diagnostic devices (Brunel, 2011; Kalorama, 2010).
Medical devices designers (industrial designers) play an important role in developing and designing POC diagnostic devices by connecting medical and technological knowledge with user input and ergonomics. When looking at international awards for POC diagnostic devices, leading designers can be found in Denmark, Sweden, the US and UK, and Austria for a large part. The Medical Design Excellence Awards (MDEA) competition is a premier awards program for the medical technology community, which recognizes the achievements of medical product manufacturers, engineers, scientists, designers, and clinicians. (MDEA, 2011) So far no Dutch designers were rewarded in the field of diagnostics, but Philips Healthcare did receive several awards as manufacturer, and was rewarded as designer for the Motiva interactive healthcare platform. The interactive information and monitoring system for people with chronic diseases was manufactured by Philips Medical Systems, and design was accredited to Celadon (San Rafael, CA), Philips Digital Systems Laboratory (Eindhoven, The Netherlands), Schematic (Los Angeles), and Silicon & Software Systems (Leopardstown, Dublin Ireland).

When looking at the overall effect of the 'industrial system' on the value chain of point of care diagnostics, there are three elements that play a role. In the Dutch health care system there is a general sound from the industrial system that the complexity of institutions, policies and regulation in the Dutch health care system is high threshold for innovation. Timelines of technology assessment of the different involved intermediates, regulatory organizations and third party payers are not synchronized, which makes the process for manufacturers not only complex, but also time-consuming (Boer, 2011). Especially for new entrants in healthcare, the barrier is high. Overall there is often a lack of overview from manufacturers about the complete value chain: which steps are required, what regulations need to be complied to, and which organizations need to be involved. (Vossenaar, 2011)
A second positive characteristic of the Dutch health care system is that there are many opportunities for public-private partnerships, which are actively supported by intermediaries and governmental institutions (NZA, 2011). This opportunity for manufacturers and designers to collaborate with hospitals and insurance companies in their research project, can help them overcome the complex health care system, as such a partnership or value chain is an important source of knowledge.
Finally, there is prejudice of health professionals and insurers on the industrial system that often ideas are supply driven and 'manufacture borne' and will only cost money (Derksen, 2011; Geertsma, 2011). Too overcome this prejudice, manufacturers need to have solid scientific proof of their concept in terms of diagnostic and analytical accuracy and clinical utility (Prakken, W., 2011). In addition, the insurance party and an expert physician need to be involved as early as possible in the development of a POC diagnostic device (Grimbere, 2011, Geertsma, 2011). In this way, the chance that the product can be integrated in current structures, and will be supported by the professional opinion, is much higher. Completely developed products sold as mobile phones for example are highly related to product failure in the health care system (Geertsma, 2011). Again, this point underlines the value of an integrated value chain approach for manufacturers.

Overall, companies need to develop a different business model for delivering value in health care systems. Traditional ways of thinking inside a firm may be hindering the value chain of POC diagnostics

6.2.7. Infrastructure

Infrastructure refers to non-natural resources that are collectively used, including energy supply systems, water supply, transport systems, technical standards, educational provision and legal systems. What is interesting for the development of POC diagnostics, is the infrastructure specifically designed for the use of POC diagnostic devices in hospitals, primary care, and home care in terms of regulation, IT infrastructure, electronic patient files, and trained staff.
At the moment in the Netherlands the accuracy and safety regulations are in development. For the use of point-of-care in primary and secondary care there is no clear regulation yet as to who is responsible for the POC device. Health professionals suggest this role for the clinical laboratories, and in addition call for standardized certifications that guarantee safety and diagnostic and analytical accuracy over time. (Groot, 2011; Prakken, F. 2011) There are pilots currently on if a regional centralized lab can do the overarching coordination of POC diagnostics in both secondary and primacy care in that region. (Kleinveld et al, 2011). Also for the use of home care there are debates that CE marking alone is not enough to protect consumers (Derksen, 2011). From both consumer groups as professionals there is a call for analytical and diagnostics accuracy certificates also for home care POC diagnostics. Overall, there is room for improvement in standardization of ICT and technology in health care (Vossenaar, 2011)
Reimbursement policies are considered very important in the development of POC diagnostics (FitzGibbon, 2010). Regarding POC diagnostics, manufacturers often have difficulties with reimbursements, because products have no reimbursement 'code' or the impact is cross-disciplinary. For example if POC diagnostics enable a shift from activities from secondary to primary care, this requires that the reimbursement budget for the hospital should decrease slightly, and increase a bit in primary care. In practice this is very hard to realize (Groot, 2011; Geertsma, 2011). Especially for IT based solutions in healthcare, that match data from different disciplines, it is very difficult to get reimbursement. Therefore some manufacturers call for changes in the reimbursement structures in the Netherlands. However the ministry of VWS has made a clear statement that the reimbursement structure is not going to be changed in the near future (Groot, VWS, 2011).

Regarding the influence of the regulatory infrastructure on POC diagnostics, in the Netherlands a clear message was given by the minVWS that the reimbursement system is not going to be changed. Although some people might not agree, this does provide stability in the system for manufacturers and third party payers, who can look for more creative constructions within the current system. The fact that the current reimbursement structures remain stable may have both a negative and a positive effect.
The negative part, which also very much relates POC diagnostics, is that within the current structure of reimbursement and DBC's it is very difficult to implement innovations that are cross-disciplinary, cross-divisional or crosses medical conditions. The reason is that in a system of set codes/DBC's per condition, which is linked to a specific amount of money covered, the interdisciplinary solutions – e-health, wireless solutions, data-communication, preventive monitoring - have no place. These new solutions require new developments in the reimbursement system. In case of point-of-care diagnostics, when an ACS test can take place at the primary care physician, a part of the DBC coverage is transferred from secondary to primary care. This requires a strong lobby to rearrange current financing – at the GP, in the hospital, the emergency care department and the insurance party. That is a large barrier for new innovations. However, and maybe because of the financial pressure everywhere - more and more people, physicians, insurance parties, and companies are getting more and more creative in financing their solutions (Geertsma, 2011).
The positive influence is stability in a system of subsidies and legal infrastructure. Insecurities that emerge for manufacturers through constant changes in RTD policies, taxes, changing (safety) regulations, and changing subsidies are considered a significant barrier for successful innovation (Hekkert, 2011). This implies that stability in the infrastructure would have a positive influence on the development of POC diagnostics.

6.2.8. Demand

The demand side or end user in the innovation system of point-of-care diagnostics can be divided in 1) the sellers of care, which are directors/boards of hospitals and health management centres, 2) providers of care: the health professionals as the general practitioner, nurses and specialists, 3) the consumer and patient, who may buy the device in a local pharmacy (the reseller).

Sellers of care

Dutch hospitals are not-for-profit by law, but as often in a competitive system very much behave as for-profit entities (Van de Ven, Schut, Rutten, 1994; Folland et al, 2010). The hospital board is responsible for negotiating prices with the insurance parties, in which they represent the providers of care. Within the hospitals, specialististic departments as cardiology, oncology and emergency care, 'rent' the facilities, and receive payments related to the number of patients they help. The most important role of hospitals in the Netherlands is to behave as social entrepreneurs and manage the delivery of high quality secondary care (Muiser, 2007). In case of the acquisition of a POC device for the emergency care department, the (financial) decision will be made by the hospital board. The lobby for the product however often starts with a medical expert, who has read about the product in a medical journal, or is involved in a pilot or research for example (Groot, B., 2011). The responsibility of maintaining and calibrating point-of-care devices in hospitals is often in hands of the central medical lab (Kleinveld et al, 2011). If a POC device falls within an existing DBC, for example Acute Coronary Syndrome, the hospital can decide to acquire the POC device without any contact with insurers or DBC-onderhoud. Because then emergency care used to send the Troponin tests to the central lab for example, but have calculated that the use of POC diagnostics is more cost-efficient, with the same diagnostic and analytical accuracy, and clinical utility. The routine and procedure stays the same, but with another tool.
Since the seventies health management centers have emerged in the Netherlands. In the Netherlands these are organizations focused on primary health care with workers of several disciplines, established at one address. The basic disciplines in a health centre are general practice medicine, district nursing, social work, physical therapy and pharmacy. There could be other disciplines as well, such as obstetrics, home help, dentistry and psychology. The main goal of health care centers is to take the independence of the individual patient as starting point, stimulate self-management, emphasize prevention, and create accessible care. One of the advantages of health management centers is that they can acquire medical resources and equipment as a shared investment between the disciplines. (Bruijn and Kirkman, 1992) In health management centers especially coordination, accessibility and storage of patient data is important. (Kleinveld et al, 2011). Besides health management centers there are many 'classic' primary care practices in the Netherlands where the general practitioner delivers primary care to a geographical population, and acts as the gatekeeper for secondary care.

Providers of care

While in secondary care the coordination of POC devices often lies with in the central medical lab, this is not as clear for primacy care practices and health management centers. POC devices are widely in use in GP practices in the Netherlands, mainly for urine screening and glucose and hemoglobine measurements. The demand for POC testing in primary care will increase in time, also because GP's are stimulated to broaden there field of expertise, to enable more specialization in secondary care (bron). This changes the question *whether* POC testing should occur in primary care, to *how* this should be facilitated. Currently number of pilot studies are conducted that test the centralization of the responsibility for quality, accuracy and calibration of the device at the regional medical labs for the primary care practices within the region, which can also store and coordinated the patient information, and communicate with hospitals in case the patient is referred (Kleinveld et al, 2011).
In many hospitals specialists already use POC testing devices, for example for troponines, blood gasses, hemoglobines, Kalium and Lactaat for instance. Helpful would be measuring procalcitonine to monitor sepsis, to start early with antibiotics. (Groot, B. 2011) As the most hospitals already have an inhouse medical laboratory, the point of interest for POC devices would be if the device would decrease the average time that patients take in emergency care for instance, or the time a medical specialist would need to do procedure which could be transferred to another medical staff. The disadvantage is that

many hospitals already have a centralized medical lab. The advantage is that the medical laboratory staff can be made responsible for the quality of the device over time. In case of primary care this would need to be set up, to prevent safety risks. In the Netherlands there is no formal Point-of-care-coordinator role established yet. This is in line with a general demand by health care professionals in primary and secondary care for more regulation for POC testing, and certification guaranteeing analytical and diagnostic accuracy over time (Kleinveld et al, 2011; Prakken, F. 2011).

Consumers of care

When looking at the role of consumers in the Dutch healthcare system, patients and consumers must protect their rights and take more responsibility for their own health(care) (Muiser, 2007). In the Netherlands the pro-active, self-managing, interactive patient 2.0 is not yet reality, although there is more and more participation in patients' health and lifestyle matters (Walhout, 2010). In case of diagnostics, patients have access to the point-of-care devices in primary and secondary care. The availability of POC diagnostic devices in local pharmacies - both in the *apotheek* as in the *drogist* - is very low, or they are unavailable. As a result, the use of POC devices in home care is quite low in the Netherlands. What is related to this concept is that there is people are sceptic towards home testing devices, in professional and private opinion. This scepticism has to do with the fact that IVD testing, or POC diagnostic testing for home care is only regulated by European and national law on product safety. POC devices have access to the market with only CE-marking, which has no guarantee on diagnostic or analytical accuracy. This means that there are a number of tests available online and in the stores that might not be better than 'a wild guess'. Home POC diagnostics require the establishment of consumer trust, more information, and legislation diagnostic and analytical accuracy (Derksen, 2011).

The active stimulation for self-management for patients by governmental institutions and health strategists is based on the observation that if patients are actively involved in their own health matters and they have access to complete and subjective information about treatments and the consequences, they would use less care than they do now (Bloem, 2011). In addition, patient 2.0 would visit his GP less often but would consult specialists and fellow patients in his online network. This network where all patients keep track of their health indicators would become a valuable source of statistic data. Examples of these types of network in the Dutch healthcare system are Parkinsonnet.nl and Mijnzorgnet.nl, supported by the Ministry of Health. According to the Quick Scan by ZonMW the national introduction of Parkinsonnet would save Euro 1450,- per patient per year for a group of 50.000 Parkinson patients, a reduction of 73 million a year. At home sensors and biosensors can play an important role in the transition towards self-management. People could be monitored real time, and visit the GP or specialist only when needed based on individually tailored health advice. However, especially in developments for home care, it is important to take into account the patients that will not fit in the new system, and protect those who are not able to work with e-health (Rathenau, 2007; Walhout, 2011).

The overall influence of the demand side on the value chain of point-of-care diagnostics can be described as a positive influence. In hospital and primary care settings, POC diagnostics devices are already in use. If the device fits within the current DBC structures, negotiations can take place between the hospital and manufacturer directly. Physicians are open-minded, and already use the devices for sometime. However, and as explained in 6.2.6., the manufacturer will need to present solid scientific proof on diagnostic and analytical accuracy and clinical utility, and publish the results in a proper medical journal, before physicians are interested in a new POC diagnostic device whatsoever (Groot, B., 2011; Prakken, W., 2011; Geertsma, 2011). In both primary care and secondary care the physician (medical professional) will be the person that sets agenda for buying a new device. They are the ones that have the most insight in possible applications and market need, and need to be willing to use the device (Geertsma, 2011).

With regard to consumers in the Dutch health care system they are quite new to the concept of POC diagnostics and need to be more educated and introduced in the possibilities of self-monitoring and self-management with POC diagnostic devices. It is expected that home-care POC diagnostics will develop as there have emerged standards in professional care. It is assumed that consumers' experience with the devices in professional care will help the diffusion of POC diagnostics (Kricka and Price, 2011). So this suggests that in order for home care POC diagnostics to develop in the Netherlands, professional

standards and quality regulation need to be developed first. What could also play a role in the slow development of self-management and home POC diagnostics in the Netherlands is that consumers/patients do not have one single independent authoritative and reliable source of information as a website about health care. Every institution has their own website with partial and subjective information, and healthcare related websites are often private initiatives. Might the Dutch government aim to develop integrated participatory health care for patient 2.0, they need to make sure that there is a subjective source of information available. In case of home diagnostics it seems very insightful to report findings on the value and usefulness of home care glucose meters on the diabetes network page in 'normal' language. But this information cannot come from the manufacturer itself.

Figure 6.4. Different Dutch information websites to improve patient choice and self-management

6.3. Map of the Dutch Health care System

The following map shows an overview of the Dutch system of organizations and institutions around POC diagnostics. The relation *between* the various components was not a topic of study in this research. The arrows in figure 6.5. represents the general relations between the different organizations and institutions in an innovation system, as they are discerned in theory (Kuhlmann and Arnold, 2002; Edquist, 1997).

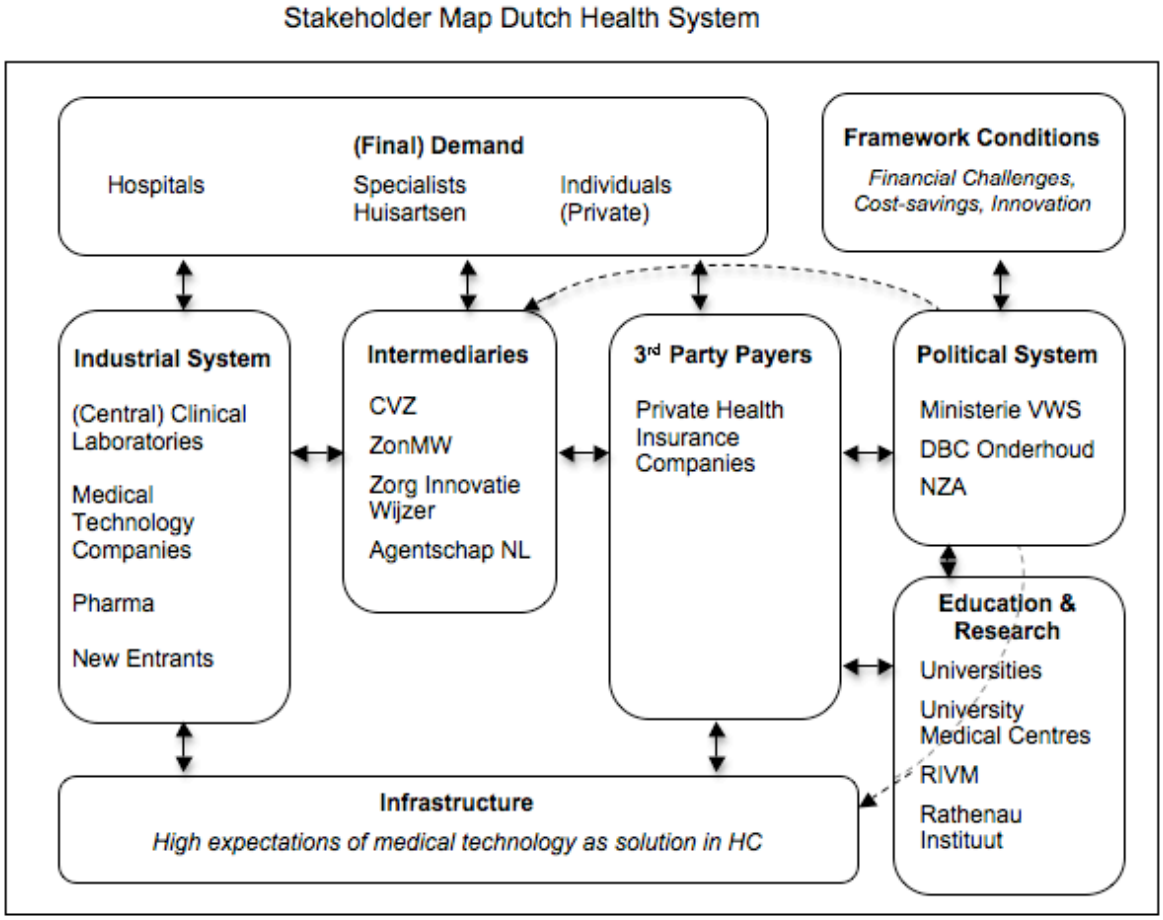


Figure 6.5. Dutch Health care System (adjusted from Kuhlmann and Arnold, 2002)

This chapter aims to identify the possible influence of the various actors in the Dutch health care system on the value chain of point-of-care diagnostics, by answering the question: *What is the influence of the key components in the Dutch health care system in relation to the value chain of POC diagnostics?*
Some specific observations are pointed out here:
The labour saving innovations and keeping up quality are high on the political and industrial agenda in the Netherlands, seemingly due to framework conditions. The political system has set goals, but has a merely facilitating role in enabling market mechanisms in health care. The responsibility for innovation in health care lies with insurers, industrial system and the medical profession for a large part. There are many new companies entering health care and new partner networks emerge in the field of POC diagnostics. The complex health care system, and especially fragmentation, regulation, and lack of structure is often considered a barrier for innovation by the industrial system.
The concept of self-management is developing the Netherlands, but there is plenty space for improvement. People are not yet acquainted with buying POC diagnostics in pharmacies. There is room for more strategy in the Dutch health care system, in providing consistent information and direction.

7. Analysis of the Results

This chapter provides an analysis of the results and insights obtained on the British and Dutch health care system and the influence of the different components in the system on the creation of value through point-of-care diagnostics. Section 7.1 starts with the overall performance of the United Kingdom and the Netherlands in delivering value through POC diagnostics. Section 7.2. presents an analysis of the two health care systems, and answers the first part of the main research question: *how do the different components in the health care system influence the value chain of point-of-care diagnostics?* Section 7.3. answers the second part of the main research question: *How can the difference between the two health care systems in delivering value through POC diagnostics be explained?* Section 7.4. summarizes the findings in a refined model that is complemented by insights from chapter 4 on how value can be created throughout the value chain of point-of-care diagnostics.

7.1. The Creation of Value through POC diagnostics in the UK & the Netherlands

Overall, this research assesses how the different components in a health care system influence the creation of value trough point-of-care diagnostics. This section will provide results on how the UK and the Netherlands deliver value through POC diagnostics, as a qualitative output measure. POC diagnostics are considered a high-value medical technology, and successful adoption of the diagnostic devices in health care is related to the way that the technology delivers value. The extent to which POC diagnostics are adopted - in market size – is a way to illustrate the creation of value through POC diagnostics in the UK and in the Netherlands as output factor. The UK has a growth rate of 9% in their In Vitro Diagnostics (IVD) market in 2009, which is above European average. The assumption is that about 30% percent of the IVD market is Point-of-care (EDMA, 2011). The Netherlands has experienced a growth of 3,7% in their IVD market in 2009. When comparing these percentages to the total health expenditures per country, the UK and the Netherlands have both spent 0,5% of their total health expenditures on IVD testing in 2009. However, if the IVD market in the UK will continue to grow at this percentage for a few years, the UK market for POC diagnostics will grow faster than the Dutch market (OECD, 2011).
When considering the adoption of POC diagnostics in primary and secondary care, no large differences are observed between the UK and the Netherlands. Given the fact that the devices will be safe, and diagnostically and analytically accurate, primary and secondary care physicians are positive about using point-of-care diagnostic devices. With regard to possibilities of screening, the devices need to become more specific and accurate. In both countries, the best way to show the value of a diagnostic device is by publishing an article on the added value through independent research in a sound medical journal. Generally in both the UK as the Netherlands, the same type of POC applications are used in primary and secondary care. These are mainly glucose, blood gases, cardiac markers, hematology and critical care, in line with global developments in POC diagnostics. The adoption of these types of POC diagnostics is related to the fact that the added value of these devices can be quite easily translated in terms of process/time/cost-effectiveness when compared to centralized laboratories, provided that diagnostic and analytical accuracy are comparable to the laboratory test. These applications fit quite well in current structures. Radically new applications as monitoring of an inflammatory profile in case of an infection, or (accurate) population wide screenings are still in development. The (regulatory) infrastructure needs to be dynamic to be able to incorporate radically new POC diagnostic devices, as existing infrastructure is one of the most important barriers for radical innovators. Both the UK and the Netherlands put effort in a dynamic system: keeping their health technology assessments up-to-date, trying to extend current criteria and take to take into account more value-based characteristics. With regard to standardization of safety and coordination, the Netherlands is lagging behind compared to the UK.
Some differences can be detected between the Netherlands and the UK with regard to the value that is delivered by home POC diagnostics. Selling POC glucose monitors, blood pressure meters, digital pregnancy tests are more accepted and much broader commercially available in the United Kingdom than in the Netherlands. The added value of these devices is more an indirect utility, as a compact glucose meter gives the patient more comfort, freedom, and ease of use. The health system in the Netherlands still can make a step forward in terms of consumer information and protection, education, and availability of home diagnostics devices.

Overall, both countries need to maintain a dynamic perspective in regulation and infrastructure with regard to new opportunities related to radically new POC devices. Experts foresee that the real hausse in point-of-care diagnostics will be related to the (inter-)national breakthrough of E-health, self-management and Electronic Patent Records.

7.2. Influence of Stakeholders on the Creation of Value through POC Diagnostics

This section presents an analysis of the results on the two health care systems, and answers the first part of the main research question: *how do the different components in the health care system influence the value chain of point-of-care diagnostics?* A schematic overview of the results is provided in the following table. On the left the different components of the healthcare system are listed. Per component, the main similarities and differences in influence on the creation of value are shown, followed by an indication on whether the influence is negative (-), positive (+) or both (-/+). The table is followed by a short analysis per component and refines the related hypothesis discerned in the theory section in chapter 2.

Table 7.1. - Overview of Results

Tabel 7.1. Main differences/similarities in the Dutch and UK health care system				
Components	UK Health System		NL Health System	
1. Framework Conditions	Ageing of the population Economic Challenges Investing in quality through patient choice		Ageing of the population Economic Challenges High hopes technological innovation: E-health and labour-saving	
	*Indirect Influence via 2, 6**	+	*Indirect Influence via 2, 6**	+
2. Political System	Top-down government strategy RTD focused on quick adoption		Facilitating role Enabling market mechanisms	
	*Indirect influence via 3, 4, and 5**	+	*Indirect Influence via 3, 4, and 5**	+
3. Research & Education	High quality fundamental research required to establish value		Establishing value through research Increasing PPP in research phase	
	Direct facilitating influence	+	*Direct facilitating influence*	+
4. Intermediaries	NICE guidance authoritative First Diagnostics Assmnt. Program.		Many intermediaries, all experts Attention for supersession	
	Direct facilitating influence	+	*Direct positive/negative influence*	+/-
5. Third Party Payers	NHS, large bureaucratic system Significant reforms New competition elements		Private social health insurance Complex Risk Equalisation Investments in self-management	
	Direct positive/negative influence	+/-	*Direct positive/negative influence*	+/-
6. Industrial System	Labs will not support POC tests Need for new business model		Complexity & regulations are barrier Need for integrated approach (PPPs)	
	Direct positive/negative influence	+/-	*Direct positive/negative influence*	+/-
7. Infrastructure	POC coordinating role Safety standards & guidance		Need for POC standards & regulation DBCs barrier for radical innovation	
	Direct influence via 5 and 6	+/-	*Direct influence via 5 and 6*	+/-
8. Demand	Stimulating larger role of GPs Hospitals negotiating partner Consumer acquainted with POCT		Stimulating larger role of GPs Need for information Consumer 'green' in home POCT	
	Heterogeneous influence	+	*Heterogeneous influence*	+
* Indirect influence on POC value chain, via component (no.) listed on the left side in this table				

1. Framework conditions

Generally a strong influence of the framework conditions on the value chain of point-of-care diagnostics can be observed, which appears facilitating for POC diagnostics. Both the Netherlands and the UK as many western countries are currently confronted with economic challenges, which resonates in the budgeting for (public) services as healthcare. Also in line with western countries, the UK and Netherlands have to address an expected increase in health care expenditures. In both countries high expectations of high value medical technology as part of solution can be observed, aiming for better allocation of resources. The framework conditions strongly drive the political and the research agenda with regard to medical innovations. This is translated in the fact that the Dutch political system has put on the agenda innovations like e-health and smart homes that address the anticipated shortage in medical staff. The British Department of Health have made a clear strategy to achieve more efficiency through higher quality of health care services and enforcing patient choice. The framework influences the industrial system by indirectly creating demand for certain types of POC diagnostic devices: devices that speed up the diagnostic process, sensors that enable self-management and smart @ home care, and screening devices that enable preventive treatments.

The theoretical assumption (H1) was that the framework conditions would have a restricting effect on the creation of value through POC diagnostics in the value chain. The refined statement is: *Framework conditions have a facilitating influence on the creation of value through biosensor technology in the value chain of POC diagnostics, via the political and industrial system*.

2. Political System

When comparing the Dutch and UK health system, overall the influence of the political system on the value chain of POC diagnostics is positive, but indirect. The British political system has formed a clear top-down strategy with regard to improvements in the healthcare system, towards more efficiency and more competition. RTD policies in the UK have been developed with the overall aim to enable quick assessment and adoption of new valuable technologies. This strategy is however not directly aimed at the value chain, but employed vertically/hierarchically in the health care system. In the Netherlands the role of the political system is facilitating and enabling, which is also indirect. The roles of VWS, DBC-onderhoud, and NZA are to facilitate and enable market mechanisms in health care.
The influence of the political system is mostly directed towards education and research, intermediaries, and the industrial system, and not to the creation of value through POC diagnostics directly. The new strategy and regulations of the British Department of Health “Equity and Excellence” would affect the demand side in the health system as well in terms of more provider responsibility and independence in the NHS and more patient choice. It is however too early to assess the implications of those plans.
Both a positive and negative influence was expected from the political system on the creation of value through POC diagnostics (H2). This statement is refined to: *The political system facilitates the creation of value though biosensor technology in the value chain of POC diagnostics, via intermediaries, education and research, and third party payers.*

3. Education & Research

In both the Dutch and the British health care system Education and Research is highly important for the development of POC diagnostics. In order to convince the medical professionals, high quality objective research is required that establishes analytical and diagnostic accuracy, and clinical utility. Institutions in the Netherlands increasingly imply cost-effectiveness of the treatment in clinical research. Preferably, (clinical) research on the value of POC diagnostics is published in a sound and respectable scientific (medical) journal. There is still quite a gap between fundamental university research that often takes place, and applied research that takes into account how to integrate and apply results in practice. To overcome this gap, increasingly public-private-partnerships are formed in the research phase of medical technology. These partnerships are actively supported by the EU framework programme. Other developments in education & research on medical devices are the establishment of valorisation and technology transfer centres.

Accordingly, the initial assumption (H3) on the influence of Education and Research is confirmed: *Education & Research have a positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics*.

4. Intermediaries

Intermediaries in the healthcare system play a facilitating role in the value chain of POC diagnostics. The most important intermediaries in the British healthcare system with regard to POC diagnostics are NICE, MTEP and DAP, which are founded with the main goal to enable quick assessment and adoption of high quality treatments and technologies. The Diagnostics Assessment Programme (DAP) is one of the first initiatives worldwide that focuses solely on assessment of diagnostic devices in healthcare. NICE guidance to use a specific diagnostic tool can be strong leverage for the manufacturer to introduce the device. The British Department of Health has actively supported NICE to become (inter-)nationally authoritative on developing quality standards in healthcare. The most important intermediaries in the Netherlands are CVZ and ZonMW, but there are many other intermediaries such as Agentschap NL, TNO, MedTech Partners, Healthvalley, Innovatiefonds Zorgverzekeraars, the Healthcare Finance Group, the Health Innovation Fund, and technology transfer centers. There are no intermediaries in the Netherlands that are solely and specifically focused to develop diagnostics. Intermediaries in the Netherlands are more horizontally structured and there is no authoritative body, which sometimes leads to fragmentation and bureaucracy. Also in the Netherlands procedures on the health technology assessment of diagnostics are kept very up-to-date.

Overall, *intermediaries have a positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics*, in line with the theoretical assumption H4. The influence of research and education is facilitating in principle, but especially in the Netherlands results suggest that more strategy and overall coordination is needed to make the current system of intermediaries really effective with regard to quick assessment and adoption.

5. Third party payers

Overall, the third party has both a positive and negative influence on the value chain of point-of-care diagnostics. In the UK the role of the third party payer is fulfilled by the NHS. The NHS is very effective in providing care for over 60 million British citizens, but is often described as fragmented and bureaucratic, and lacks incentive for quality and efficiency. Currently significant reforms in the health system are on the agenda, which aim to introduce more competition elements to address these problems. In line with reforms there are initiatives to strengthen the 'entrepreneurial' role of GPs, supporting them to take over activities that take place in secondary care for instance. This is especially interesting in case of POC diagnostics. In the Netherlands the role of the third party payer is fulfilled by private health insurers. This system requires a complex way of risk equalization to guarantee universal and equal access, but reduces the incentive by the insurers to invest in public health and innovation. However, Dutch insurers have a common interest in the financial sustainability of the health care system, and are quite proactive in partnerships around promising health research and pilot programs. A shared effort of Dutch health insurers is e-health and self-management, which also can be promising for POC devices.
Overall, a social health care system based on solidarity as in the Netherlands and the UK requires a complex role for a risk bearing third party payer, which often hampers efficiency and innovation and can be a barrier for the creation of value through POC diagnostics. This does not mean that the system or role of the third party should be changed, but indicates that manufacturers in the value chain need to be more creative and collaborate with the third party payers to overcome these barriers.

Accordingly, the initial assumption (H4) is confirmed: *the Third Party Payer has both a positive and negative influence on the creation of value through biosensor technology in the value chain of POC diagnostics.*

6. Industrial System

The industrial systems in the Netherlands and the United Kingdom are comparable in terms of the health care system around POC diagnostics. In both countries the market of POC diagnostics is growing, and there are an increasing number of competitors in the market, from the background of microbiology, pharmaceutical companies, small university spin-offs, or micro-electronics companies. There are interesting new opportunities related to the entry of companies from other industries than healthcare. In this is also an important difficulty, because companies are not familiar with the often complex procedures and regulations in health care. Especially in the Netherlands this is often seen as an important barrier by new entrants to the health care market. To overcome these barriers, there are increasing public-private partnerships in the field of medical technology. One of the most important findings is that companies developing POC diagnostics need to adapt their business model to the needs of the current health care market: POC diagnostics need to be developed in close collaboration with the users, the third party payers, and regulatory/guidance organizations to be able to fit all needs. Companies in both countries are advised to take an integrative cooperative model when developing POC diagnostics, working in a value chain or value network with shared focus. Companies that will develop a medical technology searching for a one size fits all product that is developed and delivered in isolation from its context, will have a hampering influence on the creation of value.

The initial statement on the industrial system supposed a positive influence on the creation of value by biosensor technology in the value chain of health care diagnostics. This statement (H6) is redefined to: *the industrial system has a positive and negative influence on the creation of value through biosensor technology in the value chain of POC diagnostics.*

7. Infrastructure

Generally it could be stated that in terms of infrastructure a requirement for the creation of value through POC diagnostics is regulation for quality and safety standards and certifications for the devices. In addition a specific department or person should be formally responsible for maintaining the quality and safety. This kind of infrastructure is facilitating for the creation of value through POC diagnostics.
In the UK this regulation and guidance is more developed than in the Netherlands. Another part of the infrastructure are the financing and reimbursement structures of POC diagnostic devices. Both in the UK as in the Netherlands current financing/reimbursement structures are no problem for the applications that can be used as direct alternative for current methods. However in case of a POC device that is radically different, existing reimbursement and financing structures form a barrier for manufacturers. Infrastructure is often formed by the political system, but in theory should represent the norms and values of the complete health care system. The influence of the infrastructure has impact on the value chain of POC diagnostics mostly via third party payers, which are bound by the reimbursement structures, and the industrial system.

Initially a negative influence was expected from infrastructure on the creation of value through POC diagnostics (H7), but this research showed that: *Infrastructure has both a negative and positive influence on the creation of value through biosensor technology in the value chain of POC diagnostics, via third party payers and the industrial system.*

8. Demand

Demand is divided in buyers of care, providers of care, and consumers of care. When considering the adoption of POC diagnostics in primary and secondary care, no large differences are observed between the UK and the Netherlands. Generally, primary and secondary care physicians are positive about using point-of-care diagnostic devices, provided that the devices will be safe, and diagnostically and analytically accurate. General Practitioners in both health care systems are supported to take on a more 'entrepreneurial' role as health manager, expand skills, and take over services from secondary care. This development is positive for the development of POC diagnostics. In home POC diagnostics, some differences can be detected with regard to the value that is delivered. Selling POC glucose monitors, blood pressure meters, and other home POC tests are more accepted and broader commercially available in the United Kingdom than in the Netherlands. The health system in the Netherlands can still

make a step forward in terms of consumer information and protection, education, and availability of home diagnostics devices.
With regard to the influence of 'demand' on the value chain of POC diagnostics a number of observations are important. The hypotheses defined in the theory chapter were based on the general (theoretical) assumption that demand is homogenous and represents 'user needs', which are defined by the patient mainly and by the provider. Findings in chapter 4 on the creation of value through Point-of-care diagnostics and the findings on the Dutch and UK health system have lead to the insight that 'demand' in terms of point-of-care diagnostics is *heterogeneous and strongly dependent on the type and point of application*. This is a direct result of the fact that the type and place of application of diagnostic devices is related to regulations, reimbursement structures and persons making the buying decision. For example in case of emergency POC diagnostics, the health professional advises the hospital board, the board decides on acquiring a new POC diagnostic tool, the third party payers pays (indirectly), but the end-user in this case is the patient. Based on these findings, the influence of 'demand' on the creation of value through POC diagnostics is redefined in the following statements:

First, a practicing medical experts should be involved in the development of POC diagnostics as early as possible, as they are highly able to assess the future possibilities of a POC diagnostic device in terms of clinical utility and indirect clinical utility. This would positively influence the delivery of value by the *manufacturer* of medical technology.
Second, user needs and experiences of both the provider (health professional) and the consumer of care should be taken into account in the developing phase of the diagnostic device. This would positive influence the delivery of value by the *designer* of medical technology.
Third, the sellers of care, which can be the hospital board or board of the health management center can have a positive influence on the development of POC diagnostics provided that they are proactively involved in developing a financial case and negotiating contracts, as there is plenty of room for financial innovation in healthcare and new forms of contracts that also integrate education, training, and long term commitment.
Fourth, an objective and reliable source of information about health matters and about the use of (home) POC diagnostic devices positively influences the creation of value, as it activates self-management, patient choice, and informed and critical decision making. Objective information can lead to more trust in new technologies, and can decrease distrust in commercial initiatives. This source of information would have information for consumers and for medical professionals.
Fifth, medical experts should be consulted about feedback, user experiences, and suggestions for improvements. This will positively influence the *sustainability* of the value chain.

7.3. Underlying Dynamics of the Health care System

This section answers the second part of the main research question: *How can the difference between the two health care systems in delivering value through POC diagnostics be explained?* An answer to this question requires going one step deeper to understand underlying dynamics in both health care systems. This section is based on an interpretation of the results to find an answer to what dynamics in the health care system have lead to the difference in performance of the Dutch and UK health care systems, in delivering value through POC diagnostics.

The concept of value is in this research defined as shared set of values to the most actors in the value chain of POC diagnostics. As the surrounded health care system is interrelated to the different actors in the value chain of POC diagnostics, the preferences within the system will be closer to preferences within the value chain and create less obstruction. If all elements in the system fulfil their role as they are supposed to and all preferences are integrated in the overall business plan of the POC diagnostic device, there should be a general positive drive of the innovation system towards the creation of value. In the same line of reasoning, optimal or suboptimal performance by the Dutch or UK health system suggests irregularities/inconsistencies within the value chain, or in the innovation system. As there is no such thing as 'optimal' performance as reference point, the analysis is based on a comparison between the UK and the Netherlands. The main observations are:

1. POC diagnostics for home care are more integrated and adopted in the British health care system compared to the Netherlands.
2. There are active public private partnerships in the Netherlands that focus on applied research of medical technology. These partnerships lead to integrated solutions.
3. There are specific POC coordinator functions, guidance and regulations in the UK for the use of POC devices in primary and secondary care settings.
4. There is a higher growth rate of IVD testing and POC diagnostics in the UK.

With regard to the first point, the Netherlands is lagging behind in the development and adoption of home care applications, which can be related to the fact that the concept of self-management and patient choice are further developed in the United Kingdom than in the Netherlands. In the UK, there is a proactive strategy towards patient empowerment and patient choice. This is reflected by the development of websites as NHS choices and NHS evidence, which are sound and objective sources of medical information. The UK has put effort in developing the authoritative position of the NHS in the matter of guidance and information. In the Netherlands there are plenty of websites available, but it is not possible for the average person to quickly access relevant and scientifically reliable information, that is readable at well. The lack of a sound source of information in the Netherlands could be hampering to the concept of self-management, and might not stimulate the adoption of POC diagnostics.

Second, it seems that the historical background of the Netherlands of having much private initiative in a social health care system lowers the barrier for the organization of PPPs in healthcare. These types of partnerships seems promising compared to traditional business models because these partnerships take into account the preferences and stakes of the involved parties, and increase the possibility of delivering an integrated solution.

Third, the infrastructure around POC diagnostics in healthcare is more crystallized in the UK compared to the Netherlands. The main cause seems to be related to the fact that NICE has clearly set diagnostics on the agenda. They have developed the Diagnostics Assessment Program recently and have written guidance on the safety and quality issues related to diagnostics specifically. The role of POCT coordinator by a person from the hospital chemical lab or regional lab was developed naturally in the UK but was effectively standardized through guidance. In the Netherlands this standardization still need to take place. NICE has a very proactive approach in technology adoption and maintaining quality.

Last, the growth rate of the IVD tests market and the inherent growth of the POC diagnostics market is related the complete set of positive and negative influences in the health care system that cumulate in a driving force or barrier for the delivery of value through POC diagnostics.

7.4. Refined Conceptual Model

The main question this research addresses is *"what is the influence of the healthcare system on the value chain of Point-of-Care diagnostics, and how can differences be explained between the Dutch and the UK health system?"* To be able to answer this question chapter 4 explored *how* value is created within the value chain itself.

The main findings of chapter 4 are summarized in table 7.2. It shows which parties are considered important in the value chain, and which kind of processes are important for delivering value. Creating value through POC diagnostics is an interactive process and requires taking the end-user-needs as starting point. The end-user is dependent on type and point of application. The table broadly shows how the point of application, being primary, secondary, or home care, influences the process of creating value. The value-chain as a whole is subject to the influences of the surrounding healthcare system.

Chapter 7 provides findings on the influence and dynamics of the health care system on the value chain of point of care diagnostics. This table shows the activities *within* the value chain of point-of-care diagnostics as an intermediate step towards the complete and refined model, which is shown on the following page.

Table 7.2 - Overview of the proces of creating/delivering value through POC diagnostics

Value **Biosensor Technology**	Manufacturer MedTech	Designer MedTech	3rd Party Payers	Sellers of care	Providers of care	**User/ Patient** Value
Home POC	**Analytical & diagnostic claim** -Build/Search Partnerships	**Clinical Claim** - CE Mark - Design		(Pharmacy)	Keep involved & up to date	Consumer& Patient *(GP as health manager)*
Primary care POC	**Analytical & diagnostic claim** - Publish results - Build/Search partnerships	**Clinical Claim Diagnostic - Care Path** - CE Mark - Design - Physician Involvement	- Financial & - Regulatory advice - Financial balance	**Cost/efficiency** - Build agenda - Guidance - Negotiate Contract - Financial Innovation	**Sustain** - Deliver value - Monitoring - Feedback - Incremental innovations	General Practitioner
2ndary care POC	**Analytical & diagnostic claim** - Publish results - Build/Search Partnerships	**Clinical Claim Diagnostic - Care Path** - CE Mark - Design - Physician Involvement	- Financial & - Regulatory Advice - Financial Balance	**Cost/efficiency** - Build agenda - Guidance - Negotiate Contract - Financial Innovation	**Sustain** - Deliver value - Monitoring - Feedback - Incremental innovations	Specialist

Figure 7.1. combines the findings of chapter 4 and chapter 7 in a refined conceptual model. The model aims to conceptualise the influence of the different components in a health care system on the 'creation of value' through biosensor technology in the value chain of point-of-care diagnostics.

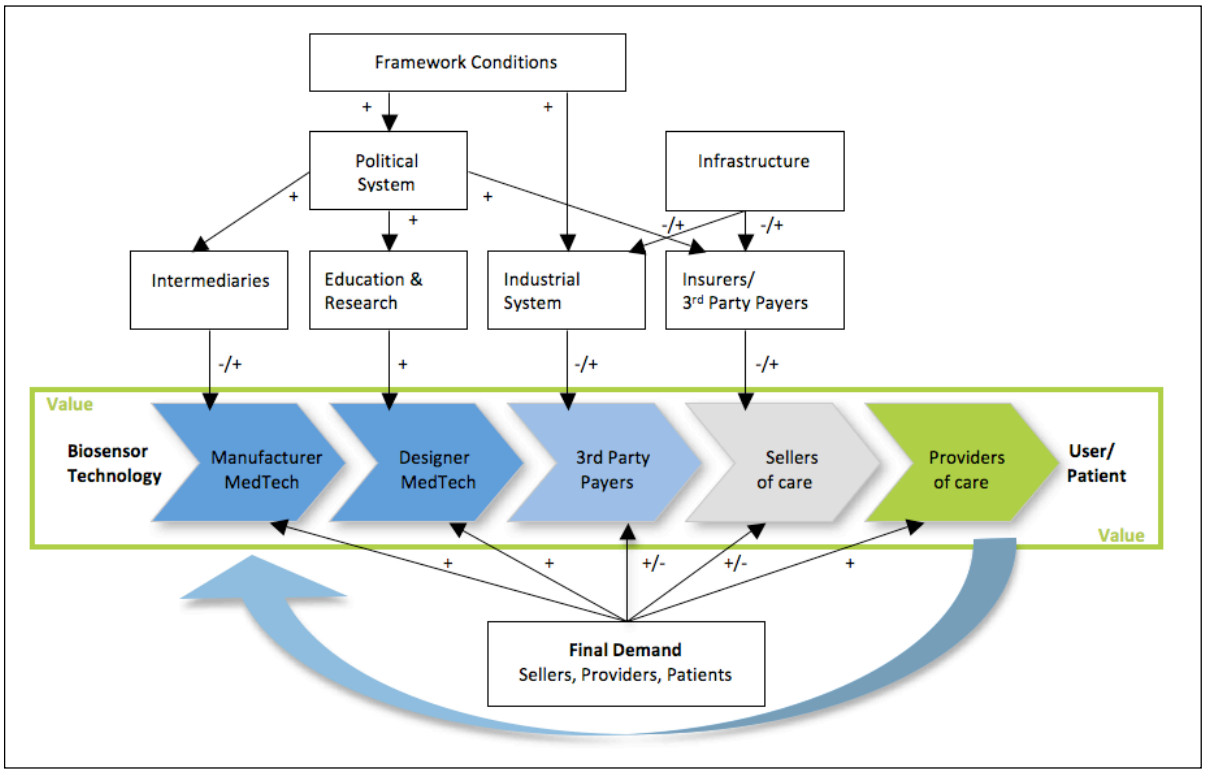


Figure 7.2 - The Value Network: a refined conceptual model

Compared to the initial conceptual model a few main refinements were made. First, the green box around the value chain indicates the interactive non-linear characteristics of the creation of value through POC diagnostics. The value created in the value chain is not necessarily directed at the end-user, but may also be directed to other parties in the VC.
Second, the process of creating value should be based on end-user needs or final demand. In case of POC diagnostics, demand is heterogeneous and dependent on the type (cardio, diabetes, cholesterol, HIV, etc) and point of application (primary, secondary and home care).
Third, the black arrows show the refined influences of different components in the surrounding healthcare system on the value chain of POC diagnostics. The political system is an indirect influence, via intermediaries, research & education, and third party payers. The framework conditions are an indirect influence via the political and the industrial system.
Finally, if (final) demand – providers, consumers and sellers of care - is integrated in the value chain as they are supposed to be, a sustainable feedback loop is created (blue arrow), supporting the value chain as a sustainable strategy for the organizations in it.

8. Conclusion

Health care in Western countries will face a number of challenges in the next few years and there is growing recognition that a solution resides in a shift towards competition aimed at creating value. At the same time there are high expectations of medical technology to address the problems. Point-of-care diagnostic devices are one of these high-value medical technologies that have the potential to fulfil an important role. Despite the economic and societal need, successful examples of new high-value innovations remain scarce. This underlines a need for better insight in how value is created and how new medical technologies as POC diagnostics can add value in a changing health care system. The Dutch and the UK health care system were compared to understand the creation of value through POC diagnostics. The main question addressed is: *What is the influence of the healthcare system on the value chain of Point-of-Care diagnostics, and how can differences be explained between the Dutch and the UK health system?* This question is answered in several steps and according to sub-questions. The first step was to define the concept of value. Then the characteristics of biosensor-based POC diagnostics were mapped out, followed by an exploration of the process of creating value in the value chain. The third and fourth step contained the exploration and analysis of the British and Dutch health care systems.

The concept of value as defined in theory seems to apply to the various ways that Point-of-care diagnostics can deliver value in practice. The importance of a correct definition of the concept of value is that it can be used as a shared focus for stakeholders developing biosensor-based POC diagnostics. The different dimensions of the way that POC diagnostics can deliver value are 1) Analytical accuracy, 2) Diagnostic accuracy, 3) Clinical utility, 4) Cost-effectiveness (the financial case), and 5) Indirect utility ((non-) medical impact on post-diagnostic care path). Biosensor-based POC diagnostics have the potential to deliver value in the health care system in diverse applications. They can play a role in infectious diseases, coagulation, diabetes (glucose), and cholesterol for example. The test can be used in critical care, primary care and home care, for reasons of monitoring, screening, diagnosing, data management, privacy or comfort. This study has indicated that different types of POC applications require specific and specialist insights in technology, microbiology, and medicine. In addition, different points of application (primary, secondary, and home) are related to different end-users, different regulation, and a different *process to deliver value*. To increase the chance for manufacturers and other parties involved in the development of POC diagnostics, ánd develop a business case that is interesting to all parties, a more sophisticated approach/business model is required.

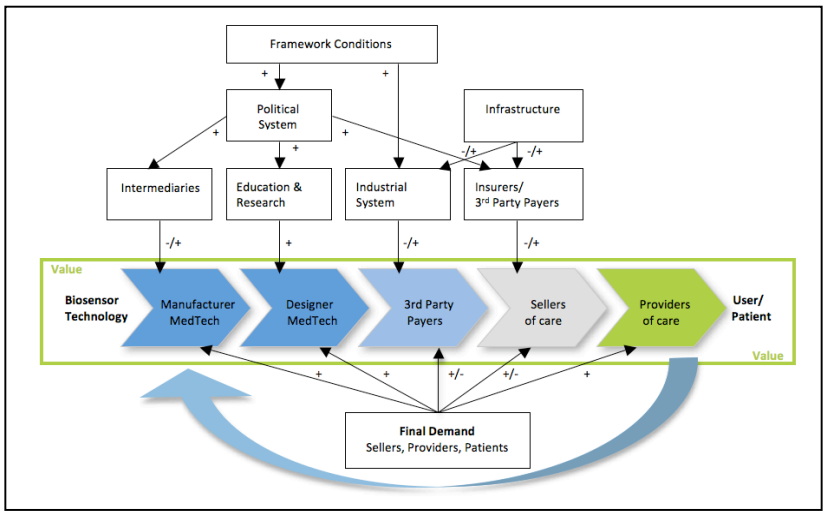
In this research we present a value chain approach to deliver value through POC diagnostics. The main parties that need to be involved in the value chain of POC diagnostics are manufacturers and designers of medical technology, third party payers, sellers of care, and providers of care. In line with theory, a number of activities are found to be important for the success of a value chain. The first is *integration*: this means building a value chain through strong partnerships with suitable and valuable candidates, but also to develop a product with the end-user and context already in mind. The second is to start the chain with *user-needs* in mind: involve an experienced practicing physician as early as possible in the development of (POC) diagnostics as this person is the most suitable person to assess clinical utility. Note that demand is heterogeneous and dependent on the application. Third is *communication*: transparency throughout the value chain and working with a shared set of values to connect the parties. Communication refers also to the publishing of results: an essential requirement for developing a POC device is that there needs to be sound objective evidence on the different dimensions of value. A fourth important role that needs to be taken care of is the *coordination and direction of the value chain*. If the value chain is successful as a whole it can support the competitive position of the parties involved.

One of the main barriers for manufacturers of medical technologies is the complex health care system, which is also different per country. This makes it worthwhile to take into account the influences of the health care system on the creation of value through POC diagnostics, when looking at a more developed model for delivering value in health care. The analysis of the Dutch and the UK health system lead to a number of findings.

The framework conditions influence the political and industrial agenda in the direction of R&D of new medical technologies. The anticipated challenges in the health system induce a strong focus on technologies enabling self-management, screening and prevention, smart homes and more efficiency. The political system has an indirect positive effect on the creation of value: in the UK there is a top-down strategic approach, but in a hierarchical system and thus indirect. In the Netherlands there is a merely facilitating influence by the political system to enable market mechanisms in healthcare, which is also indirect. Education and research is considered very important in developing POC diagnostics: objective scientific proof is essential to establish analytical, diagnostic, clinical utility and cost-effectiveness claims. Intermediaries can play a facilitating role in the adoption of POC diagnostics by formalizing procedures, conducting policy research, and writing guidance. A social health care system often requires a complex role for a risk bearing third party payer, which may hamper efficiency and innovation. This indicates that manufacturers and third party payers need to collaborate to overcome these barriers. Third party payers appear to be proactive in public-private collaborating and partnerships. In order to develop POC diagnostics and create value in the health care system, the industrial system needs to adopt an integrative and cooperative model. They have to leave behind the blockbuster model and develop integrated tailored solutions. Regulatory infrastructure is an important requirement for the development of POC diagnostic devices to guarantee quality and safety of the device over time. This also takes away scepticism from the end user. Physicians are concerned with, and involved in the development of POC diagnostics. Based on findings in this research, the involvement of an experienced practicing physician in the development of POC diagnostics is essential, as this person can identify opportunities and barriers on a medical level that are crucial for the creation of value. Home POC diagnostics are in a very early phase of development. Safety regulations, availability and information are considered important for the use and adoption of home POC diagnostics.

The British health system seems to perform better in delivering value through POC diagnostics in relation to the Netherlands. To make some remarks on the cause of this difference requires an interpretation of underlying dynamics in the health care system. The lagging behind of the Netherlands in home POC diagnostics might be related to the slow development of the concept of self-management. In the UK, there is a proactive strategy towards patient empowerment and self-management, facilitated by the fact that there is one authoritative source of information: the NHS. The infrastructure around POC diagnostics in healthcare is more crystallized in the UK compared to the Netherlands in terms of the role of a POC coordinator and guidance concerning the use of POC diagnostics, suggesting more direction and strategy within the health system.

Findings have lead to a more thorough insight on the creation of value, and enabled to refine the conceptual model proposed from theory. The model shows the different influences of the components in the health system on the creation of value through POC diagnostics. It shows the important actors in the value chain. When user-needs are integrated in the value chain at all stages of development, than a constructive and sustainable feedback loop is created. The aim of the refined model to be a starting point towards conceptualisation of the creation of value through POC diagnostics.



9. Discussion

This chapter discusses the steps taken in the empirical cycle, and the shortcomings and positive points of the research. The quality of the research will shortly be discussed in terms of reliability and validity. Suggestions for further reading are connected to the different points of discussion and can be found throughout this chapter. Finally this chapter will finish with research and policy implications.

The problem description in this research is defined as a gap between the societal and economic need for high value medical technologies, and only little successful examples of new technologies in health care. The connection between this gap and a need for more sophisticated model to develop medical technologies in healthcare is a cornerstone of this research. This means that the approach focuses specifically on how value is created by the actors in the value chain, and what might be an appropriate (proactive) approach to deliver value in healthcare through POC diagnostics, taking into account the influences of the surrounding health system. A disadvantage of this point-of-view is that the research places the business model for creating value in the centre of the study, and analyses the influences from the system on the value chain. Due to the size of this research it was not possible to assess the health care system and value chain over time, but it would be a more accurate approach to analyse the *interrelation* between the health care system and the technology (over a longer period of time).

Regarding the delineation of the research two important choices were made: regarding the technology to analyse and the countries to assess. The technology selected as topic of research is biosensor-based point-of-care diagnostics. This technology is considered high-value and has a lot of potential in delivering value in the health system. It is one of the new technologies that incorporate a mix between several fields of expertise, microelectronics, biotechnology, and medicines. As the research has illustrated (confirmed), POC diagnostics is a highly specific field of technology, with its own specific 'rules of the game' regarding innovation. This makes the technology highly interesting to study, but findings may not be generallizable to other fields of medical technology. In addition, experience shows that it is wise to be cautious with generalizing results in health care. To find out whether findings apply to other fields, first the same type of explorative qualitative analysis would have to be carried out.

The second important decision regarding delineation is the choice for the United Kingdom and the Netherlands. Research confirmed that both countries face the same challenges, and that they both try to anticipate on time to address these problems with high-tech medical innovation, and competition aimed at driving quality. The assumption was confirmed that in these completely different systems of financing, some influences and rules of the game in creating value through POC diagnostics apply to both systems. This observation makes it interesting to analyse another set of countries and see if it is possible to develop a more general value chain approach for delivering value through POC diagnostics, taking into account system specific influences. Another interesting point of research would be to analyse the creation of value in countries where POC diagnostics address a need for wireless diagnostic tools and are a solution for a lack of infrastructure.

The main theories underlying the theoretical framework in this research are value based competition, the value chain, and the Innovation System's approach. The decision to use the value chain approach was appropriate because this theory already takes into account the concept of value, and offers an perspective on the actors in the value chain that matches with the need in health care to develop concepts in a integrative network-like fashion. The difficulty that arises from using this theory is that it requires an assessment of the output of value, as some sort of performance measure of the value chain. This is rather difficult as point-of-care diagnostics is an emerging technology in healthcare. In addition, there is still a vivid discussion on how value should be defined, and the health care infrastructure is just starting to take into account value in procedures and legislation. Therefore this output measure was defined in a broad and qualitative way: as the adoption and diffusion of POC diagnostics in the health care market, in primary, secondary and home care.

The value chain approach was matched to the Innovation system approach, to explore the influence of the surrounding health care system. One of the shortcomings of using this model is that there has not been any research that has adjusted the model to the health care system specifically. In the research the decision was made to partly adjust the model of Kuhlmann & Arnold and integrate the third party payer. To balance the risk that not all components in the health care system are represented, or that influences of organizations or institutions are taken into account twice, all interviewees were asked to describe the relevant parties involved in the development and adoption of POC diagnostics.

Another limitation of using the innovation system approach is that the explanatory power of the approach lies mainly on macro level, and less on the actions of the 'entrepreneur', even though an often quoted rationale is that innovation is both a collective as an individual act (Hekkert et al, 2007). The innovation system suffers from an 'institutional determinism' which is a shortcoming because the role of the entrepreneur is very important and determining in innovation in reality. This institutionalism is partly overcome by highlighting the different important activities that should take place in the value chain, and the suggested role of an individual responsible for the value chain strategy: communication, integration, end-user as starting point and coordination. A new question arises from these findings, which asks how to organize value chains and chains of care? A value chain approach is considered a promising new approach in health care - for COPD, CVRM and diabetes for instance - and this chain could be extended to the manufacturers of care even. But who should coordinate the value chain? This entrepreneur needs to build the value chain, and understand and communicate with all actors in the value chain. Should this role be performed by an independent organization, or is the industrial system most capable to pick up this role?

Regarding the methodology, a number of discussion points can be mentioned. First the construct validity was established through several research cycles. The theoretical framework and conceptual model were developed from theory and some explorative meetings with experts in the field. Than scientific, medical and innovation research on point-of-care diagnostics are used to refine the theory. Representatives of the different components in the health care system were asked to share their insights on the creation of value, and the influence of the surrounding health system. After an analysis of both health care systems, the conceptual model was refined.

Due time it was not possible to explore the British health care system in the same fashion as the Dutch health care system. Fewer interviews with stakeholders in the British health care system were conducted than in the Netherlands. This asymmetry might have influenced the results, and maybe explained the positive view on the British health care system. For the most optimal and objective information, at least two representatives of every stakeholder group should be interviewed, in both the Dutch as the UK health system. However internal validity was safeguarded because the overall results were analysed in a comparison between the UK and the Dutch health care system, to validate and compare the observed influences on the creation of value though POC diagnostics.

In order to balance the asymmetries in the research, the data is checked by three experts in the field. The subject is interdisciplinary in the sense that POC diagnostics and this research specifically touch the field of (health) innovation studies, technology and microbiology, and the medical profession. That is why the main chapters are checked and corrected by an expert in innovation studies, a biosensor technology expert, a POC diagnostics new business expert, and a medical specialist. This data triangulation strengthens the reliability of the data.

The analysis of results has lead to a refined conceptual model, which represents a number of general propositions, based on theory, and refined with practice. However due time, and due to the fact that POC diagnostics are just emerging in health care it has not been possible to assess the actual usefulness and effectiveness of incorporating a feedback mechanisms. Assumptions regarding this feedback loop are mainly based on innovation theory and implicitly based on advice from experts in the field.

Research Implications

Findings in this research suggest that it is worthwhile to consider diagnostic devices as a completely new and different category in research and policy. Currently diagnostic devices are considered competitive to the very developed market of microbiology and laboratory diagnostics. Concerning regulation and innovation policy it is often considerd a medical device, but in technology assessment the criteria for point-of-care diagnostics are much more elaborate. The emergence of the Diagnostics Assessment Program supports this view, as it answers a need for complex health technology assessment needed for many diagnostic devices. This program underlines that a disruptive innovation as POC diagnostics requires a flexible and response innovation system, in order to enable succesful innovation.

Another implication of this research on high tech medical innovation highlights the changes that currently take place in health care systems around the world, and mainly in Western countries that will face ageing, more chronic diseases and challenges regarding financeability. Pressure in the health care system are expected to catalize innovations in health care. As explained in the previous text it would be very interesting in this time of changes to monitor and analyse the influence of the system on the development of technology, but also vice versa: to asess the influence of emerging technologies in healthcare on the surrounding health care system.

Policy Implications

Findings in this research suggests that there are number of enabling factors or prerequisites for delivering value through POC diagnostics. Research has pointed out an important role for legislation to safeguard and maintain quality and safety of diagnostic devices. This is considered one of the most important steps towards the delivery of value through POC diagnostics, and can take away scepticism. Safety and quality are much more important in health care than in other industries developing new technological applications.

In addition, both the UK as the Netherlands hope to develop the concept of self-management, the patient 2.0, preventive screening, and healthcare as described by Edison on the first page. However, research strongly suggests that self-management requires self-empowerment, sound and objective and complete information is available and accessible to all (not just the academics), it requires patient protection, clearity of the boundaries of the concept and formalized roles of the GP or physician responsible for the self-managing patient.

Both issues point out the same question regarding public health policy. Should countries and their political system take up a reactive approach, where decisions are defensive to problems, and legislation is shaped when a radical innovation is no longer considered radical? Or should the political system pursue a proactive and uniform strategy?

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Grimbrere, C.H.F. (11 mei 2011) Coordinator ZorgInnovatieWijzer p/a College van Zorgverzekeringen

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Kooij, D. (8 april 2011) New Business Development Manager Johnson & Johnson

Prakken, F.J. (8 maart 2011) Chirurgisch Assistant, Medisch Centrum Leiderdorp.

Prakken, W.J. (8 oktober 2011) Chirurg Maxima Medisch Centrum Eindhoven/Veldhoven

Suy, H. (maart, 2011) Senior Scientist, NXP Semiconductors, Eindhoven

Walhout, B. (23 maart 2011) Researcher Technology Assessment, Rathenau Instituut, Den Haag.

Boxes, figures and tables

Appendix A. Interview Questions

Standard question model for interviews in the UK and the Netherlands

Questions;

1. What is your specific role in the organization, and in specific with regard to POC diagnostics?

2. What is the role and influence of your organization with regard to the development and adoption of POC diagnostics, and the creation of value through POC diagnostics?

3. What is the complete process for a POC diagnostic device for entry to the market?

4. What are the important organizations and entities in the UK/Dutch health care system involved in the 'creation of value' e.g. development, diffusion and adoption of POC diagnostics?

5. What criteria determine if a medical technology adds value in healthcare? Is there a difference in this process between third party payers and private insurers?

6. What do you think are important barriers/opportunities for 'successful' adoption of POC diagnostics (meaning that it will create additional value)?

7. What requirements would POC diagnostics need to fulfill in your eyes, to be able to create additional patient-value? (clinical and financial case, for example in hospital care, in GP care, etc)

8. What active role is there for companies in the value-chain of POC diagnostics, to address certain difficulties or respond to opportunities, to enable the creation of patient-value through POC diagnostics?

9. Is there anything that you would like to add, or are there important issues concerning POC diagnostics that haven't been addressed in this conversation?

>> The aim of the questions is to explore the value chain of POC diagnostics, to identify the different stakeholders involved and their role, and to find out how these two elements interact in the creation of value through POC diagnostics.

Appendix B - The technology behind the biosensor

The beginning of the field of biosensors originated in the work of Clark and Lyons (1962), Guilbault et al. (1962), Updike and Hicks (1967), and Guilbault and Montalvo (1969). Clark and Lyons (1962) describe how the improvements in design and construction of electrode systems, combined with the development of stable amplifiers and recorders, has provided satisfactory systems for the rapid and accurate measurement of blood pH, pCO2, and pO2. Different types of biosensors have been developed since then for the detection of ions, molecules, proteins, deoxyribonucleic acids, and cells.

A biosensor consists of two main elements: the sensor or transducer, and the biochemical recognition element. The sensor and its transduction principles can be acoustic, optical, calorimetric, electrical, or magnetic. The transducer translates a certain biochemical event into a signal. The second part of a biosensor contains the biochemical element, or the target specific bio-sensitive receptor, which is attached to the transducer. The receptor can couple with enzymes, cell receptors, (deoxyribo-)nucleic acids, antibodies (proteins) and gases (Yogeswaran and Chen, 2008). When the bio-sensitive receptor couples with the targets present in the sample, the transducer converts the coupling event into a signal, which can be interpreted in terms of presence and absence, and concentration of the target (Frederix, 2011; Lee, 2008).

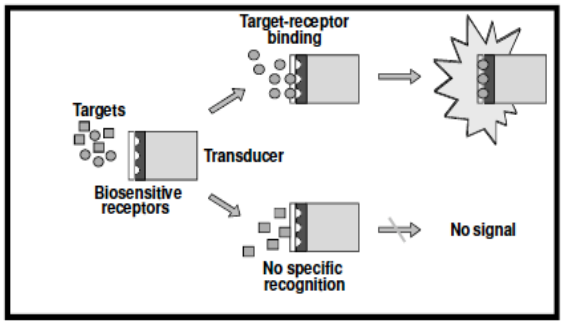

Figure 1 – Elements of a Biosensor (Frederix, 2011, University of Leuven)

The Biochemics in a Biosensor

The biochemical element in biosensor technology is a target specific bio-sensitive receptor, which is attached to the transducer by a linking layer. The transducer, the linking layer and the receptor together form the platform of the biosensor. The bio-sensitive receptor (biorecepter) is an antibody or a strand of DNA of the target molecule, or analyte (see figure 2). When a sample like blood or urine is washed over the platform, the analyte will bind to the bioreceptor, which causes a (change in the) signal (Frederix, 2011). An important feature of the biosensor platform is that it can contain a number of different biosensitive receptors, which makes it possible to measure a combination of targets at the same time (often referred to as multiplexing).

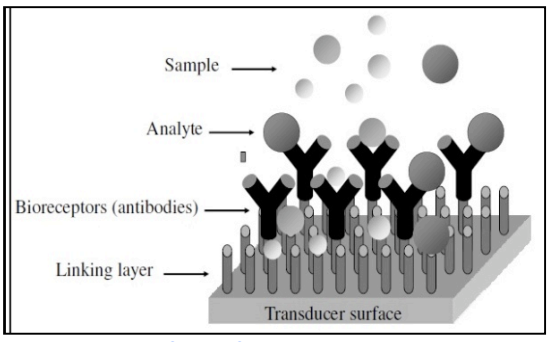

Figure 2 – Platform of the Sensor, source: (Frederix, 2011, University of Leuven)

The bioreceptor can detect (Lee, 2008)

- Enzymes
- Cells
- (Deoxyribo-)Nucleic Acids
- Antibody/antigen interactions.
- Gases

The use of *enzymes* as the biosensitive receptor was very popular in the first generation biosensors, due to the ease of construction, and the commercial availability of enzymes (Laschi et al, 2000). Although the detection limit of enzyme-based biosensors is more than satisfactory, the enzyme stability and keeping up enzyme activity remains a difficult task (Luong et al, 2008).

The last 15 years the attention shifted to affinity biosensors. These biosensors make use of binding mechanisms between *antibodies* to antigens, *cell receptors* to their ligands, *DNA and RNA* to their complementary sequences, and metabolic pathways (Luong et al, 2008). The DNA biosensor makes use of a relatively short anti-target synthetic sequence, which can detect target DNA sequences with the same length

(Frederix, 2011), and can be used repeatedly. Especially for the detection of specific viral and microbial pathogens as viruses the DNA biosensor is considered promising, because viruses are almost uniquely composed of DNA or RNA. Driven by a need in health care, biosecurity, and environmental hazards, the development of hand-held biosensors for infectious diseases has received great deal of attention (Mitra et al, 2009; Lee, 2008).
Also proteins can be detected with biosensor technology, making use of antibodies. The presence or absence or the amount of certain proteins within our body has proven useful to gain insights in our health status. Examples are human chorionic gonadotropin (hCG) for pregnancy, prostate specific antigen (PSA) for prostate cancer, and troponin I (cTnI) for myocardial infarction (Lee, 2008).
A biosensor is also able to detect *gases* or metabolites as an indication of a persons' health profile. In this case the biosensor detects changes in electrical resistance or conductance as the gas passes over the sensors. There is increasing interest in the use of gases as biomarkers as a new inexpensive and rapid tool to collect diagnostic information. 'Breathalizers' are already being used to detect acetone in a persons' breath as indicator for diabetes. Increasing research is being conducted on metabolites detectable in breath, as a first indicator of cancer. (ScienceDaily, 2010)

The Sensor in a Biosensor

The first element of biosensor technology is the biochemical reaction as described in 4.1.2. The second element is the transducer that detects the coupling/binding event, and translates the event into a signal. The transduction principles can be (Lee, 2008):

- Calorimetric
- Magnetic
- Electrical
- Acoustic
- Optical

Although all transduction principles are used, and have been feasible in biosensor technology, the most common/popular methods are electrochemical and optical detection, followed by an acoustic biosensor (Luong et al, 2008).

The basic mechanism behind the *calorimetric biosensor* is that a constant power is applied to a reference. Under closely controlled conditions, the sample is then added and the target binds to the receptor. Up to 80% of the heat generated in the reaction may be registered as a temperature change in the sample stream. This ΔT is detected and translated into a signal. A *magnetic sensor* detects a change in the local magnetic field after a biochemical reaction using magnetic beams.
Electrochemical sensors measure the electrochemical changes of a binding event, which can be a change in the measured voltage between the electrodes, a change in the measured current at a given applied voltage, or a change in the ability of the sensing material to transport charge (Widdershoven et al, 2010; Suy, 2011). Electrochemical biosensors seem to be very appropriate in 'field' applications as point-of-care, and for miniaturization. Due to the high sensitivity, simplicity and cost competitiveness that can be achieved with electrochemical biosensors, more than half of the biosensors reported in the literature are based on electrochemical transducers (Luong et al, 2011).
Optical sensors make use of optical fibers to direct light to a sensing film. This sensing film can be probed with evanescent waves to decrease the optical background signal from the sample and increase sensitivity. The measured signals can include absorbance, fluorescence, chemiluminescence, surface plasmon resonance, or changes in light reflectivity. Optical biosensors are very suitable for screening a larger number of samples simultaneously, but the disadvantage is that they cannot be easily miniaturized, which is important in point-of-care settings. Nevertheless, research and development leads to improved optical methods that have the potential to replace the use of electrochemical methods for some applications. (Luong et al, 2008)
An *acoustic, or piezoelectric biosensor* makes use of a quartz crystal as sensor, which oscillates at a constant frequency. When the target or analyte is attached to the surface of the crystal, the oscillation frequency changes, the shift being proportional to the mass of the analyte. Similar to optical detection, acoustic detection requires a larger and more sophisticated instrument to detect a signal compared to some other techniques (Luong et al, 2008)