Making eCare work! Defining a pre-development validation method for eCare and mHealth services

Josse Pyfferoen, Tom De Backer

Supervisors: Prof. dr. ir. Sofie Verbrugge, Prof. dr. ir. Didier Colle
Counsellor: Ir. Frederic Vannieuwenborg

Master's dissertation submitted in order to obtain the academic degree of
Master of Science in Industrial Engineering and Operations Research

Department of Information Technology
Chair: Prof. dr. ir. Bart Dhoedt
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Dankwoord

Na het afronden van onze studie als industrieel ingenieur zijn we in september 2016 samen begonnen aan de tweejarige master *Industrial Engineering* & *Operations Research*. Na onze herhaaldelijke succesvolle samenwerking tijdens groepswerken en soms ook tijdens het instuderen, stonden we uiteindelijk voor onze grootste uitdaging tot dusver: het samen schrijven van een thesis.

Toen ir. Frederic Vannieuwenborg in april 2016 het thesisonderwerp rond eCare en mHealth services kwam voorstellen waren we meteen gefascineerd. De globale aandacht voor gezondheidszorg en de stijgende kosten ervan maakt deze thesis immers erg actueel en interessant. Een tweede gesprek over het thesisonderwerp wekte onze interesse alleen maar meer op.

We hadden uiteraard wel weet van gadgets zoals fitbits, maar wij begonnen deze thesis zowat als leken betreffende gezondheidszorg en eHealth. Frederic zorgde er echter al snel voor dat we wegwijs geraakten in de complexe gezondheidszorgsector en meer bepaald in de wondere wereld van eHealth. Bedankt Frederic, om ons een heel jaar lang te begeleiden en op de goeie weg te zetten. Bedankt om onze vragen telkens uitgebreid te beantwoorden. Bedankt voor je kennis, je inspiratie en je tijd gedurende onze tweewekelijkse meetings.

Hartelijk dank ook aan onze promotoren prof. dr. ir. Sofie Verbrugge en prof. dr. ir. Didier Colle, die ons de kans gaven om deze boeiende thesis te voltooien. Bedankt voor het mogelijk maken hiervan en bedankt voor onder meer het motiverende gesprek eind juni vorig jaar.

Ten slotte willen we zeker ook onze naasten bedanken. Bedankt mama's en papa's voor de onvoorwaardelijke steun tijdens onze zes jaar als student. Dankjewel aan al onze vrienden en vriendinnen voor de steun gedurende het jaar, en in het bijzonder, dankjewel Justine!

Tom De Backer, Josse Pyfferoen, juni 2017

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***Abstract*— The number of digital health services, also known as eHealth, is currently growing at a fast pace. Driven by an aging population and new costly technologies these services hold the potential to reduce the healthcare expenditures and increase the quality of care. However, the adoption of these services seems challenging and often fails. This work provides a methodology in which a new eCare or mHealth service is compared with the current care. The methodology is translated into an online tool, which allows the user to evaluate this innovative service through a pre-development validation method. Case based research indicates that the methodology is able to process the desired input data and identify a gap in the business models of the actors, which forms a barrier for adoption. It also provides various solutions to tackle the identified barriers (if possible) by reallocating the benefits/costs of the service. It should however be stated that it provides an *assessment of the potential* of a new eHealth service, and not a definitive inference.**

***Index Terms*— digital health services, web tool, pre-development validation method, win-win reallocation**

I. INTRODUCTION

Current socio-economic changes, caused by an aging population, continuous introduction of new but costly medical technologies and an overall pressure on financial resources form a challenge for our care system. More care will be needed in the near future whilst the budget cannot increase at the same pace. To do so, cost-effectiveness of healthcare technologies and practices should be optimized and more attention for prevention instead of curing is required. ICT supported care services also known as mHealth and eCare services hold the potential to change the current way of providing care and allow better health prevention [1]. Despite the large existing offer, currently no significant adoption of these services can be witnessed in most Western European countries. Reasons for this are a lack of evidence of their efficacy and effectiveness, which results in a resistance for care professionals, who play a major role in the adoption of new health services [2]. On top of that, the absence of a regulatory and financial framework makes it unattractive for health professionals to use it because their current business model is often impacted in a negative way when adopting these kind of services.

II. OBJECTIVES

The goal of this master thesis is threefold. Firstly a methodology for performing cost-effect and cost-utility analyses of eCare service versus the usual care from the perspectives of the various stakeholders should be defined. Once the input data are processed, potential barriers for adopting the eCare or mHealth service should be identified, followed by suggestions or opportunities to tackle these barriers. Reallocation methods should be formulated for the financial resources in order to become a potentially viable business case. The third goal is the development of a generic model in the form of an online tool that will allow a) validation of the methodology and barrier identification and b) other users to evaluate an eCare or mHealth service of their interest.

III. METHODOLOGY

Off all existing barriers, the unclear business model and a lack of financial support play a major role in the low adoption. It is this barrier that will be identified with the methodology, that resulted in a *ten-step plan*. Every actor wants to know *'What is in it for me?'* before accepting the new service. The person with the innovative digital health service can assess the influence on the business models of the actors using the designed tool. If the tool concludes that there is a potential viable business case, provided that benefits/costs are reallocated, win-win reallocations are proposed.

A. Collecting input data of the current care and new service

The first step exists of identifying the different actors that play a role in the current and/or new situation. Difference is made between the eCare provider (name of the actor who provides the new service), the receivers (the care givers e.g. nurse, general practitioner (GP)) and the other actors (e.g. patient, insurer).

A second step, independent of the previous one, concerns the market characterization. Based on age, acceptance of the new technology, specific characteristics of the service and maybe other requirements, the eCare provider targets user segments from the Belgian population. It would be unrealistic to assume that in no time the current care is replaced with the new eHealth service. The number of customers (= the number of patients using the new eHealth service) in year i is therefore modeled using the Gompertz-curve [3]. In that way the 'new situation' consists of a mix of patients using the current care and patients using the eHealth service.

In step three the current care is sketched: the different processes (e.g. visit to general practitioner) are identified. Figure 1 illustrates the current care for patients who suffer from chronic heart failure (CHF).

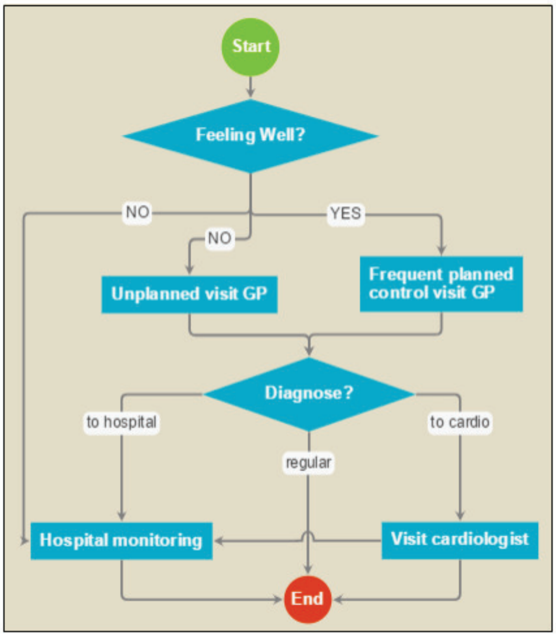

Fig. 1. Process scheme of the current care for CHF patients

This is followed by probably the most time-consuming step: the input of data concerning the previously identified processes. For every actor a table like table I should be completed. As can be seen, the user needs to assess the monetary value of the time investment for the actors in this process. It is the value for a certain actor of executing the process for one hour. A high value indicates that the actor has a great willingness to pay for a decrease of one hour of this process. There is also the possibility to input one-off transactions between two actors.

A fifth and sixth step are identical to step three and four, but now it concerns the eHealth service. With the new service a novel actor arises: the eCare provider. In step six there is asked to assess the costs for this service provider. Both one-off, ongoing, population dependent and population independent costs are handled.

PROCESS: (name of the process)					
Money					
...	€	from	(actor)	to	(actor)
Time					
...	minutes	for	(actor)		
Monetary value of time					
...	€/hour	for	(actor)		
Frequency					
...	times per year				

TABLE I

INPUT DATA FOR A PROCESS

B. A first comparison

The previous steps concerned sheer the input of data. In the next phase, the input is processed and a first comparison between the current situation (current care) and new situation (combination of current care and new service) is generated. The total time investment and total profit/loss for every actor are visualized over the time horizon for both situations. This gives a first indication of the potential of the new service, pure financially.

C. Estimating the qualitative effects

To assess the global potential of the new service, money [€], time [minutes] and qualitative effects [/] need to be compared. To do so, the input of qualitative effects is handled in a seventh step.

Qualitative effects are primarily important for the patient (e.g. increased mobility, peace of mind) and secondly for the care givers (increase in Quality Of Life (QOL) patient, quality of care, etc.). To also express this as a financial unit, there is asked for the yearly willingness to pay (per patient) of the actor for every inputted qualitative effect.

Apart from this, the qualitative effects concerning the patient are assessed with the EQ-5D method. This is necessary to determine the Incremental

Cost-Effectiveness Ratio (ICER), which will be used in the final step of the methodology.

D. Barrier identification

Now that all input data are retrieved, money, time investment and the qualitative effects are added together for both the current and new situation so that the profit/loss every actor has in the new situation can be calculated. The average yearly difference over the time horizon is called $delta_a$ and has a positive value if actor a prefers the new service. If there is any actor who has a negative delta, which means he prefers the current situation and would block the adoption of the new service, a barrier is identified. An illustrative example is visualized in figure 2. In this situation two barriers are identified: actor2 and actor4 will block the adoption of the new service.

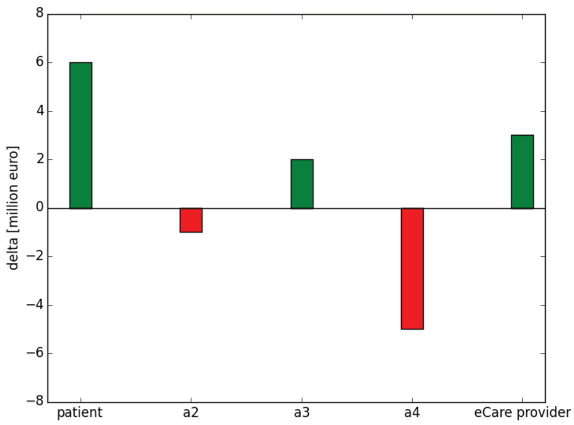

Fig. 2. Visualization of deltas

The gap is defined as the sum of deltas over all the actors and indicates if the service has potential to get adopted.

$$gap = \sum_a delta_a$$

E. Tackling the barriers

Four different situations can be achieved, depending on the value of the gap (positive or negative) and the value of the ICER (new service is cost-effective or not cost-effective). The latter is compared with the societal willingness to pay, which in this master thesis is defined as the GDP per capita (Belgium). If the gap is positive, a possibly viable business case can be achieved by reallocating the costs/benefits of the new eHealth service, so that a win-win situation is obtained. If on top of this the service is cost-effective, the government can act as a payer [4].

	cost-effective	not cost-effective
gap ≥ 0	2 (++)	1 (+)
gap < 0	3 (?)	4 (- -)

TABLE II

POSSIBLE SITUATIONS AFTER THE EVALUATION OF BOTH SITUATIONS

IV. VALIDATION OF THE METHODOLOGY

The methodology is translated into an online tool, of which the home page is displayed in figure 3. To validate the designed concept, the methodology is tested via case research. To assess the robustness, two completely different cases are handled.

Fig. 3. Start page of the web tool

A. Case research

1) CHF: The first case concerns a telemonitoring service for chronic heart failure (CHF) patients that aims to increase the QOL of the patient and decrease the number of hospitalizations, which is an expensive process. Literature studies indicate the potential of this kind of service [5].

The patient is daily monitored at home, which takes about ten minutes. The results of the monitoring are sent to a CHF-specialized nurse. If some measurements are out of the normal range, the nurse analyzes the alarm and contacts the patient via a phone call with further information.

The final output provided by the tool indicates that the gap is positive and that the service is cost-effective. The new service would result in a decrease in the receivings of the general practitioner, cardiologist and especially the hospital (because the hospitalizations of CHF patients are reduced with a factor two). The greatest benefit is witnessed for the insurer, followed by the patient. To achieve a viable business case, reallocations of the costs/benefits are necessary. The tool also generates a warning that in the new situation the nurse has to work up to six times as much. This is not feasible in practice and requires additional full-time equivalents.

Common sense tells that a decrease in hospitalizations ($\sim$ a more healthy population) is a positive fact. It seems however to be a major reason of why adoption of the service is difficult if there are no reallocations of benefits to the hospital. This sets the current financing model for hospitals into question, since there is really no financial benefit to provide this type of services.

2) SMART: SMART is the name for a fictive mHealth service that tries to reduce waiting times at the general practitioner's practice by creating a virtual queue. The focus of this service lies on the improvement of a disturbing element in health care, not on improving the health status of a patient itself. When it is almost the patients' turn for a consultation, an automated text message is sent to the patient via the mobile phone. Leaving for the general practitioner shortly after the receipt of this notification ensures that the patient avoids long queues and that he arrives approximately five minutes in advance. Ignoring these notifications, and hereby arriving to late will result in a penalty. Four actors participate in this service, the patient, the general practitioner, the eCare provider and the insurer.

Three scenarios are tested: a worst-case, an average-case and a best-case scenario, dependent on the waiting time. Table III represents the average waiting times [min] for each of these three scenarios.

	worst	average	best
current process	15	22,5	30
new process	10	7,5	5

TABLE III
AVERAGE WAITING TIME AT GP'S PRACTICE FOR THREE SCENARIOS

The gap for each of the three scenarios is positive, even when a very low value is assigned to the monetary value of time for a patient waiting at the general practitioner's practice. The critical value of this parameter is 1,01 € in the worst-case scenario. Hence every value above or equal to 1,02 € will result in a positive gap. But a barrier is identified: the general practitioner has a negative delta. His receivings stay the same while he has a startup cost for the service plus a (small) yearly fee per patient. Consequently the new service has potential to get adopted, but a reallocation of the costs/benefits is necessary.

The tool however generates a warning stating that ICER cannot be used to determine if the new service is cost-effective. This is because no significant health status changes take place in the new service in comparison with the current one.

Three main reallocation proposals are suggested: equal division, proportional division and division based on the financial risk. The equally divided reallocation method seems to be the fairest proposal at first sight. However, in this way the insurer gets part of the profit although nothing changes for him. To solve this unfairness, an option in the tool is activated to set the insurance's delta to zero. In this way the patient, the general practitioner and the eCare provider divide the total profit.

B. *Performance of the web tool*

The web tool was able to process and analyze two similar cases: a telemonitoring service for CHF patients and a teleconsultation service for COPD (Chronic Obstructive Pulmonary Disease) patients, both with the aim to reduce the number of hospitalizations. To validate the robustness, a totally different, fictive case (SMART) was successfully investigated. The latter indicates that waiting times at a general practitioner's practice can be reduced with the introduction of an mHealth service. This can increase the quality of the service (a visit to the general practitioner), satisfy the patients and give the general practitioner more control over his schedule, which could make him willing to pay for the service.

V. CONCLUSION

The methodology introduced in this master thesis is designed as a pre-development validation method for innovative digital health services. It is translated into a web tool, which can be used by everyone who wants to assess the potential of his innovative idea. It might in fact also be used to compare two non-healthcare related services.

Case research indicates the potential of the methodology and web tool. Barriers are identified and solutions are provided to tackle these barriers. It should however be stated that it can be used as an assessment. No definitive conclusions can be made based on the output of the tool. The quality of this output is strongly related to the quality of the input of the user.

VI. FUTURE WORK

The basis is provided for a well-working pre-development validation tool. There is however one valuable thing that the tool currently lacks: the possibility to perform a sensitivity analysis. There are after all a lot of input variables which can show variability (e.g. the time spent to a certain process) or that have to be estimated (e.g. the number of customers in a certain year on the time horizon). Allowing to specify the range in which the input variables can vary could result in some valuable insights. In that way the final step would provide a worst, average and best case scenario.

Apart from the sensitivity analysis, the methodology seems to be complete. The structure and mindset seems to be on point. If in the future the methodology/tool would be further developed, it is recommended to focus on the single steps in detail as the bigger picture seems to fit. Some simplifications are made: for example in step 2, where the market target is estimated via a Gompertz-curve, it is assumed that there are only two services available: the current care and the new eHealth service. Every targeted customer uses or the current care, or the eHealth service. Game theory may be applied.
Another important recommendation for future work concerns the Net Present Value (NPV), which is currently not used. It can be used to estimate the future profitability of the investment of the eCare provider by taking the discount rate into account.

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List of Acronyms

CEA	Cost-Effectiveness Analysis
CHF	Chronic Heart Failure
COPD	Chronic Obstructive Pulmonary Disease
CSS	Cascading Style Sheets
DOP	Digitaal Onco Platform
EU	European Union
GDP	Gross Domestic Product
GP	General Practitioner
HTA	Health Technology Assessment
ICER	Incremental Cost-Effectiveness Ratio
ICT	Information and Communication Technology
mHealth	Mobile Health
OECD	Organization for Economic Co-operation and Development
PHP	Hypertext Preprocessor
QALY	Quality Adjusted Life Years
QOL	Quality Of Life
INAMI	l'Institut National d'Assurance Maladie Invalidité)
WHO	World Health Organization

Chapter 1

Introduction

"The emergence of a true multimedia record seems likely. Perhaps clinicians will once again be able to look at all aspects of their patients, including blood smears and x-rays. Perhaps they will be able to see patients for the first time and know what they looked like a year ago, or what their hearts sounded like. In this way, perhaps the computer, which is blamed for taking us away from our patients, can bring us closer." [1]

—- JAMES J. CIMINO, 1997

1.1 Problem statement

Current socio-economic changes, caused by an aging population, continuous introduction of new but costly medical technologies and an overall pressure on financial resources form a challenge for our care system. More care will be needed in the near future whilst the budget cannot increase at the same rate. To do so, cost-effectiveness of healthcare technologies and practices should be optimized and more attention for prevention instead of curing is required.
ICT supported care services also known as mHealth and eCare services hold the potential to change the current way of providing care and allow better health prevention [2], [3]. Despite the large existing offer, currently no significant adoption of these services can be witnessed in most Western European countries. Reasons for this lay in the fact that there is a lack of evidence of their efficacy and effectiveness.
This results in a resistance for care professionals. On top of that, the absence of a regulatory and financial framework makes it unattractive for health professionals to use it because their current business model is often impacted in a negative way when adopting these kind of services [4], [5].

eHealth applications are applicable for numerous of diseases and practices. However, the success of eHealth projects is precarious. HelloFysioApp is a platform for online physiotherapy in the Netherlands and one of the many so called e-Fysio services. Instead of going out to the physiotherapist, patients can do their exercises at home based on an online video. The start of the project (2010) was very promising with lots of positive comments both from physiotherapists and patients. Despite the success the providers of the platform stopped the project in November 2016 [6]. The reason for this is the lack of payments from the insurers. Although, in the same week as HelloFysio quited, new e-Fysio services started up with the same goals but with different financing methods.

The healthcare sector may be different for various countries. Although, they have all one thing in common: it is a very complex sector with many diverse actors who defend their own interests. This makes it very hard for an innovation to succeed in this sector. If the new service is not positively evaluated by all the actors, the potential for adoption is limited.

1.2 Goal of the thesis

The goal of this thesis is threefold:

- Defining a methodology for performing cost-effect and cost-utility analyses of eCare service versus the usual care from the perspectives of the various stakeholders.

For each actor involved in the service delivery, all required costs and effects need to be identified. These expenses do not only include the direct financial costs (such as initial investments or recurring subscription costs), but also indirect costs such as additional administrative effort, opportunity costs of time investment, etc. can be crucial for the viability of the business case. Adopting a novel eCare service hopefully not only results in additional costs but also in some positive effects. Effects can be quantitative such as a higher throughput, a decrease in hospital beds or length of stay, etc. The methodology should provide a method by which the quantitative and qualitative effects can be evaluated. Comparing the qualitative effects (such as a higher quality of life) of the novel eCare or mHealth service with the usual care will be less straightforward than comparing quantitative effects.

- Identification of potential barriers for adopting the eCare or mHealth service followed by suggestions or opportunities to tackle these barriers.

Integrating eCare services into the current healthcare landscape introduces new processes and a new kind of interaction with the patient. Depending on the nationally installed health care system this new sort of patient interaction disrupts the current way of care provisioning in terms of patient monitoring and payment models. In Belgium typically a fee for service system is installed. Introducing novel eCare services in such a system is challenging. Often the lack of a proper financial framework forms a barrier for adoption. There is no financial incentive for additional administrative work that is needed. In contrary, additional work means less time to examine patients which results in a lowered income for the medical practitioner and the hospitals they work in. Via the methodology a mapping of all the roles of the stakeholders should be done, which allows the identification of such contradictions in the business case. Once all potential barriers are detected, innovative reallocations methods of the financial resources hold the potential to formulate a potentially viable business case.

- Development of a generic model in the form of an online tool that will allow a) validation of the methodology and barrier identification and b) other users to evaluate an eCare or mHealth service of their interest.

www.makingecarework.be should become an online reference evaluation tool for future users and eCare providers to evaluate the impact of their novel eCare service on the business case of the involved stakeholders. Via the web tool, the developed generic methodology should allow modeling all the costs and effects for the involved stakeholders, identify potential barriers and formulate guidelines in order to overcome these issues.

The ultimate goal of this thesis is therefore to evaluate the total impact of the introduction of a new eCare or mHealth service both from a payer and societal perspective as well from the perspective of the involved actors.

1.3 Overview of the thesis

Before there can be started with developing a methodology, a literature study has been executed. The first goal of this literature study was to get to know the complex healthcare sector and its current context. After gaining knowledge about the traditional healthcare, the wonderful world of eHealth was explored. Chapter 2 describes the parts of the literature research which were useful for this master thesis.

With the knowledge obtained from the literature study, a methodology was composed. The methodology resulted in a 10-step plan. Each single step has been discussed in detail in chapter 3.

This methodology was translated into an online pre-development validation tool. The approach used to make the website is briefly highlighted in chapter 4.

In chapter 5 the designed tool is evaluated via case research. Based on this, the overall performance of the methodology and tool is discussed.

This dissertation finally ends with chapter 6, which gives an overall conclusion and some possible suggestions for further research.

Chapter 2

Literature study

Why is their need for digital services in healthcare? Which different kind of digital services exist? What is the reason that adoption is challenging and slow? How is the eHealth situation in Belgium? In this chapter there has been tried to give an answer to these kind of questions.

2.1 The current healthcare context

First of all the current healthcare context is sketched. This identifies the need for new and better care. But it is hard to innovate successfully in the healthcare sector. To do so, one needs to account for many actors and within complex legislations. Therefore the main actors in healthcare are briefly discussed in this section, as is the Belgian healthcare system.

2.1.1 Rising costs and an aging population

The healthcare sector is a complex world with a lot of different parties that have different interests and with complex legislations and regulations. According to the World Health Organization (WHO), a good health system delivers quality services to all people and this when and where they need them. The exact configuration of services may be different from country to country, but in all cases it requires a robust financing mechanism; a well-trained and adequately paid workforce; reliable information on which to base decisions and policies; well maintained facilities and logistics to deliver quality medicines and technologies [7].
These requirements are hard to realize because of the global challenge of the risings costs in healthcare and because of the higher expectations that people have these days (as a result of a higher income). These rising costs are mainly caused by new expensive medical technologies, an aging population and the (long) treatment of chronically ill people. This often results in governments that focus to much on the saving of healthcare costs and too little on the quality of care. Or as the Organization for Economic Co-operation and Development (OECD) formulates:

"While the stakeholders are mostly focused on the financial relationships, the ultimate social goal of health care systems can be seen as producing health, which is the key factor contributing to improved welfare and well-being" [8].

Currently, the healthcare sector is faced with following trends [9]:

- The demographic shift towards an aging population;
- A rise of chronic diseases and in disease burden;
- An increasing demand for quality healthcare services; and
- Difficulty to control expenditures and to assign incentives in a fair way.

Especially the aging population is a remarkable challenge to deal with. Figure 2.1 illustrates the population pyramid of the European Union (EU) population by sex and by age groups.

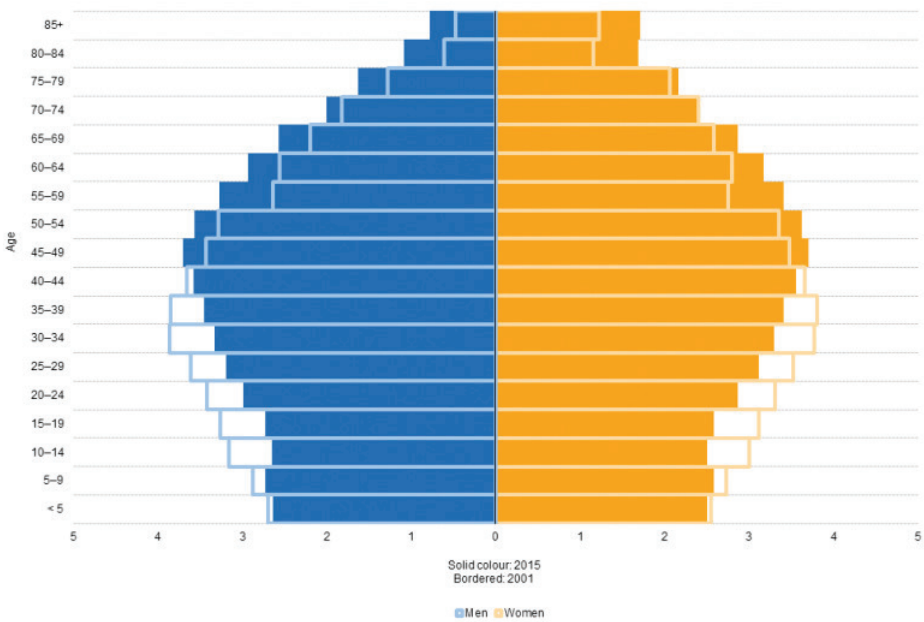


Figure 2.1: Distribution of the EU population by sex and by age groups: 2001 versus 2015 [10]

The bordered color represents the year 2001, while the solid color represents the year 2015. There is a clear difference at the top of the pyramid which confirms the aging of the population. According to Eurostat's projection the distribution in 2080 would look like the one displayed in figure 2.2. This shows that if this evolution continues, the 85+ group would form the greatest part of the EU population. This aging population is due to low birth rates and the evolution of the medical technologies which results in a higher life expectancy [10]. The shape is quite remarkable: one would expect that the age groups below the 85+ group would decrease gradually.

There are for example less people in the 80-84 age group than in the group below and above. This is probably due to the large increase of the people in the 85+ group, which represents a much larger amount of different ages than the others (who are grouped per five years). The higher life expectancy might explain this.

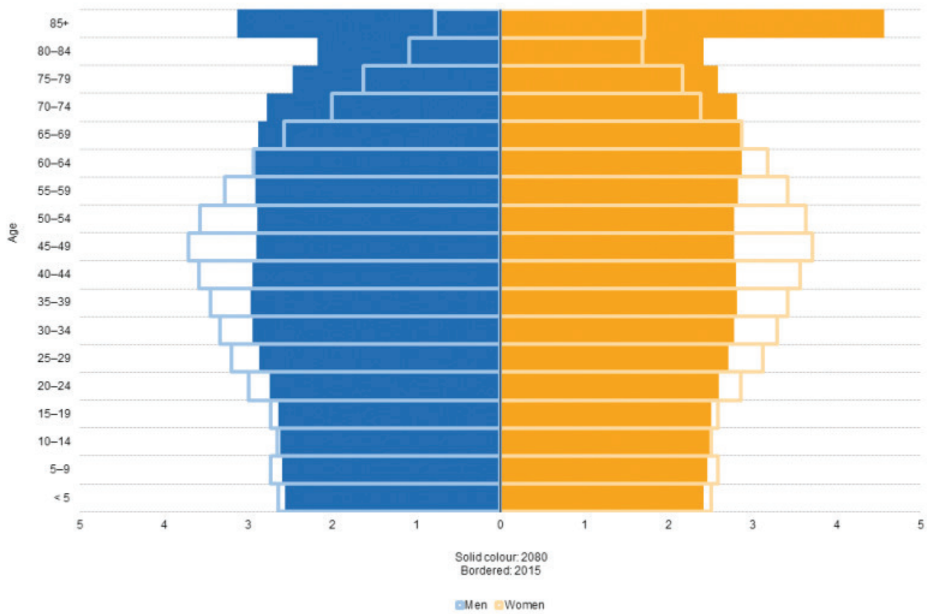


Figure 2.2: Projected distribution of the EU population by sex and by age groups: 2015 versus 2080 [10]

According to the WHO the proportion of the world's population aged 60 or more, will double from about 11 % to 22 % between 2000 and 2050 [11]. This would mean an increase from 605 million to 2 billion people aged 60 or more over the same period. The number of people aged 80 years or older will even quadruple between 2000 and 2050. The number of people who will be no longer able to look after themselves in developing countries is also forecast to quadruple by 2050 (long stays in hospitals, mental health problems, dependent living because of limited mobility etc.). This evolution rises the need for long-term and chronic care.

In a study concerning the fiscal sustainability of health systems, the OECD states that in order to maintain the healthcare needs of today and fund the future medical advances major reforms are needed [12]. If the government fails to contain costs, public expenditure on health and long-term care in OECD countries will increase from around 6% of the Gross Domestic Product (GDP) to approximately 9 % in 2030. This will even rise to 14 % by 2060 according to OECD projections. In all OECD countries the health expenditures have risen more rapidly than economic growth. This phenomenon is visualized in figure 2.3. In Belgium the average health spending growth per capita was about 2 % larger than the GDP growth per capita (1990-2012).

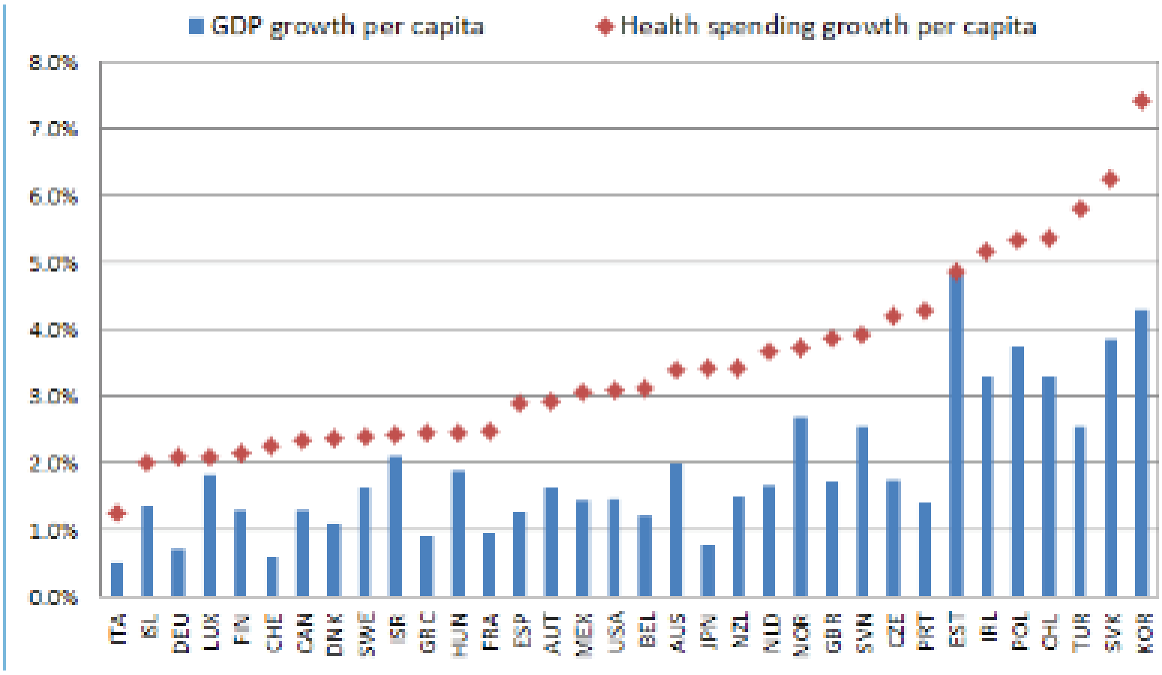


Figure 2.3: Average growth rate of health spending and GDP per capita, 1990-2012 [13]

The in this section described challenges for the current health care sector rise the need for new and better care. ICT supported services have great potential to fulfill this need.

2.1.2 The Belgian healthcare landscape

Which actors are involved in the Belgian healthcare system? What is their task? Who is responsible for payments? In this section the Belgian healthcare landscape is sketched.

First of all the (most important) different actors and their roles are shortly explained. These actors do of course not only appear in Belgium.

- Patient: the care-dependent person for who the other actors assert. He is the user of health care (often taxpayer).
- First line caregiver: the first line care consists of professional actors who provide the first contact for diagnosis. Everyone who searches care can make use of this kind of caregiver without restrictions. This category consists of the general practitioners (GP), nurses, physiotherapists, dentists etc.

- Second line caregivers: professional actor to which the first line caregiver can refer, in most cases for severe or acute disorders. The specialized doctors (e.g. neurologist, orthopedist etc.) are part of this category.
- Informal caregiver: the person who gives care to a patient who is a relative (e.g. friends, family). This is informal care that is given voluntarily and (often) unpaid.
- (public) Insurer: covers payments of certain healthcare for the patient. In Belgium there is a compulsory insurance and there are certain additional insurances.
- Government: responsible for among others the legislation concerning the national healthcare system, maintaining good quality and easy access etc.

The relation between these actors in the Belgian healthcare system is depicted in figure 2.4. An actor can give a service (care) to another actor (full arrow), an actor can pay another actor (dotted arrow) or refer some actor to another actor (curled line). The INAMI (l'institut national d'assurance maladie invalidité) mutualities represent non-competing public insurers. The care providers are often conventional.

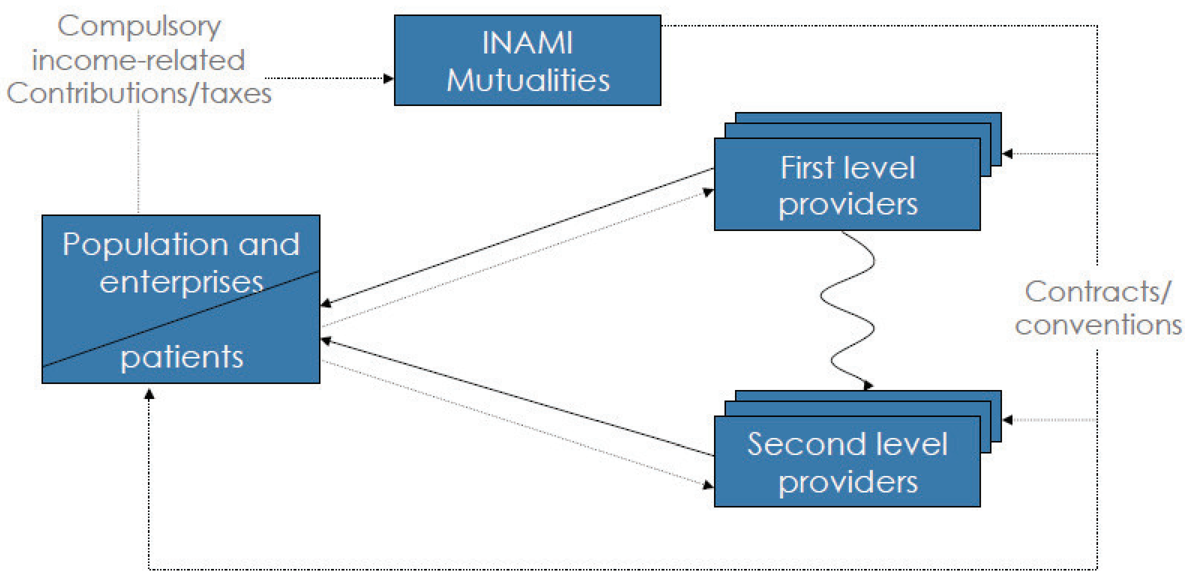


Figure 2.4: Healthcare system in Belgium: compulsory insurance with reimbursement of patients [14]

The Belgian healthcare system has some specific characteristics [14].

- Liberal: the biggest part of the care givers (medical, paramedical) work on an independent base with a fee-for-service financing and have diagnostic and therapeutic freedom. This financing system means that the care giver is paid per performance. The more patients he handles, the greater his income.

- Compulsory health insurance: there is a system of compulsory health insurance whose management asks for deliberation between the different actors in the care sector (insurance companies, health care workers, funders, government).
- Free choice: free choice of the patient in terms of choice in care givers as well as choice of (private/public) care institution.

Positive about the Belgian healthcare system compared to others is that there is more equity and solidarity. But it also has disadvantages: the sickness funds are in fact just passive payment offices and there are few incentives for efficiency.

2.2 The rise of eHealth

The term eHealth is used for the first time in scientific literature in 1999 [15]. Since then, a lot has been written about the great potential of eHealth. The first high level conference on eHealth was held by the European Commission in May 2003. The conference dialogue, where ministers of health and telecommunications of 25 different European countries were present, was justified by three main reasons: (1) eHealth is the single-most important revolution in healthcare since the advent of modern medicine or hygiene, (2) there are numerous European eHealth achievements and (3) European expertise can satisfy national and international needs for health services. The case for eHealth was intended to encourage the dialogue regarding the next steps for health systems by involving policymakers, healthcare professionals and citizens [16].
In 2005 the WHO adapted a resolution on eHealth [17]. The resolution invited WHO Member States to conceive and implement health information systems, to evaluate eHealth activities and to share knowledge on cost-effectiveness, thus ensuring quality, safety, ethical standards, data confidentiality, privacy, equity and equality [9]. It also states that before eHealth can be successful the benefits should be evidence-based.

Nowadays people value health a lot; 'health' is one of the most popular categories in the *App Store* and *Google Play Store*. A very broad offer of applications concerning health is available. But what is eHealth (electronic Health) exactly? It is a relatively new term that is rising especially in the last decade. Literature provides a lot of different definitions for eHealth and its relatives. In a first part of this section there has been tried to define these digital services.
The rise of eHealth results in a new actor in healthcare: the *eCare provider*. A second part of this section handles the role of this eCare provider. Although there is evidence that certain

services hold the potential to reduce costs and increase the quality of life, little adoption of these services is witnessed. There has been searched for reasons for this lack of adoption and for different eHealth projects. In a last subsection there is zoomed in on the current eHealth situation in Belgium.

2.2.1 What is eHealth

What is eHealth? Lack of consensus on the meaning of this term has led to uncertainty among academics, policymakers, providers and consumers. The WHO gives the following broad definition to eHealth:

eHealth is the use of information and communication technologies (ICT) for health [18].

Pagliari et al. [15] performed a systematic review with the goal to formulate a clear definition. In their survey they come up with 36 different definitions for eHealth. It is clear that definitions of eHealth vary with respect to the functions, stakeholders, contexts and theoretical issues targeted. Some of them encompass a broad range of medical informatics applications. However, most of the defintions emphasize the communicative functions of eHealth. They concluded their survey with the following definition for eHealth, adapted from Eysenbach:

eHealth is an emerging field of medical informatics, referring to the organization and delivery of health services and information using the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a new way of working, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology [19].

Eysenbach explains that the "e" in eHealth not only stands for electronic, but implies a number of other e’s, which together perhaps best characterize what eHealth *should* be. The different e’s and their description is summarized in table 2.1.

Efficiency	Increase efficiency in health care, thereby decreasing costs.
Enhancing quality of care	Increasing efficiency involves not only reducing costs, but at the same time improving quality
Evidence based	eHealth interventions should be evidence based in a sense that their effectiveness and efficiency should not be assumed but proven by rigorous scientific evaluation
Empowerment of consumers and patients	By making the knowledge bases of medicine and personal electronic records accessible to consumers over the Internet, eHealth opens new avenues for patient-centered medicine, and enables evidence-based patient choice.
Encouragement of a new relationship	Between the patient and health professional, towards a true partnership, where decisions are made in a shared manner.
Education of physicians	Through online sources (continuing medical education) and consumers (health education, tailored preventive information for consumers).
Enabling information exchange and communication	In a standardized way, between health care establishments.
Extending the scope of health care	Extending the scope of health care beyond its conventional boundaries. This is meant in both a geographical sense as well as in a conceptual sense. eHealth enables consumers to easily obtain health services online from global providers. These services can range from simple advice to more complex interventions or products such as pharmaceuticals.
Ethics	eHealth involves new forms of patient-psychician interaction and poses new challenges and threats to ethical issues such as online professional practice, informed consent, privacy and equity issues.
Equity	To make health care more equitable is one of the promises of eHealth, but at the same time there is a considerable threat that eHealth may deepen the gap between the "haves" and "have-nots". People, who do not have the money, skills, and access to computers and networks, cannot use computers effectively.

Table 2.1: The 10 e's in eHealth according to Eysenbach [19]

eHealth is the global term used to comprise different application areas. In the COCIR eHealth toolkit a glossary is added with dozens of definitions for certain applications within the broad field of eHealth [20]. The for this master thesis most important ones are listed below.

- **TELEMONITORING**: Telemonitoring refers to systems and services using devices to remotely collect/send vital signs to a monitoring station for interpretation. Telemonitoring is the remote exchange of physiological data between a patient at home and medical staff at hospital to assist in diagnosis and monitoring (this could include support for people with lung function problems, diabetes etc). It includes (amongst other things) a home unit to measure and monitor temperature, blood pressure and other vital signs for clinical review at a remote location (for example, a hospital site) using phone lines or wireless technology [20].

- **TELEMEDICINE**: Telemedicine can be defined as the delivery of healthcare services through the use of information and communication technologies (eHealth), including wireless and mobile connectivity (mHealth), in a situation where the actors are not at the same location. The actors can either be two healthcare professionals (e.g. teleradiology, telesurgery) or a healthcare professional and a patient (e.g. telemonitoring of the chronically ill such as those with diabetes and heart conditions, telepsychiatry etc). Telemedicine includes all areas where medical or social data is being sent/exchanged between at least two remote locations, including both care provider to patient/citizen as well as doctor-to-doctor communication [20].

- **ELECTRONIC MEDICAL RECORD (EMR) / ELECTRONIC PATIENT RECORD (EPR)**: Electronic Patient Record (EPR), Electronic Medical Record (EMR), Computerised Patient Record (CPR) are synonymous. They refer to an individual patient's medical record in digital format generated and maintained by a care provider, such as a hospital or a physician's office. Such records may include a whole range of data in comprehensive or summary form, including demographics, medical history, medication and allergies, immunization status, laboratory test results, radiology images, and billing information. The purpose of an EPR/EMR can be understood as a complete record of patient encounters that allows the automation and streamlining of the workflow in health care settings and increases safety through evidence-based decision support, quality management, and outcomes reporting. [20]

- **mHEALTH**: Mobile health, or mHealth, is the provision of eHealth services and information that relies on mobile and wireless technologies. Similarly to eHealth, of which it is part, mHealth describes a broad set of technologies that can support a variety of health-related services, and is not a separate category of services in itself. Mobile technologies are utilised across the range of healthcare, social care, wellness and prevention, and form an integral part of telemedicine, telehealth and telecare [20].

A term that is less discussed in literature (and even cannot be found in the COCIR glossary) is *eCare*. Just like eHealth, in this dissertation eCare is interpreted as an umbrella term for all ICT-supported services which focus on long term care and non-medical care provisioning and processes. This includes services that support healthy aging, activities of daily living (ADL) and ambient assisted living (AAL). Existing solutions include home monitoring systems to support independent living and systems to enhance social contact of elderly.
Electronic medical records for example are considered as an eHealth application but not as an eCare application. Although electronic health records are widely used and form an important application of eHealth, this dissertation focuses on eCare and mHealth services.

2.2.2 The eCare provider

With the development of new eHealth services a new actor arises: the eCare provider. The term eCare provider will further be used in this dissertation for the actor who builds, maintains, operates and distributes the eCare or mHealth service. Note that the name eCare provider is in this dissertation used as a global term for the provision of eHealth services (and not in particular eCare services).

One single eHealth service is often part of an eHealth platform that is used for multiple services or is provided by different providers. The development of an eCare platform results in costs for development, production and maintenance. The typical tasks of eCare platform providers are depicted in figure 2.5. One can see that the tasks of the eCare providers are split in four: build and maintain, operate, distribute and connect [21]. The hardware provider develops the hardware necessary for the service. This will result in production costs but also in a large upfront cost. Hardware can for example be the sensors used to measure certain parameters of the patient via telemonitoring. Apart from the hardware also software needs to be built and maintained (e.g. software used to read the measurements of the sensors).
The patient's data needs to be stored somewhere, so servers need to be bought to store the data. If desired, a call center can be available to take the emergency calls.
With customer services often a distribution channel is used to take care of the distribution, marketing, sales and billing processes. This is not necessarily the responsibility of the eCare provider but can for example be the task of a care organization.
At last the patient should often be connected to the Internet. This can be assured by a network connectivity provider or by the patient himself.

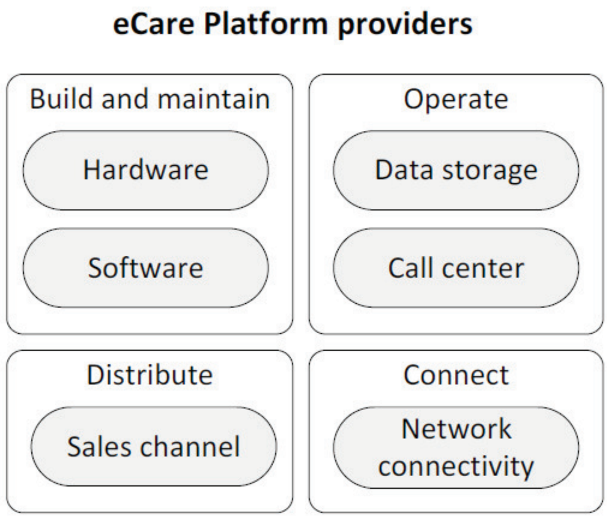


Figure 2.5: Different roles of the eCare (platform) provider [21]

Further in this master thesis the costs for an eCare provider introducing a new service will be estimated. The main costs that can possibly be incurred are explained above. Of course this will be different from service to service.

2.2.3 Lack of adoption

"Whilst eHealth offers the potential to improve patient outcomes and reduce costs, it must first be acknowledged as part of treatment regimens by healthcare systems before it can be adopted widely." [22]

Despite the large existing offer and great potential, eHealth technologies often face adoption problems. Because of a mismatch between the postulated benefits and the actual outcomes, the impact of eHealth technologies is often questioned.
One of the reasons of this is the lack of evidence about the effect of eHealth technologies [23]. This results in care professionals who are often skeptical to eHealth and show little support for these new technologies [24].

According to Li et al, the medical doctors are the key driving force in pushing eHealth initiatives. Without their acceptance and actual use the benefits of eHealth would be unlikely to be reaped [25]. They performed a systematic review to identify and synthesize the influential factors to health care providers' (those medical doctors) acceptance of various eHealth systems. From the literature 40 different factors were identified and grouped into seven clusters: (1)

health care provider characteristics, (2) medical practice characteristics, (3) voluntariness of use, (4) performance expectancy, (5) effort expectancy, (6) social influence, and (7) facilitating or inhibiting conditions. This is visualized in figure 2.6.

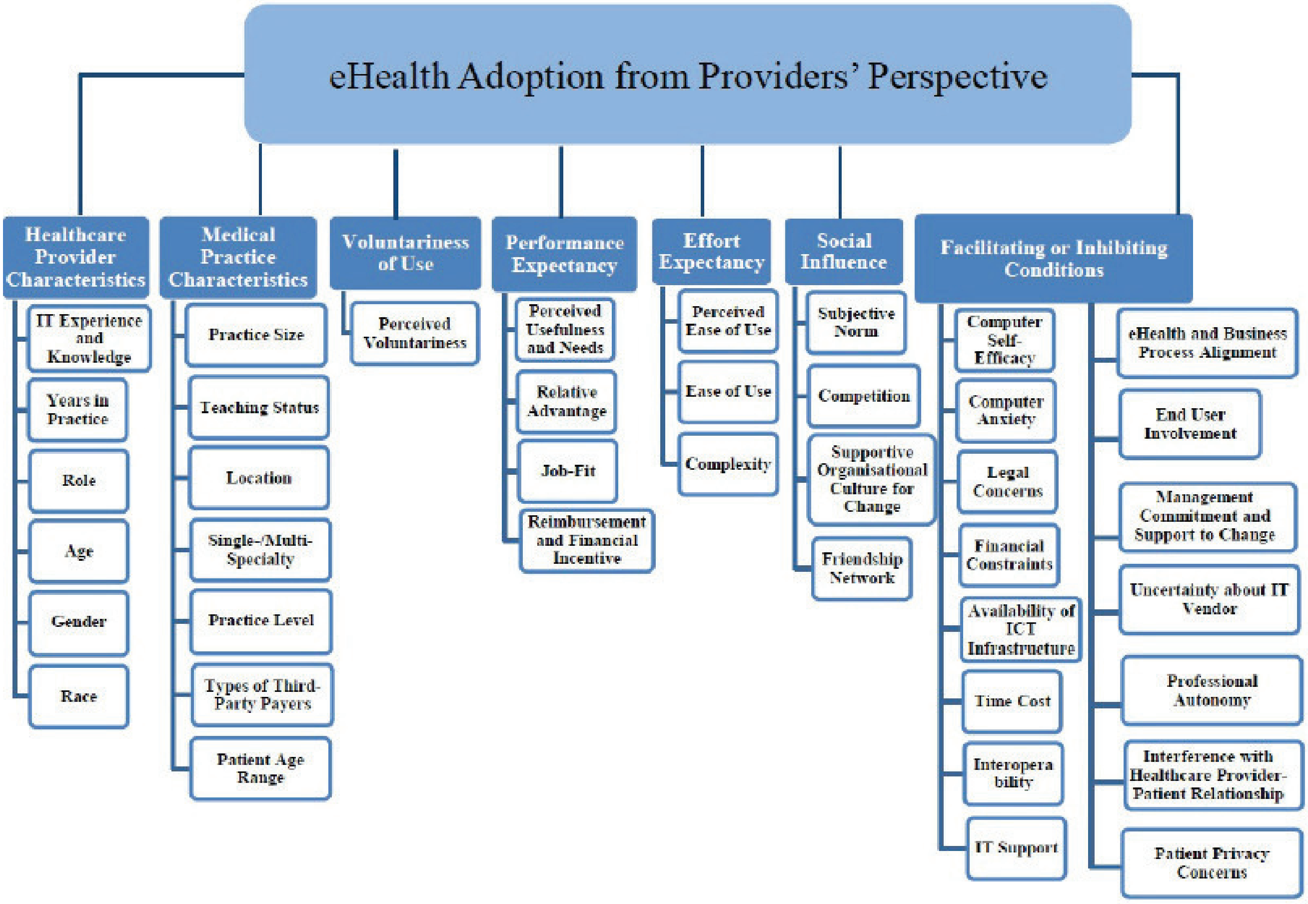


Figure 2.6: eHealth acceptance factors and clusters [25]

With the identification of these 40 factors that determine the adoption of eHealth from the providers' perspective, they hope to help decision makers at health care settings and policy makers at the health sector better understand eHealth adoption issues and take action to facilitate the eHealth innovation process.

More specific, the role of the general practitioners is pivotal to realize adoption. GPs play a crucial role in facilitating access to and the delivery of care [26]. General practitioners are a pivotal node: the realization of the promises that eHealth offers are greatly influenced by the adoption and use of eHealth by the GPs. As currently there is a shift for more integrated care and towards a greater role for the GP, he can either play the role of catalyst or bottleneck for digital innovations in health care. A survey of GPs was conducted in 31 countries (EU27 + Croatia, Iceland, Norway, and Turkey) to measure and explain levels of availability and use (adoption) of eHealth applications and services [27]. In this benchmarking study a method was developed to calculate a composite index, which represent the eHealth adoption among general practitioners in 2013. It is a *composite* index because it is composed of four different eHealth adoption indexes: electronic health records, health information exchange, telehealth and personal health records. The result is displayed in figure 2.7.

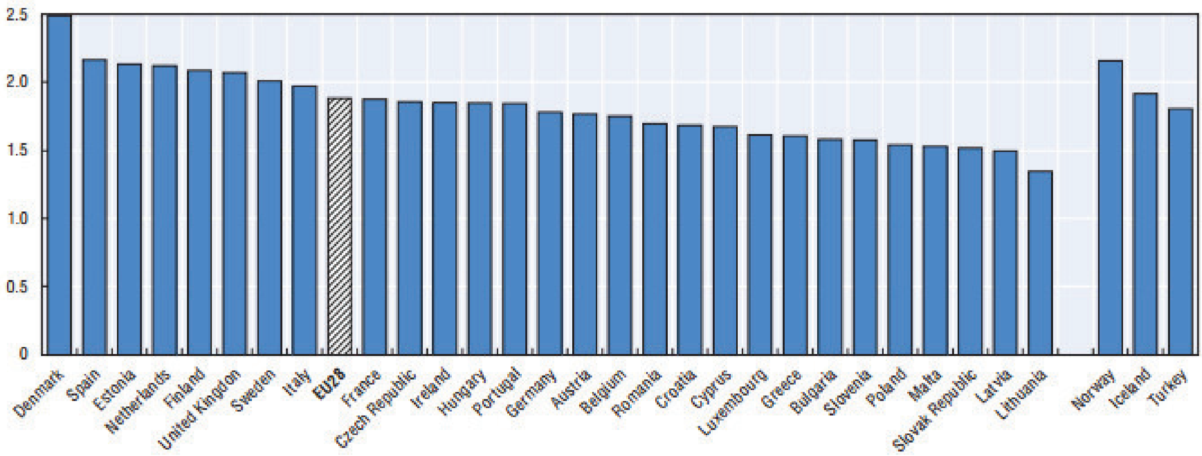


Figure 2.7: Composite index of eHealth adoption among general practitioners, 2013 [28]

The values of the index represent: do not know (not aware) = 0; do not have it = 1; have it and do not use it = 2; use it occasionally = 3; use it routinely = 4. The average composite index is 1,897 which is quite low. As defined by the four measurement pillars, eHealth did not yet reach full availability, whereas usage is very modest in EU27. Especially the adoption of telehealth and personal health records is very low. The general practitioners in Belgium are with a value of 1,752 below the average. A possible reason for this is the liberal fee-for-service system. When an eHealth service increases the quality of life of a patient, it is possible that he needs less care and thus sees less medical doctors. As a result of the pay for performance payment system, these medical doctors will thus receive less money. Denmark on the other hand clearly has the highest score (2,49). The Netherlands, known as an innovative country in healthcare, has also one of the highest scores for the index.

The same was done for the adoption of eHealth of European hospitals in 2013 [28]. This time the score is on a scale from 0 to 1 and distinction was made between deployment and availability & use. The averages for EU member states were 0,44 for eHealth deployment, and 0,30 for availability and use (figure 2.8). Again the results show that there is a lot of room for improvement as no country was close to the optimal score of one. Although, there was a little increase in comparison with a similar survey of 2011. The more Northern located countries achieved the highest score. Belgium is in contrast to the adoption of eHealth for GPs above the average now.

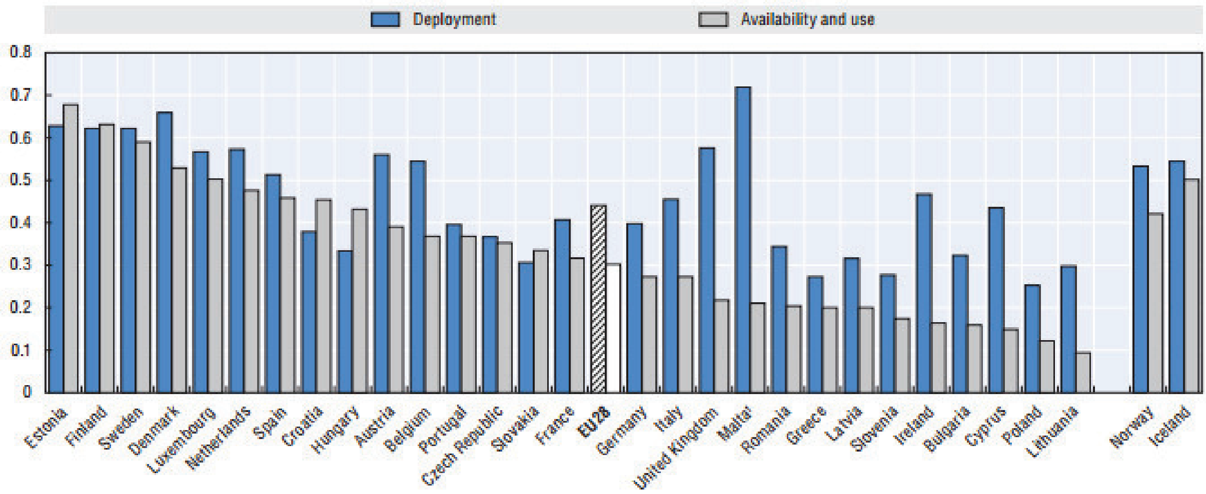


Figure 2.8: Composite indicators of eHealth adoption in hospitals, 2013 [28]

There can be concluded that adoption of eHealth services is influenced a lot by the GPs' characteristics and attitudes. These principally concern the lack of resources and financial incentives, of data interoperability, and of sound regulatory frameworks [27]. To fulfill the vision set out in the European Commission eHealth Strategy, improvement in the adoption of digital health services is not only needed in the primary care, but also in the hospital sector [29].

Investors first need to have trust in their project before they finance it. This is not different for eHealth projects, which are often complex innovations. An eHealth innovation (especially those concerning chronic diseases) needs coordination and communication as often a lot of stakeholders are involved [30].
Another reason for the low impact of eHealth technologies is the fact that eHealth technologies are often developed without participation from the end user which often results in usability problems [31]. Studies and literature state the importance of a development process involving all important stakeholders, of which the end users are a part in order to increase the adoption of eHealth technologies [32].
There is obviously need for a better fit between human, technological and contextual factors in order to uptake eHealth technologies. Therefore, Van Gemert-Pijnen et al. believe that a *holistic* approach is needed to increase the impact of eHealth technologies [33]. With a holistic approach they mean that they emphasize the importance of the whole, with interdependence between the different parts and avoid a separate analysis of its parts. Their research resulted in a holistic framework for the development of eHealth technologies: *The CeHRes Roadmap* (figure 2.9).

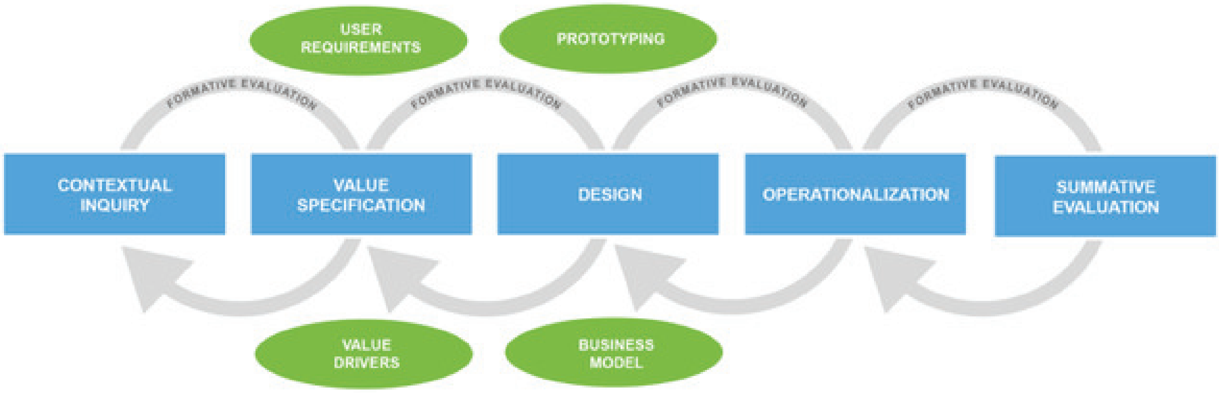


Figure 2.9: CeHRes Roadmap for the development of eHealth technologies [33]

The holistic approach is based on six principles that they derived from the review of current frameworks as well as from empirical research.

- Principle 1: eHealth technology development is a participatory process
- Principle 2: eHealth technology development involves continuous evaluation cycles
- Principle 3: eHealth technology development is intertwined with implementation
- Principle 4: eHealth technology development changes the organization of health care
- Principle 5: eHealth technology development should involve persuasive design techniques
- Principle 6: eHealth technology development needs advanced methods to asses impact

This subsection zoomed in on the barriers that are currently faced for adoption of eHealth services. They are summarized in table 2.2. Especially the fourth barrier in the table (a lack of financial support/the unclear business model) is a major motivation for this master thesis.

Barrier	Description
A complex value network for eHealth services	Integrating digital health services demands an intensive collaboration of several care actors. That is in contrast with the current and fragmented way of the often polarized care provisioning. Often the cost/benefit allocation for these actors is distorted.
Added value is unclear, still needs to be proven or is hard to quantify	Digital health services are new and innovative and therefore the impact of it is not proven yet. Also these services will impact more the quality of care and quality of life, which is harder to measure and quantify.
Technological barriers	There exist issues on data format standardization in order to guarantee exchangeability.
A lack of financial support/ the unclear business model	Integrating digital health services often require efforts from professional care providers. This impacts their business model in a negative way. Without a clear financial structure or compensation, their motivation to adopt and support these services is and will remain low.
Current perceptions of the involved actors on the healthcare system affects willingness to pay	Because of the installed care insurances, Western European citizens (and other countries where many healthcare costs are covered by public health insurances) are not used to pay (fully) for new medical devices or digital health services.
Privacy concerns & legal issues	Together with the use of ICT supported care services, automatically questions on data security and privacy rise.
Ignorance	A new eHealth service might have a lot of potential, but if no one knows it exists it cannot be adopted. A good marketing strategy can be valuable. Patients and care givers should also be completely informed about the possibilities of the service.

Table 2.2: Current barriers for the adoption of digital health services [34]

2.2.4 Some eHealth projects

In this section two eCare projects are described. They had great influence on the making of the methodology, which will be handled in the next chapter.

Telemonitoring for patients with chronic heart failure

Patients who suffer from chronic heart failure (CHF), their heart is to weak to pump the normal amount of blood. This low oxygen supply is compensated by a higher heart rate, vascular stenosis, thickening the myocardial muscle or an increase in blood volume. The disease is featured by a high mortality and low quality of life [35].
In Belgium about 1 to 2 percent of the budget for health care goes to the care for CHF patients [36]. About two third of that is caused by the cost of hospitalizations. It is the leading cause of hospitalizations for people above 65 years. This number will even grow because of the aging population. It is estimated that there are over 200 000 chronic heart failure patients in Belgium, especially elderly people. These numbers show that focusing on prevention and reducing the hospitalization for CHF patients has great potential for reducing the costs and improving the quality of life. Various projects are therefore started in different countries in order to reduce the (re)hospitalization rate and the mortality rate due to the disease. The service that will be described here is mainly based on two projects. The first one is Dutch and is called e-Cardiocare. The other one is a Belgian project on initiative of the Hasselt heart center and has been executed in seven different hospitals [37]. It is a telemonitoring service: CHF patients have a scale, hearth rhythm monitor and a blood pressure monitor at home. They measure their weight, heart rhythm and blood pressure every day. This because a significant increase in a patient's weight during a short period could for example be a result of fluid retention which may be caused by a decompensation in the case of a heart attack. The measurements are sent to the care giver. That can be the general practitioner or a specialized heart failure nurse. Most projects give their preference to the latter. The results are interpreted by the heart failure nurse and when there is an alarm (the measurements are above or under certain predetermined bounds) measures are taken. If the condition of the patient seems very severe, counteractive measures can be executed as early as possible. The nurse can ask the cardiologist for feedback. This daily monitoring aims to reduce the amount of rehospitalizations, which of course increases the QOL of the patient.

A systematic review of services as described here reports that the most commonly measured and reported outcomes were mortality and heart failure rehospitalization [38]. Limitations are found in the fact that there is a lack of high-quality evidence of these remote patient monitoring interventions. On the other hand, the results of the overview demonstrate that telemonitoring had beneficial effects on clinical outcomes of heart failure including a reduction in mortality, heart failure hospitalization, all-cause hospitalization and an improvement in QOL.

Teleconsultations for Chronic Obstructive Pulmonary Disease

A team of the Odense University Hospital (OUH) and Medisat has implemented a telemedicine service called *the patient briefcase*. It is a treatment method for patients suffering from COPD (Chronic Obstructive Pulmonary Disease) in their own homes, as opposed to hospital admission. The goal is to provide a solution for COPD patients that offers safety and comfort. Patient empowerment and an improved competence to taking action are other goals of this project. When COPD patients get an upsurge, they are often hospitalized. They are discharged after on average eight days. That means a patient stays for a quite long period in the hospital. It is this long period that the patient briefcase avoids by already discharging the patient approximately 36 hours after the hospitalization. In that way he can recover in its familiar environment. Within 24 hours after discharge, a technician installs all the necessary equipment at the patient's home. This patient briefcase consists of a built-in computer including a web camera, microphone and measurement equipment. From then teleconsultations take place every day for one week (via Internet connection, wireless network or satellite). This means that a total of seven teleconsultations per patient take place. During the teleconsultation from home, the patient measures pulse, saturation and spirometry with guidance. He is in contact with a specialized COPD nurse, who is handling the treatment from her base at the hospital. This nurse collects the patient measurements electronically on a screen at the hospital. Meanwhile the patient could take readings of the measurements on the telemedicine equipment. The patient receives advice and the treatment is further discussed [39]. Figure 2.10 depicts a teleconsultation between the patient at home (left) and a nurse at the hospital (right). The patient is busy with the pulse-oximetry measurement, while the nurse has three screens in front of her: one with the patient's measurements (data), one with the patient's health record and at her right side she sees the patients live.

Figure 2.10: Illustration of a teleconsultation via the patient briefcase [39]

2.2.5 eHealth situation in Belgium

Also in Belgium eHealth is rising. But as in many of the other OECD countries, very little adoption is witnessed. Agoria, the federation of companies of the Belgian technological Industry, sketched the current eHealth situation in Belgium [40]. The nine barriers they encountered are similar to the ones described earlier in this chapter:

- Need for a structure to reimburse equipment and services
- Lack of legal and deontological clarity
- Need of an integration between the processes
- Lack of business models
- No integrated end-to-end solutions
- Acceptance of care givers and patients
- Lack of education for the users
- No IT-standards
- Too little investments in networks of the new generation

To cope with these barriers, Agoria formulated four demands that are necessary for the development of eHealth in Belgium: (1) a study needs to be performed in which the financial en economical impact of eHealth on the budget for healthcare is analyzed, (2) a framework needs to be created for the reimbursements on different levels, in particular for chronic disease, (3) legal and deontologial clarity concerning the informed consent and reimbursements and (4) the creation of a steering committee consisting of the main actors in (e)Healthcare. These recommendations come together with investments in education, network infrastructure and integration & use of international standards [40].
In the remaining of this subsection some Belgian eHealth initiatives are discussed.

eHealth platform

The *e-Health platform* is a public institution that is the center of eHealth in Belgium. Its mission is to facilitate the access to medical information in a good organized electronic service without harming the privacy of the patients nor the privacy of the care provider. Everyone who is active in the healthcare sector can use this integrated service that cannot only help with simplifying the administration of the process, but it can also improve the quality of the treatment and the safety of the patient.
Ten assignments are created to achieve the goals that are drafted by the legislator. The main

cause of these objectives is to create an ergonomic and accessible platform to all members of the health care community, also focusing on supporting all existing initiatives. Creating a unified vision and strategy, led by efficiency and effectiveness, is leading the way to the cooperation between all health care institutions [41].

Vitalink

Vitalink is a Flemish governmental online platform to stimulate the collaboration between care givers and patients without harming their confidentiality. The patients choose whether, where and when someone can get access to the information. The information available on Vitalink: summaries of the medical files of the patients, details and information about vaccinations, details and information about medication and studies of the population.
The online platform is fastly growing: over six million data were available on Vitalink in April 2017. The intention is that Vitalink is integrated in existing eHealth applications so that the doctors should only open one application to find all information [42].

Actieplan eGezondheid

eGezondheid is also an online platform, with information about a plan, constructed by the federal government, to create an integrated eHealth platform in Belgium. Trough twenty action points they want to achieve an online eHealth landscape where information about every patient is available to care providers and patients themselves as of 2019.
For example action point nineteen concerns mHealth. Its purpose is to make eHealth services mobile accessible. This should, among other things, stimulate and facilitate the cooperation between all health care institutions.
Every general practitioner will keep an electronic medical file about their patients and every other care giver will keep a general patient file. Patients are capable of reviewing and completing their files with valuable data and information is given to them to understand their own file [43].

Digitaal Onco Platform (DOP)

Digital Onco Platform (DOP) is a support for patients with cancer and their environment through telecounseling and telemonitoring. The goals of the DOP project are the development, implementation and the evaluation of a digital oncological platform for patients with cancer, treated in the oncological center of the university hospital of Ghent. DOP was developed as a pilot test for patients with a metastatic renal cell carcinoma with a systematic treatment and

for patients with a bone tumor or sarcoma.
The platform was developed in a way that a roll out to other tumor types and other centers goes smoothly in the future. Therefore there was opted to integrate DOP in the existing collaborative care platform (CoZo).
The goal of this new eHealth service is to offer customized education to patients, timely monitoring of clinical parameters and toxicities as a result of antitumour treatment, timely detection of psychological risk factors and improve the communication between care givers mutually and patients. In that way there is aimed for an increase in self management, participation, empowerment, QOL, satisfaction and compliance [44], [45].

2.3 Cost-effectiveness analysis (CEA)

Cost-effectiveness is a term closely related to HTA (Health Technology Assessment). A HTA seeks to inform health policy makers by using the best scientific evidence on the medical, social, economic and ethical implications of investments in health care [46]. Assessment includes:

- synthesizing health research findings about the effectiveness of different health interventions;
- evaluating the economic implications and analyzing cost and cost-effectiveness;
- appraising social and ethical implications of the diffusion and use of health technologies as well as their organizational implications;
- HTA process helps identify best practices in health care, thereby enhancing safety, improving quality and saving costs.

In this thesis it is of course not the aim to determine if a health intervention is safe or if there is any scientific evidence on the effects of the treatment. Although, it is the aim to compare both costs and effects of a health intervention. This section handles about cost-effectiveness analysis of a (new) medical treatment, which is a part of a HTA. In this analysis costs and effects of two or more health treatments are compared. It tries to determine whether or not a medical treatment should be reimbursed. This section is based on an introducing book concerning health economics [47].

2.3.1 Cost-effectiveness

The goal of a health care policy is to produce health and gain health (not in the first place to save money). A healthy population increases production and consumption and finally increases welfare. The government therefore obviously wants a healthy population. For some treatments they foresee reimbursements for the patient. But how do they decide if a (new) treatment should be reimbursed or not? A possible measure for this is the cost-effectiveness of a certain medical intervention.

A health economic evaluation is a comparing analysis of two or more interventions in function of costs and effects. This evaluation can be done through a cost-effective analysis (CEA), which compares the additional cost with the effects in order to determine if a certain treatment is cost-effective or not. Cost is measured in monetary units, while effects (which are hopefully positive and can thus be called benefits) are expressed in other units. These benefits do not have to be expressed in monetary terms as is the case in a cost-benefit analysis. The unit in which the benefits are expressed is called 'QALY': Quality Adjusted Life Year.

To determine whether or not an intervention is cost-effective, the incremental cost-effectiveness ratio (ICER) is calculated in the following way:

step 1: calculation of the difference in costs between 'new' and 'current' (C_N-C_C)

step 2: calculation of the difference in efficacy between 'new' and 'current' (E_N-E_C)

step 3: calculation of the incremental cost-effectiveness ratio (ICER) using equation 2.1

$$ICER = \frac{C_\mathrm{N} - C_\mathrm{C}}{E_\mathrm{N} - E_\mathrm{C}} \tag{2.1}$$

This ratio is now compared to the limit of affordability, which is the societal willingness to pay. But which value has this willingness to pay? In other words: how much does the society want to pay to gain one unit of health for the patient?

Figure 2.11 illustrates the situation where a current treatment is compared to a new treatment. The vertical axis represents the total cost of the treatment, while the horizontal axis represents the health effect expressed in QALYs. On the figure there is another coordinate system that can be found. The current treatment method is located in the origin of this coordinate system (the white circle). Every point at the right of this origin represents a situation where there is a health gain for the patient in comparison with the current treatment. Every point below the origin represents a less expensive treatment.

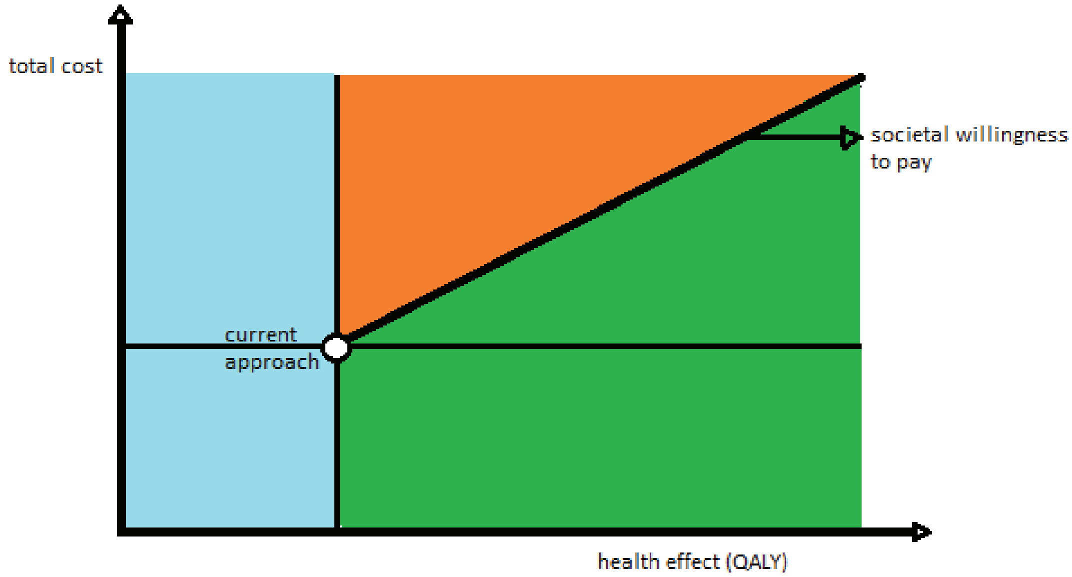


Figure 2.11: New treatment versus current treatment in two dimensions: costs and health effects

The blue colored zone is not discussed here because it represents the situations in which the patients QOL decreases in comparison with the current situation. The green rectangle represents obviously positive situations: a better quality of life at a lower total cost. The green triangle represents the situations in which there is health gain at a greater cost. Situations within the green colored zone are cost-effective. The black diagonal represents the societal willingness to pay. A lot has been written about the value of this limit. Published data shows that 30 000 € - 50 000 € per QALY could be used as the limit to be cost-effective in Belgium, but it varies from country to country. The World Health Organization on the other hand formulated it as one to three times GDP per capita. According to the OECD the GDP per capita in Belgium was 46 800 $ in 2016 [48]. With an exchange rate of 0,9162 this results in 42 878 € (rounded). If further in this dissertation the ICER is calculated it will be compared with the latter.

2.3.2 Quality Adjusted Life Years

Health care needs to produce health in the most productive way, the most efficient way. If a new intervention is more expensive than the current situation, then this net cost needs to be weighted compared to the health effects.

To find the societal willingness to pay one should express gain health in a certain unit, as been said before. In existing health economics evaluations there appear different indicators for health gain: number of symptom-free days, quality adjusted life years, amount of years without complications etc. All this is tried to comprise in one unit, a unit of health. A widely used unit for this is the QALY. The principle of QALY is that one combines the quality and the quantity of life in one concept, which is illustrated in figure 2.12.

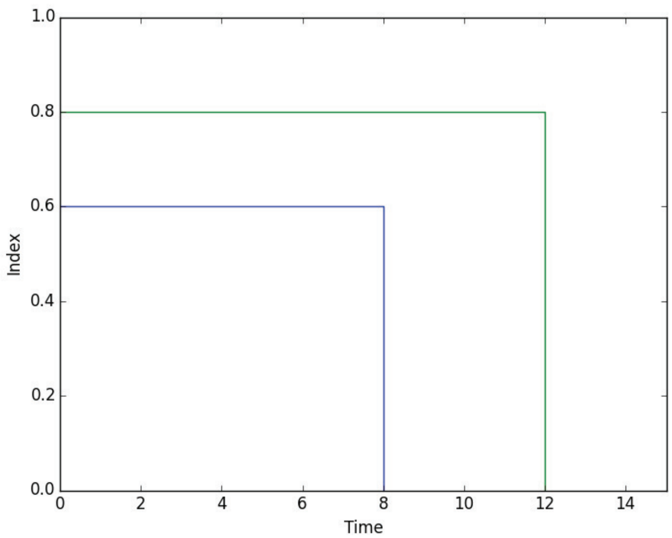


Figure 2.12: Schematic representation of QALY

The y-axis represents the index, which has a value between 0 and 1. One equals a perfect health condition while zero equals dead. The index is a measure for the quality of life of a patient. It is described as the utility of the health condition. This y-axis thus represents the quality. The x-axis represents the quantity, which is expressed in life years. One can see that two different curves are plotted in the figure. Suppose that a patient suffering from a certain disease lived for eight years from the moment of the diagnosis using the current treatment method. It is estimated that during this eight years, his quality of life equals a value of 0,6. This value can be seen as a certain weight. To express this in terms of QALYs this utility should be multiplied with the number of years lived. Therefore the quality adjusted life years of the patient equals 4,8 (0,6 * 8). This is the situation represented by the blue curve. Note that this value equals the surface below the curve. Suppose now that there is a new treatment method available that both increases the quality of life and the remaining life years of the patient. This is represented by the green curve. The QALY now equals 9,6 (0,8 * 12). The gain in QALYs equals the difference between both surfaces below the curves. The gain is therefore 4,8 QALYs (9,6 - 4,8).

2.3.3 How to measure the index

How can this index be measured? There are different methods available for this. One could use the visual analogue scale (VAS), the standard gamble (SG) or perform a time trade off (TTO)

[49]. A generic method that will be used further in this master thesis is developed by EuroQol and is called the EQ-5D method. In this method five questions are asked to the patient regarding its mobility, self-care, usual activities, pain/discomfort and anxiety/depression:

Mobility
1: I have no problems walking about
2: I have some problems in walking about
3: I am confirmed to bed
Self-care
1: I have no problems with self-care
2: I have some problems washing or dressing myself
3: I am unable to wash or dress myself
Usual activities (e.g work, study, housework, family activities)
1: I have no problems with performing my usual activities
2: I have some problems with performing my usual activities
3: I am unable to perform my usual activities
Pain/discomfort
1: I have no pain or discomfort
2: I have moderate pain or discomfort
3: I have extreme pain or discomfort
Anxiety/depression
1: I am not anxious or depressed
2: I am moderately anxious or depressed
3: I am extremely anxious or depressed

Each answer on a question represents a value of 1, 2 or 3. Based on the answers on the five questions a profile is composed. There are $3^5 = 243$ different profiles. Every profile represents an original value for the utility. The different profiles and their utility are listed in appendix A.1. A patient that has for example no problem with walking about, some problems with washing himself, some problems with performing the usual activities, extreme pain and moderately anxious has a profile of 12232, which results in a utility of 0,2073. Note that in the table there are also negative values. This in fact means that dead is preferred.

2.4 Adoption theory

A new eCare or mHealth service targets a particular group of users. In the majority of the cases this target group consists of patients suffering from a particular disease. This means that customers are segmented based on their disease/condition. This is however not always the case. For example with eConsultations a patient has a video call with his general practitioner. In that case the majority of the Belgian population is in fact the customer target. Based on age, acceptance of the (new) technology, specific pathologies, the characteristics of the service and other requirements potential user segments can be targeted.

Not all of the customer targets are achieved in practice and of course it takes a certain amount of time before new services are used by the target population. To assess the real number of customers adoption theory can be applied.
Adopters of an innovative idea (eHealth service) can be categorized in five different groups according to Rogers: innovators, early adopters, early majority, late majority and laggards [50]. Over different years, the cumulative percentage of these different groups (the adopters) forms an S-shaped curve. This curve can be modeled with different distributions. One that is often used in a forecasting model is the Gompertz curve. Special with the Gompertz curve is that it is assymetric: the adoption is slowing down as it progresses. It assumes that the period in which there is an increasing growth of adoption is shorter than the period in which this growth is decreasing [51]. This curve is usually used for consumer adoptions in techno-economical research [52]. It is modeled using equation 2.2.

$$S = m * e^{-e^{-b(t-a)}} \tag{2.2}$$

This function has three parameters: m, b and a. It is modeled in function of t, which represents the time (in years).

- *m: maximum market potential*
  This represents the maximum percentage of all possible customers that the innovation can maximally have.
- *b: rate of adoption*
  This parameter defines the velocity of the adoption, in other words the slope of the adoption of curve.
- *a: inflection point*
  This parameter represents the year in which the adoption changes from a progressive

increase to a degressive increase. At this point saturation starts and the adoption goes slower.

These parameters need to be estimated carefully in order to estimate the market potential. Figure 2.13 shows a possible adoption curve with parameters m = 0.85, b = 0.6, a = 3. One can recognize the typical S-shape of this cumulative curve.

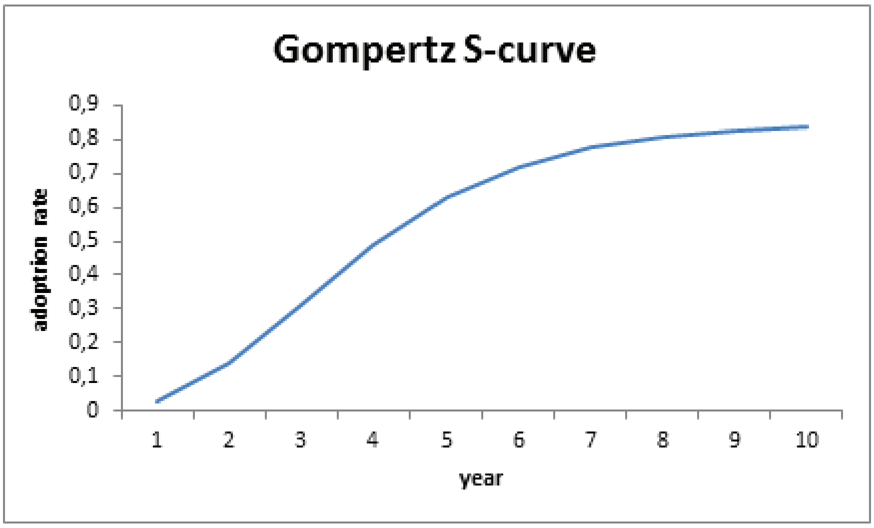


Figure 2.13: S-shaped adoption estimation

2.5 Conclusion

The literature study made it very clear what the motivation is behind this master thesis. An aging population and many chronic diseases increase the healthcare costs, which results in an ever-increasing part of the GDP per capita spending to healthcare. Therefore governments focus too much on saving costs instead of assuring high quality care [47]. ICT-supported services, called eHealth services, offer a solution to cope with these high expenditures and deliver high quality care. Despite the large potential adoption of these services remains difficult. The main barriers for the adoption of digital health services are a complex value network for eHealth services, the added value is unclear, technological barriers, a lack of financial support/ an unclear business model, current perceptions of the involved actors on the healthcare system affects willingness to pay and there are privacy concerns & legal issues.
Off all these existing barriers, the unclear business model and a lack of financial support play a major role in the low adoption. Every actor wants to know '*What's in it for me?*' before accepting the new service. To identify a possible negative impact on the business model of one

of the actors, a pre-development validation methodology will be composed. The next chapter handles this methodology.

Chapter 3

Methodology

3.1 Introduction

3.1.1 Use of the methodology

The methodology that will be defined in the next section is a *pre-development validation method* for a new digital health service. This means that it can be used to evaluate an innovative eHealth service. The service does not exist yet or no pilot project has yet been executed. The methodology/web tool will be used to assess if the innovation has potential to be successful and get adopted. As the literature study showed innovating is hard, and especially in the complex healthcare sector where there are many actors with different interests. The tool can of course not assess e.g. if the planned marketing strategy will be sufficient to reach the market target. It is designed to assess if there is a viable business case.

Most services focus on increasing the quality of life of the patient. Often (one of) the care givers e.g. the general practitioner will treat less patients because of their increased health and witness a decrease in his income. This results in an actor (the general practitioner) who does not want to participate in the innovation. Without his participation the innovation cannot succeed and he will block adoption. In other words: there is no viable business case.

The input of the tool consists of a lot of data concerning the current care and the new eHealth service, while the output of the tool is focused on the detection of gaps in the business models of the actors and suggestions for reallocations of benefits/costs for the actors. The ultimate goal is to suggest whether or not the innovation has potential and which changes can be made in the concept before introducing the service to the market. Therefore this pre-development validation tool is primarily aimed for the innovator, the person with the idea for a new digital health service. Probably this will be the eCare provider.

It is important that the user of the tool knows a lot about the new eHealth service, but also about the current situation (that he wants to change with the innovation). Before the tool is used, the user should possess sufficient knowledge about the different processes (costs, time spendings etc.) that the targeted patients go through. Garbage in will result in garbage out.

Scope definition

The knowledge obtained during the literature study has been used to define a methodology in which two services (the current service and the new eCare or mHealth service) are compared in terms of costs and effects. The first of these two is the current service (subscript c), also formulated as current treatment, current situation or current care further in this chapter. The other service is the new eCare or mHealth service (subscript n), also formulated as new treatment, new situation or eHealth/eCare/mHealth service further in this chapter. If the formulation eHealth service is used, this can either refer to an eCare service or a mHealth service.

The methodology is based on the Belgian healthcare system. This among other things means a fee for service payment system and cost sharing between patients and his insurer.

3.1.2 10-step plan

The methodology is composed of ten different steps, which are explained in detail in the next section. To not get lost in the variables and equations of the different steps, each step is concisely introduced in this subsection.

The 10-step plan is schematically displayed in figure 3.1. Every blue box represents a step of which the main goal is to gather input data about the healthcare services. The purple boxes denote steps in which the tool converts the input data into certain output.

In a first simple step there is asked to identify all the actors who play a role in the current and/or new service. As there is always a patient (both current and new service) and always an eCare provider (only in new service) these actors are standardly included. Other actors might be chosen from an available list or can be given in manually. There are three categories of actors: *the receivers* (GP, specialist, nurse etc.), *the eCare provider* and *the other actors*.

Step two concerns the characterization of the market. Information is needed about the amount of patients targeted with the services and how this number evolves over the time horizon (default value of ten years). To estimate the actual customers that will use the eHealth

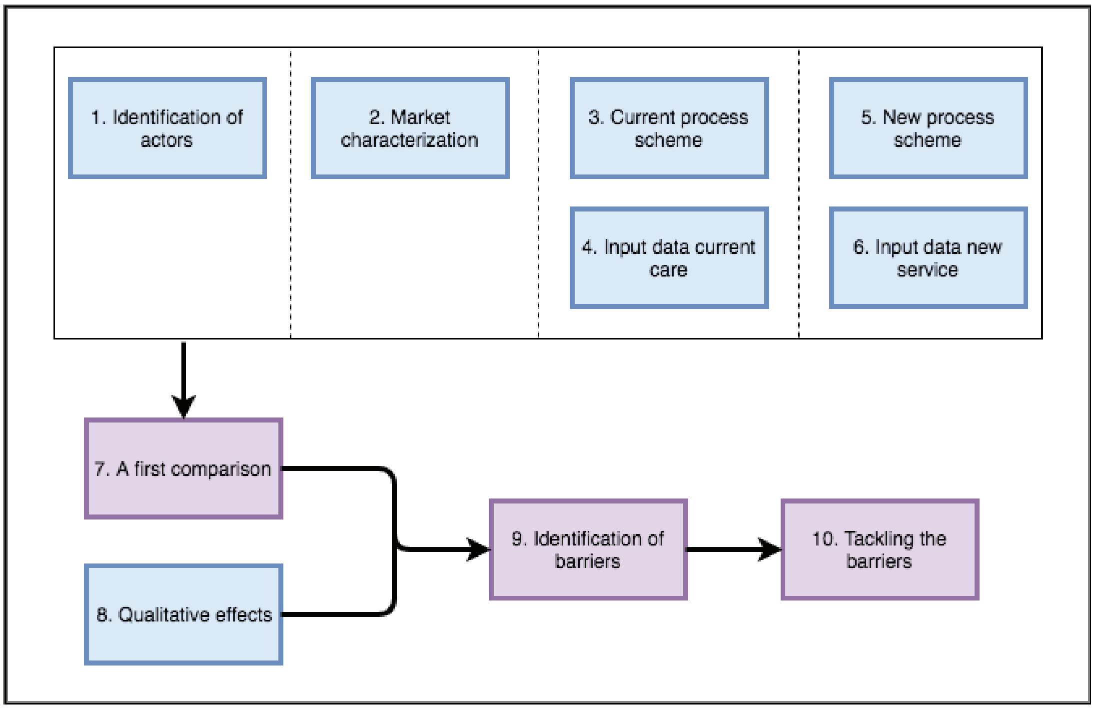


Figure 3.1: Schematic overview of the ten-step plan

service, adoption is applied. This adoption results in the fact that in the new situation exists of patients using the current care and of patients using the eHealth service.

A third step consists of sketching the flow of the current situation, by creating a process scheme that represents the possible processes a patient can go through (e.g. frequent planned control visit to general practitioner).

The fourth step is a completion of the previous one. All the monetary transactions between actors and their time investment are the input values of this step (for the current care). This is mainly based on the process scheme drawn up in the previous step.

Step five and six are similar to step three and four, only now it concerns the new eHealth service. This service results in a new actor: the eCare provider. The costs that the latter incurs for developing and maintaining the service are estimated.

A first indication of the potential of the new service is provided in step seven. All the information obtained in the first six steps is processed and visualized. For every actor two graphs are displayed: one for the profit/loss and one for the time investment (both over time). On each graph a curve representing the current situation and a curve representing the new situation can be found. This will show for every actor which service he will prefer in terms of time consumption and which service he will prefer in terms of monetary profit/loss. This step is called *a first comparison* because there cannot be concluded yet which service the actors will prefer globally as time and money are expressed in different units.

To compare both services globally the qualitative effects should first be identified. This is handled in step eight. Here the qualitative effects of the new service (better/worse than the current care) are estimated for all the actors. A second part of this step consists of calculating the indexes which will be used further to determine the ICER. The value of this ratio will then determine if the eHealth service is cost-effective or not.

To identify potential barriers money, time and the qualitative effects of the service need to be expressed in the same unit so that they all can be compared. This is done in step nine, which processes the monetary value of the time consumption (input step four and six) and the monetary value of the qualitative effects (input step eight). Now the two graphs for every actor (time, money) from step seven can be combined into one. On top of this, the monetary value of the qualitative effects (step 8), which can either be positive or negative, is added. This results for every actor in one total profit/loss of the new service in comparison with the current one. This value, called *delta* and expressed in € per year, is the average yearly difference over the time horizon. If delta has a negative value for an actor this indicates that this actor prefers the current care and will probably block the adoption of the eHealth service: a barrier is identified.

In the tenth and last step the previously identified barriers are tackled through reallocations of the costs and benefits.

3.2 Description of the methodology

3.2.1 Identification of the actors

For each actor involved in the service delivery, all required costs and effects should be identified. To be able to do so, these actors/stakeholders will first need to be identified. Therefore, the first step of the methodology is the identification of the different actors who have a role in the care process.

All actors should be selected as input in this step, which means both those that appear in the current and in the new situation. A list of common actors is available from which one can select those that are applicable for the services. The user can also add an actor manually if a desired actor cannot be found in the list.

The original reason why healthcare is necessary is because there is a patient who's suffering from some disease and needs treatment in order to get better. Thus even if the new service is not in the first place focused the patient, he will always be a part of it. Therefore, the patient will always be one of the actors. As this methodology applies on eHealth services, the eCare provider will also always be one of the actors. Together with the patient he is automatically selected as one of the actors.

The government has an important role (primarily as guard) within the national healthcare system. Not only is it important to stimulate the positive external influences, to block the negative ones and to value public goods, it is also necessary to maintain good quality and easy access to healthcare, to avert an increase in the prices and avoid that health insurance companies would refuse high risk persons. The government has also the important task to determine which treatments should be reimbursed. The government should however not be considered as an actor for the user of the tool and is thus not on the list of actors. The government is in fact represented via the insurer of the patient. The actor *Insurance* represents this private insurer of the patient.

The care givers are also important actors in the health care landscape. The general practitioner (GP), specialists, physiotherapists or other persons who's jobs are to provide care to patients form a special category of actors in the methodology. They will be labeled as *receivers*. Because they earn money by giving care to patients the reasoning in further parts of this methodology will be different for these actors from other actors (e.g. the insurers). The reason for this will be clarified in further steps. The actors from the category receivers on the available list are: GP, specialist, physiotherapist, psychologist and nurse. For every actor that is added manually by the user, he can choose to label this actor as a receiver.

Other actors that are part of the list are insurer, hospital, nurse and family caregiver. The subscript a will further in this dissertation be used to denote actor a.

3.2.2 Market characterization

In this second step the market will be characterized. As explained in chapter 2 certain customers are targeted with the eHealth service. Based on age, acceptance of the new technology, specific pathologies, specific characteristics of the service and maybe other requirements user segments are targeted from the Belgian population. When a new service is available it will probably take some time before the majority of the target population really uses it. To obtain realistic values for the number of users of the service, the theory of adoption will be applied. In the first part of this step the adoption parameters will be determined. In a second part there will be asked for numerical input values concerning the targeted segment. All the information required in this step is finally combined to determine the number of patients using the current service and the number of patients using the new digital service. The number of patients using the current service in the current situation will of course be equal to the total number of users. In the new situation however, the total number of patients who use a service will be a combination of patients using the current care and patients using the new eHealth service. Due to the adoption characteristics the fraction of patients using the new service will be low in the beginning and grow towards the end of the time horizon.

Adoption parameters

Adoption will be implemented in order to give the provider of the new service insights concerning the market potential. A possible way to model this is using the S-shaped adoption curve

(Gompertz), as described in chapter 2. The time horizon can be chosen by the user of the tool, but its default is set to ten years. The curve has three main parameters that the user can choose: maximum adoption percentage (m), inflection point a) and the rate of adoption (b). Default values are m = 0,85; a = 3,5; b = 0,55.

What is the maximum adoption percentage? $= m$
When is the inflection point? $= a$
What is the rate of adoption? $= b$

Number of patients and evolution of patients

Further in this methodology the costs for the different actors will be compared. To have an idea about the total cost there has to be known how much patients could potentially benefit from the new service. A healthcare service could have the goal to treat patients with a particular disease, but this is not necessarily always the case. With preventive services completely healthy customers can be targeted. These (healthy) customers are although also called patients. There will thus need to be asked how much patients there are in Belgium suffering the particular disease, or, more general, how much patients patients are there targeted initially. Or in the case of a disease treatment, how much patients there are known to have the disease. For example with COPD and diabetes, it is estimated that there are a lot more patients suffering from these diseases than there is known [53].

Apart from the current number of patients, the evolution of patients suffering from the disease needs to be expressed. This is because the impact on the costs of the new eCare service will be estimated over the coming years and probably the number of patients targeted will evolve over time. Every year a fraction of the patients (potential users of the eHealth service) will die. On the other hand, every year there will also be new patients. This means that to obtain the evolution in number of patients per year, the mortality rate and the number of new patients needs to be known. In most cases the mortality rate is known as well as the (estimated) total number of patients in the future years.

To obtain this information three questions are formulated.

How many patients are currently targeted with the new service? $= TotalPatients_0$

What is the average mortality rate (yearly) for the considered population? $= MortalityRate$

How is the number of patients growing in percentage per year (to give in 5%, type 0,05)? One has to take into account that a fraction will die due to the disease (cfr. mortality rate) and of course also to other things. = PatientGrowth

For reasons that will be explained in step ten there is also asked a fourth question concerning the remaining life years the average patient has left.

How many life years has the average patient left? = LifeYears

With this information the total patients per year (subscript i) can be calculated using formula 3.1. Together with the adoption parameters this number is now used in order to estimate the number of patients that will use the new service in year i (formula 3.2). The number of patients using the current service can then easily be obtained using formula 3.3.

$$TotalPatients_i = TotalPatients_0(1 + PatientGrowth) \tag{3.1}$$

$$Patients_{in} = TotalPatients_i * m * e^{-e^{-b(i-a)}} \tag{3.2}$$

$$Patients_{ic} = TotalPatients_i - Patients_{in} \tag{3.3}$$

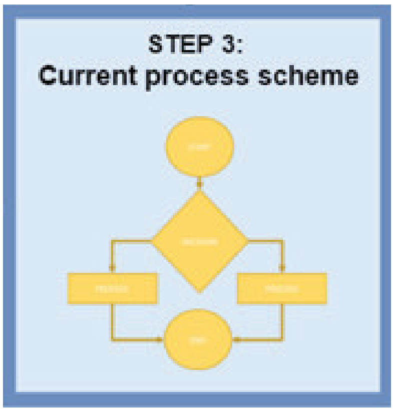
Apart from these numbers, the number of new patients for every situation is also of interest. This number needs to be known to calculate the total one-time costs for example, which occur when a new patient starts using the service. The total number of new patients can simply be calculated using formula 3.4. To estimate the part of these new patients who will use the new service, adoption is applied again. It is assumed that for the new patients the same fraction will use the new service as with the 'old' patients. Formula 3.5 and 3.6 are used to calculate the total number of new patients in year i in the new situation and total number of new patients in year i using the current situation respectively.

$$TotalNewPatients_i = TotalPatients_{i-1}(PatientGrowth + MortalityRate) \tag{3.4}$$

$$NewPatients_{in} = TotalNewPatients_i * m * e^{-e^{-b(i-a)}} \tag{3.5}$$

$$NewPatients_{ic} = TotalNewPatients_i - NewPatients_{in} \tag{3.6}$$

3.2.3 Current process scheme



In this third step the current situation is outlined on the basis of a process scheme. This gives a visual overview of how the current care is organized. A process scheme exists of different processes that need to be identified. A process can be a visit to the GP, a monitoring period in the hospital, certain administrative tasks etc. This is a very important step as the way of asking for the input data (see next step) highly depends on this process scheme.

The objects to make the process scheme with are kept limited to keep it as simple as possible. A simplistic model is illustrated in figure 3.2. The process scheme always begins in 'start' and ends in 'end'. The lines in the process scheme represent the flow of patients. Between these buttons there are two other buttons that can be used. The blue parallelogram represents a question. After this symbol a bifurcation is always made. The question is often formulated as a yes-no question. Depending on the answer the patient follows to the next process.

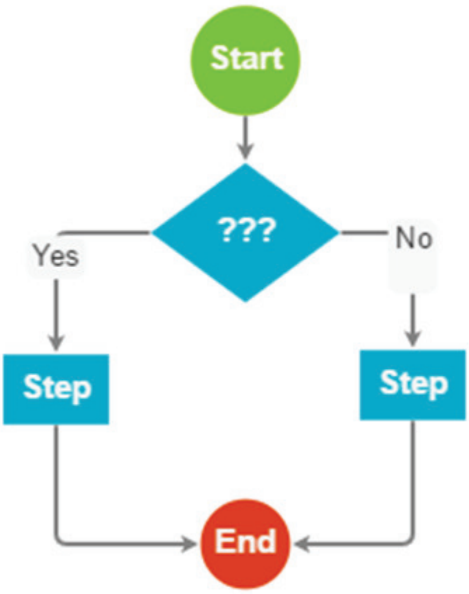
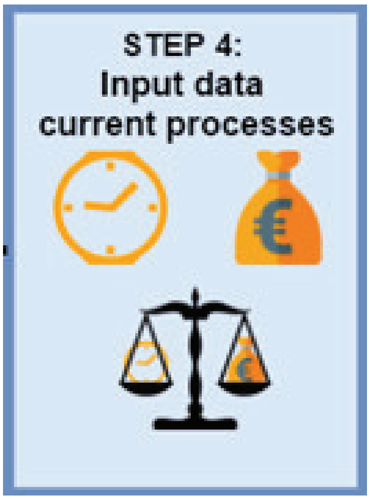


Figure 3.2: Illustration of a simplistic process scheme

3.2.4 Input data current situation



In this step data input is asked concerning the time and money of the processes that make part of the current care. In the process scheme different processes are identified with the blue rectangles. Processes that are part of the current care are denoted with the subscript p. Information is needed about the time investment, monetary flow and the frequency. For every time an actor spends to a process there will be asked to assess the monetary value of this time investment. The monetary values are expressed per patient per year. But not all transactions can be expressed per year: some costs are not ongoing but are a one-off transaction. There will also be dealt with these costs in this step.

Input of monetary flow, time and frequency

Every process takes some time for any actor (t_{ap} represents the time needed for actor a to carry out process p). A planned regularly visit to the general practitioner for example takes a certain time for this doctor and for the patient.

There will often also be a flow of money FROM an actor TO another actor regarding this process. So for the 'from-actor' this will be a cost (c_{ap} = cost of process p for actor a), while for the 'to-actor' this flow of money is a receiving (r_{ap} = receiving of process p for actor a). At last there will be asked to give in the frequency of the process (f_p = frequency of process p). In this way the occurrence of the action will be known. The latter is expressed in *times per year*.

Summarized this means that every process appearing in the process scheme of the previous step has three components that need to be given in: time per event, money per event and the frequency per year. The units in which this needs to be done are shown in table 3.1.

	Unit
Money	€
Time	minutes
Frequency	times per year

Table 3.1: Units of the input data of the processes

One should be careful with the input data of the monetary transactions. A simple and frequently used process is an unplanned visit to the GP because the patient does not feel well. At the end of the consultation the general practitioner asks a certain sum (e.g. 25 euro) to the patient. The patient pays this sum and goes home. Afterwards, his insurer will reimburse the greatest part of this sum. The monetary flow of this process is depicted in figure 3.3a. Further in this methodology the total cost of the service will be calculated by taking the sum of all the costs of the processes. For this example the total cost of the process is 25 €. However, if one would give in the costs like in figure 3.3a the total sum of the costs for the actors would be 44 € (25 + 19). The sum of the costs should always be equal to the total cost of the process. Therefore the input of this process should be as displayed in figure 3.3b.

PROCESS: UNPLANNED VISIT TO GP				
Money				
25 €	FROM	Patient	TO	General practitioner
19 €	FROM	Insurer	TO	Patient

(a) wrong

PROCESS: UNPLANNED VISIT TO GP				
Money				
6 €	FROM	Patient	TO	General practitioner
19 €	FROM	Insurer	TO	General practitioner

(b) right

Figure 3.3: Input of monetary transactions

It can be possible that there is a cost for an actor but the receiver is not relevant. Suppose that in the current situation the patient needs to travel daily to the hospital for a treatment. With the new eHealth service he only needs to go once a week to the hospital. This means that in the new situation the patient can save money because he needs to pay less fuel. In this case the fuel consumption is an important cost which cannot be neglected. But the receiver of this cost is irrelevant (e.g. owner of the gas station). To deal with this there is an actor 'sink' available who can only receive payments.

Every process in the process scheme has something to do with the patient. If for example the data is filled in for the process 'planned visit to the GP': this takes 20 minutes for the GP, one hour for the patient (taking traveling time into account), there will be a flow of 19 € from the insurance company of the patient to the doctor and 6 € from the patient to the doctor (patient fee) and this takes place twelve times per year. All these data are thus measured in euro per patient, minutes per patient and times per year per patient. This means that the units in table 3.1 are *per patient*.

When a patient is treated by a nurse in the hospital the nurse gets payed by the hospital. The gross hour wage for a nurse can for example be 30 € per hour. To give this in correctly, one should first of all fill in the time a nurse spends to this process. When this is done one needs to fill in the money flow for this process using equation 3.7. This represents the cost for the payer, while another actor receives this payment (equation 3.8). Of course the a in both formulas cannot represent the same actor.

$$c_{ap} = \frac{grosshourwage}{60} * t_{ap} \tag{3.7}$$

$$r_{ap} = \frac{grosshourwage}{60} * t_{ap} \tag{3.8}$$

If for any reason some payments cannot be given in because of the absence of some process in the process scheme, they can still be manually added. This should be avoided as much as possible but it might come in handy if the user of the tool does not really know to which process he needs to allocate a certain payment.

Are there any costs (= $ExtraCostPP_{ac}$) and receivings (= $ExtraRecPP_{ac}$) per patient that are not given in in one of the processes? [€ per year]

$$ExtraPP_{ac} = ExtraCostPP_{ac} - ExtraRecPP_{ac} \tag{3.9}$$

For every actor the sum of all costs and receivings from the different processes can now be made. Using formula 3.10 the yearly loss per patient in the current situation is calculated. This cost, formulated as *MoneyCost*, is the sum of the monetary loss of all the processes with the extra costs. It is used to calculate the costs for the eCare provider and 'other actors'.

$$MoneyCost_{ac} = \sum_{p} f_p(c_{ap} - r_{ap}) + ExtraPP_{ac} \tag{3.10}$$

Note that often (e.g. for the actor *patient*) the total receivings will be zero because an actor often has only costs and no receivings for using a service.

For the receivers it is more useful to express the money as total receivings (profit) rather than as total cost (loss) because this would be a negative value otherwise. Equation 3.10 is therefore slightly changed for these actors. The total profit per patient per year can be calculated using formula 3.11 (for a = receiver).

$$MoneyRec_{ac} = \sum_{p} f_p(r_{ap} - c_{ap}) - ExtraPP_{ac} \tag{3.11}$$

The same can be done to express the total time an actor spends per patient per year (formula 3.12). This formula is the same for all type of actors (so no distinction between receivers or other actors).

$$Time_{ac} = \sum_{p} f_p t_{ap} \tag{3.12}$$

Monetary value of time

The goal of the methodology is to compare costs, time and effects of the new service with the current way of working. To do this efficiently, these components will have to be expressed in the same unit. This unit will be a monetary value: €. There will be dealt with the qualitative effects in a further step. However, in this step the time of every process (for the current situation) is an input value so the conversion of time into a monetary value can already be handled here. But how does this conversion from time [h] into money [€] work? The question that needs to be answered is:

$$\boxed{\textit{What is the monetary value of one hour for this process?} = s_{ap}}$$

This question should be answered without keeping in mind the actual financial cost of the process. The monetary value of time for actor a for process p is represented by s_{ap}.

For the patient this could also be formulated as: *'How much would you maximally pay to avoid this process for one hour per year with a new service?'*. It therefore is a special way of asking for the willingness to pay of the patient. This might sound contradictory as the patient wants to *pay* a certain price to visit his GP for example. If the patient does not really care that he needs to visit his GP then he can give the monetary value of this time-consuming process a value of zero. On the other hand, if he really dislikes this process the monetary value is greater than zero.

For the receivers a question like *'What is the monetary value of one hour?'* is hard to answer. Suppose that a patient goes to his general practitioner because he does not feel well. The process of the GP examining the patient takes of course time for both GP and patient (e.g. 30 minutes). The patient estimates that he is willing to pay 10 € per hour to avoid having to go to his GP, apart from the real cost that going to the GP involves. But what is the monetary value of examining a patient for one hour for the GP? As for the GP this process forms a part of his receiving, he obviously would not pay to avoid this process. Therefore the time that a GP (and other actors from this category) spends to a certain process should not be converted into a monetary value. This is the main reason why there has been made a distinction between receivers and other actors in step one. How this time investment is taken into account will be handled later.

Thus for every process a table like 3.2 should be filled in.

PROCESS: (name of the process)					
Money					
...	€	from	(actor)	to	(actor)
Time					
...	minutes	for	(actor)		
Monetary value of time					
...	€/hour	for	(actor)		
Frequency					
...	times per year				

Table 3.2: Input data for a process

This method of giving in the data is repeated for every process appearing in the process scheme. All the money that flows from one actor to another in the current situation needs to be filled in in this step.

Input of the one-off costs

The last input of this step concerns the one-off transactions. This cannot be correctly filled in using the explained method because the frequency cannot be expressed in times per year. Actors can have certain one-off costs when using a service. This can be a cost for every new patient, e.g. when the GP needs certain equipment that is specific for every unique patient (this will probably not occur that much). This cost can easily be handled.

Are there any one-off costs per new patient for an actor a (= OneOffCostPP$_{ac}$) and one-off receivings per new patient for an actor a (= OneOffRecPP$_{ac}$)? [€ per new patient]

$$OneOffPP_{ac} = OneOffCostPP_{ac} - OneOffRecPP_{ac} \tag{3.13}$$

On the other hand there are also one-off costs that do not need to be made for *every* every unique patient. There can be a one-time cost for equipment per every additional patient. It can also be that this cost is not incurred per single patient, but per certain amount of patients.
When the GP needs for example a laptop with special software that analyzes certain parameters of a patient who is monitored at home, the cost for this equipment is probably the same for monitoring five patients as for monitoring six patients. But this equipment will probably have a certain limit (concerning the capacity). In this example it might be that the software can handle the monitoring of maximum 50 patients. The one-off cost of monitoring 50 patients is for example 1 000 €, while for 51 patients the GP would need another unit and thus the cost would be 2 000 €. This kind of cost is less straightforward to implement.
If one simply asks after this one-time cost for an actor (e.g. the GP) this cost should be multiplied with the number of GP's (that use this service and so incur this cost). This means that there should be asked for every actor how much there are of them, which is practically very hard.

Another possibility could be to take a general number of patients (e.g. 1000) and ask for the one-time cost per thousand patients. The answer of this question divided by thousand and multiplied with the number of patients using the service would then be this one-time cost. One simplification with this method is that it makes no distinction between the fact that it can be that the cost for thousand patients is for example 20 000 €, while the costs for 50 000 patients is also 20 000 €. A second simplification of this method is that it does not cope with the fact that it can for example be that one GP monitors five patients (while the capacity is 50) and another one three. This one-time cost should then in fact be made twice because both GPs need to make the one-off cost. But this method would only incur a cost of one unit because it only looks at the capacity ($8 < 50$).
To cope with the first simplification of the previous method there will be asked after this capacity.

$$\boxed{\textit{Per how many patients is there an extra one-off transaction?} = capacity_{ac}}$$

$$\boxed{\textit{What is the value of this transaction?} = serviceCost_{ac}}$$

Of course there should be specified who the payer is (pays $serviceCost_{ac}$) and who the receiver is (receives $serviceRec_{ac}$).

The one-off cost for actor a in year i in the current situation can be calculated via equation 3.14.

$$OneOffCost_{aic} = \begin{cases} \left\lceil \dfrac{TotalPatients_i}{capacity_{ac}} - \left\lceil \dfrac{\max\limits_{1 \leq j \leq i-1} (TotalPatients_j)}{capacity_{ac}} \right\rceil \right\rceil * serviceCost_{ac} & \text{if A True} \\ 0 & otherwise \end{cases} \tag{3.14}$$

Where A is *True* if: $TotalPatients_i > \max\limits_{1 \leq j \leq i-1} (TotalPatients_j)$

In the same way the one-off receiving is obtained (equation 3.15).

$$OneOffRec_{aic} = \begin{cases} \left\lceil \dfrac{TotalPatients_i}{capacity_{ac}} - \left\lceil \dfrac{\max\limits_{1 \leq j \leq i-1} (TotalPatients_j)}{capacity_{ac}} \right\rceil \right\rceil * serviceRec_{ac} & \text{if A True} \\ 0 & otherwise \end{cases} \tag{3.15}$$

The one-off transaction for an actor is then defined by substracting the receiving from the cost (equation 3.16).

$$OneOff_{aic} = OneOffCost_{aic} - OneOffRec_{aic} \tag{3.16}$$

The splitting in the formula is necessary because the cost needs to be zero if in any of the previous years payments are done for a greater number of patients than the current year. This can be clarified with a numerical example. Suppose that in year one there are 10 000 patients, in year two 9 850 and in year three 9 950 and that per 100 patients a cost of 500 € is incurred. If this cost would always be made (no matter if A is true or not) the one off costs in year one two and three 3.14 would become:

$$OneOffCost_{a,1,c} = \left\lceil \frac{10000}{100} - \left\lceil \frac{0}{100} \right\rceil \right\rceil * 500 = 100 * 500 = 50000€$$

$$OneOffCost_{a,2,c} = \left\lceil \frac{9850}{100} - \left\lceil \frac{10000}{100} \right\rceil \right\rceil * 500 = (99 - 100) * 500 = -500€$$

$$OneOffCost_{a,3,c} = \left\lceil \frac{9950}{100} - \left\lceil \frac{9850}{100} \right\rceil \right\rceil * 500 = (100 - 99) * 500 = 500€$$

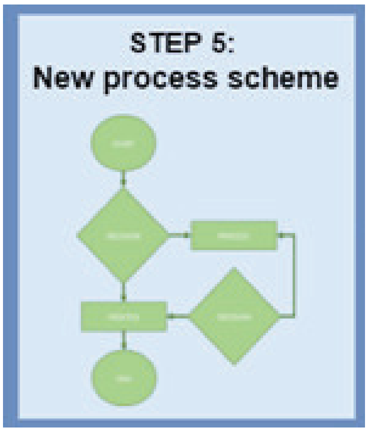
.

Obviously $OneOffCost_{a,2,c}$ and $OneOffCost_{a,3,c}$ should be zero because in year one a one-off cost is paid for a capacity of 10 000 patients.

For a lot of actors the one-off costs and receivings will be zero in the current situation. However, these costs will often occur in the new situation (note that the telemonitoring example here is in fact already an eHealth service).

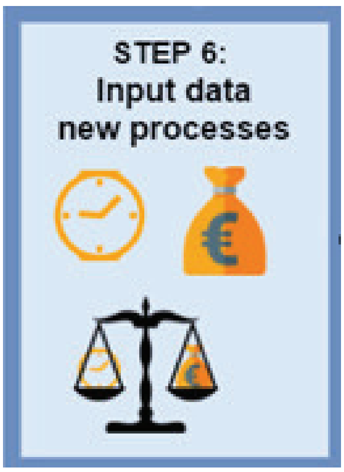
Note that often this cost will be used with a capacity of one, which means that the cost is incurred per additional patient.

3.2.5 New process scheme



This is exactly the same as step three except for the fact that now this is for the new situation, which means the situation with the eCare or mHealth service. Again a process scheme is created. As the current care method would be replaced with the digital health service, the process scheme cannot be identical to the one for the current care. Some new processes will show up, while probably a few processes from the current process scheme will also be present (e.g. unplanned visit to the general practitioner). However, probably the data (e.g. the frequency will be different). The processes of the new process scheme are marked with the letter k.

3.2.6 Input data new situation



This is exactly the same as step four except for the fact that this step concerns the eHealth service. Again the required data for the processes in the previous step are gathered. This means the monetary transactions, time consumption, monetary value of time, extra costs and one-off costs. This step has also an additional part in comparison with step four. As this methodology applies on eCare and mHealth services, there will be a new actor in the new situation: the eCare provider. This eCare provider (highly likely that this will be the user of the tool) will incur certain costs while developing and maintaining the new digital health service. In this step there will be asked to estimate the costs for the service provider.

Input of monetary flow, time and frequency

In the same way the input values of time (t_{ak}), costs (c_{ak}), receivings (r_{ak}) and frequency (f_k) are processed, as are the extra transactions.

Are there any costs (= $ExtraCostPP_{an}$) and receivings (= $ExtraRecPP_{an}$) per patient that are not given in in one of the processes? [€ per year]

$$ExtraPP_{an} = ExtraCostPP_{an} - ExtraRecPP_{an} \tag{3.17}$$

With these input values the yearly profit per patient for *the receivers* are calculated using equation 3.18.

$$MoneyRec_{an} = \sum_k f_k(r_{ak} - c_{ak}) - ExtraPP_{ac} \tag{3.18}$$

For all the other actors the yearly loss per patient are calculated using equation 3.19.

$$MoneyCost_{an} = \sum_k f_k(c_{ak} - r_{ak}) + ExtraPP_{ac} \tag{3.19}$$

The yearly time spent in the new service is calculated using equation 3.20.

$$Time_{an} = \sum_k f_k t_{ak} \tag{3.20}$$

Monetary value of time

Also in this step the monetary value of time makes part of the input. This monetary value will further be used in step nine.

What is the monetary value of one hour for this process? $= s_{ak}$

Input of the one-off costs

The eHealth service can also require one-time transactions. As explained earlier the new situation consists of actors who make use of the current service and the eHealth service.

Are there any one-off costs per new patient for an actor a (= $OneOffCostPP_{an}$) and one-off receivings per patient for an actor a (= $OneOffRecPP_{an}$)? [€ per new patient]

$$OneOffPP_{an} = OneOffCostPP_{an} - OneOffRecPP_{an} \tag{3.21}$$

There are also one-off costs that do not need to be made for every new patient, but have to be made per a certain amount of patients (limited capacity).

Per how many patients is there an extra one-off transaction? = $capacity_{an}$

What is the value of this transaction? = $serviceCost_{an}$

Of course it should be specified who the payer is (pays $serviceCost_{an}$) and who the receiver (receives $serviceRec_{an}$).

$$\begin{aligned} OneOffCost_{ain} = & \left\lceil \frac{Patients_{i,c}}{capacity_{ac}} - \left\lceil \frac{\max\limits_{1 \leq j \leq i-1}(Patients_{jc})}{capacity_{ac}} \right\rceil \right\rceil * serviceCost_{ac} \\ & + \left\lceil \frac{Patients_{i,n}}{capacity_{an}} - \left\lceil \frac{\max\limits_{1 \leq j \leq i-1}(Patients_{jn})}{capacity_{an}} \right\rceil \right\rceil * serviceCost_{an} \end{aligned} \tag{3.22}$$

Where the first term is zero if: $Patients_{ic} < \max\limits_{1 \leq j \leq i-1}(Patients_{jc})$

And the second term is zero if: $Patients_{in} < \max\limits_{1 \leq j \leq i-1}(Patients_{jn})$

$$\begin{aligned} OneOffRec_{ain} = & \left\lceil \frac{Patients_{i,c}}{capacity_{ac}} - \left\lceil \frac{\max\limits_{1 \leq j \leq i-1}(Patients_{jc})}{capacity_{ac}} \right\rceil \right\rceil * serviceRec_{ac} \\ & + \left\lceil \frac{Patients_{i,n}}{capacity_{an}} - \left\lceil \frac{\max\limits_{1 \leq j \leq i-1}(Patients_{jn})}{capacity_{an}} \right\rceil \right\rceil * serviceRec_{an} \end{aligned} \tag{3.23}$$

This one-off gain/loss can then be calculated using equation 3.24.

$$OneOff_{ain} = OneOffCost_{ain} - OneOffRec_{ain} \tag{3.24}$$

These input data are thus processed in an identical way as for the current situation. The only difference is that the last handled one-off cost from above is defined as the combination of the current and new service.

Costs for the eCare provider

In this subsection the costs for the eCare provider are estimated. This is quit hard as there are a lot of different costs for this actor that are probably unknown. There are one-off costs as well as ongoing costs and population dependent costs as well as population independent costs. The typical costs for the eCare provider are described in the previous chapter. Probably these costs are not exactly known yet and will thus need to be estimated. The costs are split into four different categories and will be given in by the user by answering the questions below.

> *What are the population independent one-off costs that are made at the startup? Keep in mind the costs for development and infrastructure e.g. the purchase of servers.*
> *= Startup [€]*

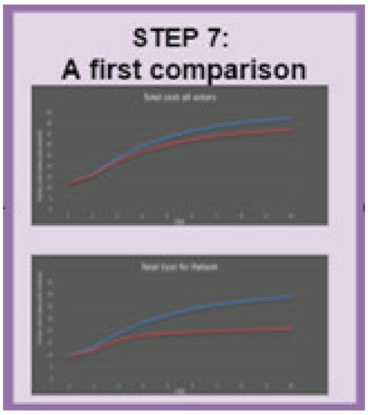
> *What are the yearly population independent costs? Keep in mind costs for offices and employees. = YearlyInd [€/year]*

> *What are the population dependent one-off costs per unique patient? This is the one-off cost for equipment that is specific for one patient. = PopOnce[€/new patient]*

> *What are the population dependent one-off costs? Keep in mind costs for servers and the purchase of equipment. = PopOnceExtra [€/patient]*

> *What are the yearly population dependent costs? Keep in mind costs for maintenance, repair, employees, etc. = YearlyPop [€/patient/year]*

3.2.7 A first comparison



The previous six steps consisted purely of gathering information about the current and new service. In this seventh step a first output is generated. Firstly the input of the previous steps is used to derive formulas for the yearly cost/receiving and the yearly time investment, which is done for both the current and new situation and depends on the type of actor (receiver/eCare provider/other actor). These costs and time investments are displayed on a graph over the complete time horizon for every actor. At last the total cost (sum of costs of all actors) of both services is compared.

For the receivers

The total profit in year i for actor a (a 'receiver') in the current situation ($\mathrm{Rec_{aic}}$) is calculated using formula 3.25. This profit is calculated for ten years.

$$Rec_{a,i,c} = MoneyRec_{ac} * TotalPatients_i - OneOffPP_{ac} * NewPatients_i - OneOff_{aic} \quad (3.25)$$

In the same way the total profit in year i for actor a in the new situation ($\mathrm{Rec_{ain}}$) is calculated using formula 3.26. Note that the receivings are coming both from patients using the current service and patients using the eHealth service.

$$\begin{aligned} Rec_{a,i,n} = {} & MoneyRec_{ac} * Patients_{i,c} + MoneyRec_{an} * Patients_{i,n} \\ & - OneOffPP_{ac} * NewPatients_{i,c} - OneOffPP_{an} * NewPatients_{i,n} - OneOff_{aic} - OneOffain \end{aligned} \quad (3.26)$$

The time investment in both situations is calculated with the same formula for every actor. In the current situation equation 3.27 gives the total time spent in year i for actor a, while equation 3.28 should be used for the new situation.

$$Time_{aic} = Time_{ac} * TotalPatients_i \quad (3.27)$$

$$Time_{ain} = Time_{ac} * Patients_{ic} + Time_{an} * Patients_{in} \quad (3.28)$$

For every actor the model will automatically display two figures: one concerning the money per year and one concerning the time spent.

For the eCare provider

For the eCare provider the cost in the current situation is obviously zero. In the new situation his total cost can be calculated using formula 3.30 in the first year (i = 1) and formula 3.31 for the other years. Apart from the costs that he makes, his total receivings are also calculated (formula 3.32). The separate calculation of total costs and total receivings for this actor is necessary because they will both be used in step 10.

$$Cost_{provider,i,c} = 0 \qquad \forall i \tag{3.29}$$

$$\begin{split} TC_{provider,1,n} = {} & (PopOnce + OneOffCostPP_{provider,n}) * NewPatients_{1,n} + OneOffCost_{provider,1,n} \\ & + YearlyInd + \Big(YearlyPop + ExtraCostPP_{provider,n} + \sum_k f_k c_{provider,k}\Big) * Patients_{1,n} \\ & + PopOnceExtra * \max\Big(Patients_{1,n} - \max_{1 \leq j \leq i-1}(Patients_{jn}), 0\Big) + Startup \end{split} \tag{3.30}$$

$$\begin{split} TC_{provider,i,n} = {} & (PopOnce + OneOffCostPP_{provider,n}) * NewPatients_{i,n} + OneOffCost_{provider,i,n} \\ & + YearlyInd + \Big(YearlyPop + ExtraCostPP_{provider,n} + \sum_k f_k c_{provider,k}\Big) * Patients_{i,n} \\ & + PopOnceExtra * \max\Big(Patients_{in} - \max_{1 \leq j \leq i-1}(Patients_{jn}), 0\Big) \qquad \text{for i } \neq 1 \end{split} \tag{3.31}$$

$$\begin{split} TR_{provider,i,n} = {} & OneOffRecPP_{provider,n} * NewPatients_{i,n} + OneOffRec_{provider,i,n} \\ & + \Big(ExtraRecPP_{provider,n} + \sum_k f_k r_{provider,k}\Big) * Patients_{i,n} \end{split} \tag{3.32}$$

The total loss is then calculated via formula 3.33. Due to the adoption and the costs at the startup it will probably take some time before the eCare provider starts making money. But of course it is his goal to make money from some point in time. This means that $Cost_{provider,i,n}$ will probably have a positive value for low i and negative for other years. When this value is negative the provider makes profit.

$$Cost_{provider,i,n} = TC_{provider,i,n} - TR_{provider,i,n} \tag{3.33}$$

For the other actors

The financial loss for the other actors can be calculated using equations 3.34 and 3.35. When $Cost_{ain}$ or $Cost_{aic}$ has a negative value this means that this actor makes profit.

$$Cost_{a,i,c} = MoneyCost_{ac} * TotalPatients_i + OneOffPP_{ac} * NewPatients_i + OneOff_{aic} \tag{3.34}$$

$$\begin{aligned} Cost_{a,i,n} = {} & MoneyCost_{ac} * Patients_{i,c} + MoneyCost_{an} * Patients_{i,n} \\ & + OneOffPP_{ac} * NewPatients_{i,c} + OneOffPP_{an} * NewPatients_{i,n} + OneOff_{aic} + OneOff_{ain} \end{aligned} \tag{3.35}$$

As illustration a typical progress for the loss for an actor over time (e.g. the patient) is plotted in figure 3.4. In this case the new situation (combination of actors using the current service and actors using the new service) is less expensive for the patient. For low i however this difference is small. The curves move further away from each other as the time increases. The reason for this is adoption: in the first year only about 3 % of the patients uses the new service, while in year ten this is about 80 %. As more and more people use the new service (which is less expensive) over time, the difference between both situations becomes larger.

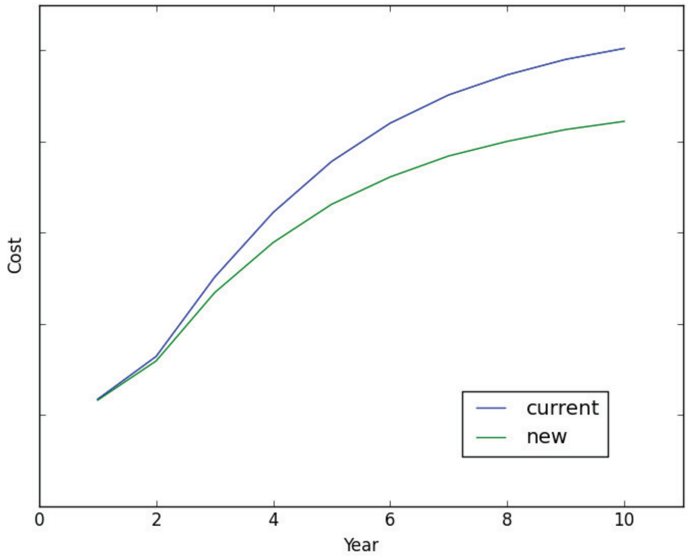


Figure 3.4: Illustration of a first plot of the cost for both situations for a normal actor

Total cost of the service

When a new health service is introduced on the market both the selling price and quality of the service are of great importance. In this subsection the total cost of the new service is compared to the total cost of the current situation. This is without the qualitative effect of the service (quality) and without looking at any differences in time investment. This cost is thus the sum of the costs for all actors. The total cost consists only of real costs, by which is meant that no receivings are included. These costs are calculated using equation 3.36 and 3.37 for the current and new situation respectively.

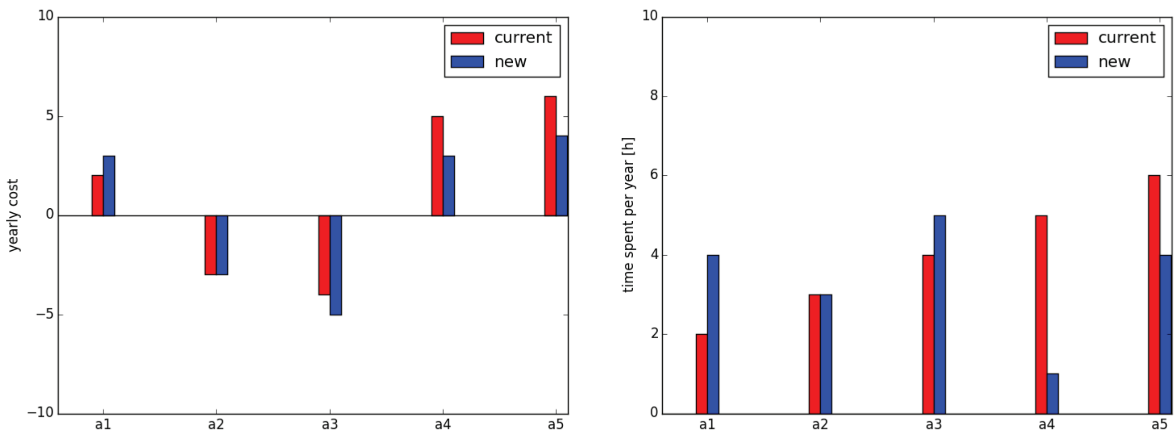
One should be careful for double counting with calculating the total cost of a service. Some actors pay certain costs to the eCare provider to use the eHealth service. The eCare provider himself has of course also all kind of costs to develop the service. But these costs are eventually covered by the actors who pay for using the service. So including both the costs of the eCare provider and the payments of the other actors to the eCare provider would give a wrong view of the total cost. Therefore the costs for the eCare provider are not included in formula 3.37.

$$TotalCost_{ic} = \sum_a \bigg(\Big(\sum_p f_p c_{ap} + ExtraCostPP_{ac} \Big) TotalPatients_i + OneOffCost_{aic} + OneOffCostPP_{ac} * TotalNewPatients_i \bigg) \qquad for \quad a \neq provider \tag{3.36}$$

$$
\begin{aligned}
TotalCost_{in} = \sum_{a} \Bigg(\Big(\sum_{p} f_p c_{ap} + ExtraCostPP_{ac} \Big) Patients_{ic} + OneOffCost_{aic} + OneOffCost_{ain} \\
+ \Big(\sum_{k} f_k c_{ak} + ExtraCostPP_{an} \Big) Patients_{in} + OneOffCostPPac * NewPatients_{ic} \\
+ OneOffCostPPan * NewPatients_{in} \Bigg) \qquad for \quad a \neq provider
\end{aligned}
\tag{3.37}
$$

Overview

To have a general overview of the difference in (financial) loss/profit between both services, this total cost over the time horizon is visualized for all actors on a bar chart. The same is done for the total time spent in both situations. An illustrative example (with fictive numbers) is displayed in figure 3.5a and figure 3.5b.

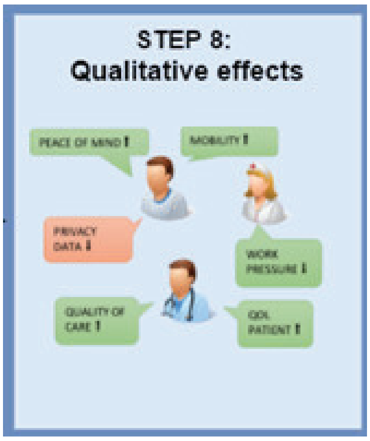


(a) Yearly profit (loss) on average

(b) Yearly time investment on average

Figure 3.5: Comparing the current and new situation in terms of time and money

3.2.8 Qualitative effects



In this step the qualitative effects of the current and the new situation will be identified. These qualitative effects refer to all the effects of a health service except for time and money, which are quantitative effects. Together these effects form the KPIs (Key Performance Indicators). These KPIs represent the variables by which both situations can be evaluated. In a first part of this step there will be asked to select the qualitative effects for all the actors, while in a second part the EQ-5D method is applied. The latter is necessary to determine if the new service is cost-effective, which will be important in step ten, where costs/benefits are reallocated. This eight step is the last step that consists of only input.

Estimating the qualitative effects

The qualitative effects are especially important for the patient, who is normally benefiting from the new service. Probably the patient will have more qualitative effects than the other actors. These effects are also different from the effects that the other actors experience. For the other actors it is often more difficult to express the qualitative effects. Two lists with effects have been made up: one for the patient and one for all the other actors. Both can be found in appendix B. At first both lists contained an equal number of effects, but it turned out that it was often too difficult to effectively estimate the effects for the other actors than the patient. Therefore there has been chosen to suggest only a few possible effects that are more general. They are primarily suited for the care givers. Therefore there are two lists with possible effects: one for the patient and one for all the other actors. Note that the list with effects are not the only possible qualitative effects of a service. The user of the tool can add effects himself manually. For some actors (e.g. the eCare provider) qualitative effects are irrelevant.

Per actor the user should select those effects for which there is a difference in the current and the new situation. This effect can either be positive or negative. For all of these selected effects a score should be given for both situations, going from -3 to +3 (discrete scale). This means that there are seven possible scores: -3 represents a very bad qualitative effect, 0 is rather neutral and +3 means that the service is scoring very good on this qualitative effect. This score is an indication for the strength of the effect. This method of asking for a score is fairly easy to answer. However, to be able to compare the qualitative effects with the quantitative (time and money) these qualitative effects should be quantified into a financial basis.

The input value of the scores have not much to do with the conversion into money, they are just an indication of the strength of the effect. However, once that all the effects are given in for an actor, the scores will be displayed automatically on a bar chart. This visualization of the scores makes it more easy for the user to estimate the monetary value of each effect. Now for every qualitative effect on this chart there will be asked for the willingness to pay.

How much money per patient would this actor maximally pay yearly to experience this effect? = q_{aj} *[€/patient/year]*

The notation q_{aj} represents the monetary value of effect j for actor a and will be used in future calculations. Suppose that the user of the tool has selected four qualitative effects for which he thinks there is a difference between both situations. For effect one he gives the current situation a score of +1 and in the new situation this qualitative effect gets a score of +3. In the same way he gives a score to the other three effects. This example is illustrated in figure 3.6. In this example the new eHealth service is beneficial for three qualitative effects. For the last effect the score in the current situation is zero (neutral), while in the new situation it is negative. This can for example occur when in the new service the patient's data is visible for more care givers and he feels a bit uncomfortable with this lack of privacy. With this figure as possible help, the user should give in the monetary value of each of these qualitative effects.

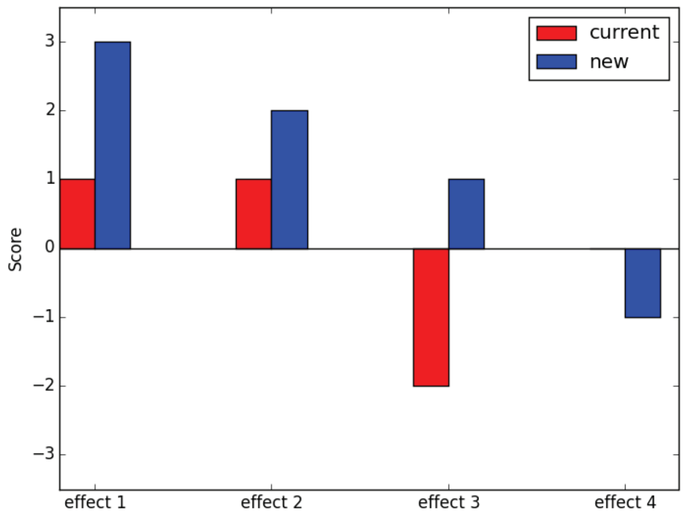


Figure 3.6: General example of a bar where the actor selected four qualitative effects

Qualitative effects in the EQ/5D method

Probably the patient is an actor having a great benefit with the introduction of the new service. A lot of projects focus on increasing the QOL or on extending the amount of life years. As described before, one can calculate the ICER to determine whether or not an intervention is cost-effective (compared with the current situation).

The EQ-5D method described in chapter 2 will be used to estimate the effects of both the current (E_C) and new service (E_N). After obtaining the index corresponding with the calculated profiles from figure A.1 (appendix), one can interpret the difference in terms of quality of life between both situations. Remember the formula to calculate the ICER:

$$ICER = \frac{C_N - C_C}{E_N - E_C}. \quad [€ / \text{QALY}].$$

With:
C_N = cost of the eHealth service [€]
C_C = cost of the current care [€]
E_N = effects of the eHealth service [QALY]
E_C = effects of the current service [QALY]

E_N and E_C are expressed in QALYs: the quality of life combined with the quantity of life. The quality of life is equal to the index, which will be calculated here using the EQ-5D method. For now the quantity of life (the remaining life years) is not relevant. This will be clarified in step 10, when the costs in the numerator and finally the ICER are calculated.

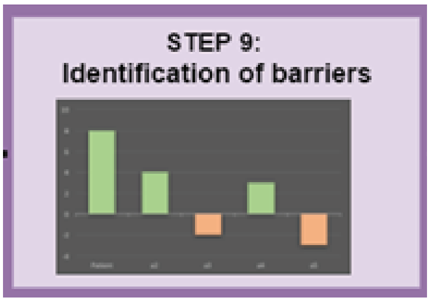
This ratio can be very important for innovations in health care. If some new expensive treatment does not seems to be cost-effective then it will be very hard to get adopted because the government will probably not consider reimbursements. The fact that a new service is cost-effective or not will be important in the last step of the methodology.

So for both situations five questions need to be answered:

What is the mobility level of the patient?
How is the patient's level of self-care?
How well can the patient perform its usual activities e.g. going to work, family activities?
How much pain of discomfort does the patient experience?
How anxious or depressed is the patient?

With each question having three possible answers, as described in chapter 2.

3.2.9 Influence of time and qualitative effects: identification of barriers



In preceding steps both quantitative (monetary transactions and time investment) and qualitative data (effects of the service) were collected. In step seven the yearly cost or receiving for every actor was calculated and visualized. In that step two graphs were displayed for every actor: one concerning his monetary spendings and one concerning the time investment. In this step these graphs will be combined into one graph using the monetary value of time, which was one of the input values asked for in step four and six. The input of the previous step, the qualitative effects, will also be converted. In this way everything is expressed in a financial unit. Once the total cost/receiving for every actor is calculated (consists of money, time and qualitative effects) both situations are compared. The difference per actor is defined as *delta*. Formulas are derived for this delta. Again a distinction is made between the receivers, the eCare provider and the other actors. If the eHealth situation is more expensive than the current care, a barrier is detected. A barrier is a potential reason of why a new service will not be adopted. In this case a barrier exists when an actor feels disadvantaged with the new situation, or in other words, when the new situation is more costly or results in less receiving for an actor. As the involvement of all the actors is of major importance for the success of the new service, the non participation of one actor can block adoption. Finally the sum of all deltas (called the *gap*) will indicate the global potential of the service.

Influence of time investment and qualitative effects

First of all the monetary value of time and qualitative effects that acted as input data in previous steps are converted using the number of patients. Remember that qualitative effects are only used in the new situation. If a certain beneficial qualitative effect is the result of the new eHealth service, than this effect is converted in a positive monetary value for the new situation. On the other hand, if a certain qualitative KPI gets worse in the new situation, this results in a negative monetary value for the new situation. The financial impact of the qualitative effects for an actor a in year i in the new situation can therefore be calculated using equation 3.38. The values of the qualitative effects for the current situation are thus per definition chosen zero (equation 3.39).

$$QualityEffect_{ain} = \sum_{j} q_{aj} Patients_{in} \tag{3.38}$$

$$QualityEffect_{aic} = 0 \tag{3.39}$$

The total monetary value of time for actor a in year i is calculated using formula 3.40 in the current situation and formula 3.41 in the new situation. Remember that the monetary value of time for actor a for process p(k) is represented by $\mathrm{s_{ap}}(\mathrm{s_{ak}})$.

$$TimeCost_{aic} = \sum_{p} s_{ap} t_{ap} TotalPatients_{i} \tag{3.40}$$

$$TimeCost_{ain} = \sum_{p} s_{ap} t_{ap} Patients_{ic} + \sum_{k} s_{ak} t_{ak} Patients_{in} \tag{3.41}$$

Now that all the key performance indicators are converted into a financial unit the total costs/receivings can be calculated for the different actors and barriers can be detected.

Delta for the other actors

The total cost TC (financial & time investment & qualitative effects) for the other actors can now be calculated via equation 3.42 for the current situation and 3.43 for the new situation. One can see that the qualitative effects (if they have a positive value) lower the total cost in the new situation: it decreases the cost through perception.

$$TC_{aic} = Cost_{aic} + TimeCost_{aic} \tag{3.42}$$

$$TC_{ain} = Cost_{ain} + TimeCost_{ain} - QualityEffect_{ain} \tag{3.43}$$

Delta is then easily obtained via equation 3.44. It is defined as the difference in the total cost of current and new situation and expressed as an average difference per year.

$$delta_{a} = \frac{1}{10} \sum_{i=1}^{10} (TC_{a,i,n} - TC_{a,i,c}) \tag{3.44}$$

Delta for the receivers

For the receivers the total receiving in the current situation is defined as the monetary receivings (equation 3.45). For the eHealth service the total receiving is the sum of the monetary receivings and the monetary value of the qualitative effects (equation 3.46).

$$TR_{aic} = Rec_{ain} \tag{3.45}$$

$$TR_{ain} = Rec_{ain} + QualityEffect_{ain} \tag{3.46}$$

In order to calculate delta, the time investment of these actors should be taken into account. For the category receivers 'monetary value of time' is less relevant like stated before. When physicians make one million euro per year in 25 000 hours in the current situation and one million euro per year in 50 000 hours in the new situation, this decrease in earnings per hour obviously would form a barrier. It is clear that this time investment cannot be ignored. Therefore not only the total receivings of both situations needs to be compared, but also the receivings per hour need to be counted in.

Depending on the total receivings (more/less in the new situation) and hourly receivings (more/less in the new situation) four different situations can occur. This can be seen in table 3.3. For each of these situations a formula is derived to calculate the delta of these receivers.

	receivings/hour New $\geq$ Current	receivings/hour New $<$ Current
$\mathrm{TR_{ain}} \geq \mathrm{TR_{aic}}$	1 (++)	2 (?)
$\mathrm{TR_{ain}} < \mathrm{TR_{aic}}$	3 (?)	4 (- -)

Table 3.3: Possible situations for the receivings and receivings per hour for the care givers

Note that the total receivings are defined as the sum of financial receivings and the monetary value of the qualitative effects. The hourly receivings are thus not simply the monetary receivings. A nurse for example has a fixed wage, expressed in euro per hour. Purely financial, her hourly receivings will thus always be the same (e.g. 30 € per hour) in both situations. But here the perception of the qualitative effects is added to the receiving. If the latter is not equal to zero the nurse will have a different hourly receiving in the new situation compared to the current one.

- **Situation 1 (++): more receivings in new situation & more receivings per hour in new situation**

This is obviously a beneficial situation for the receiver. More money is earned in total and per hour. No potential barrier is detected in this situation. The delta is therefore equal to the difference in receivings between the new and current situation (formula 3.47).

$$delta_a = \frac{1}{10}\sum_{i=1}^{10}(TR_{a,i,c} - TR_{a,i,n}) \tag{3.47}$$

- **Situation 2 (?): more receivings in new situation & less receivings per hour in new situation**

To illustrate the case of receiving more money in total but less money per hour an illustrative situation for a physician is displayed in table 3.4. In this table the total receivings over the time horizon of ten years and the hourly receivings for both situations can be found (for e.g. a physician).

	current situation	new situation
total receivings TR [€]	80 000	100 000
total time worked [hours]	1 600	2 127,66
avg receivings per hour [€/hour]	50	47

Table 3.4: Illustration of a physician receiving more money in total but less money per hour

If one only takes the total receivings in consideration there is no barrier because with the new service there are more receivings for the physician. But there is a (small) difference in receivings per hour. In this situation there will be asked if this decrease forms a barrier for the physician:

Does the decrease in receivings per hour form a barrier?
a) Yes, I do not want to earn less money per hour than in the current situation.
b) No, I am happy that I earn more money in total.

If the answer is a) then delta will have a negative value. As the physician wants to make at least as much money per hour as in the current situation the value of delta is given by equation 3.48. It represents the amount of money the actor would receive if he works the number of hours from the new situation but receives the amount of money per hour from the current situation.

$$delta_a = \frac{1}{10}\sum_{i=1}^{10}\Big(TR_{a,i,n} - \frac{TR_{a,i,c}}{hours_{a,i,c}}\ hours_{a,i,n}\Big) \tag{3.48}$$

Applied on the example this gives a delta of:

$$delta_a = \frac{1}{10}\Big(100000 - \frac{80000}{1600}2127,66\Big) = -638,3.$$

When the answer is b) there will be asked after the willingness to pay for this increase in total earnings. An additional question is asked.

How much % of the current receivings per hour is the maximum that you are willing to earn less per hour in the new situation (assuming the time spent in the new situation stays the same)? = hr%

Delta is then calculated using formula 3.49. This formula will result in a positive value for delta (at least if the user inputs a value for hr% that does not contradict itself).

$$delta_a = \frac{1}{10}\sum_{i=1}^{10}\Big(\Big(HourlyRec_{a,i,n} - HourlyRec_{a,i,c}(1 - hr\%)\Big)hours_{a,i,n}\Big) \tag{3.49}$$

Applied on the example with a value of hr% that equals 10%, delta becomes 425,53.

$$delta_a = \frac{1}{10}\Big(47 - 50(1 - 0,1)\Big)2127,66 = 425,53$$

- **Situation 3 (?): less receivings in new situation & more receivings per hour in new situation**

In this case the new service results in more total receivings for the receiver, but less receivings per hour. Similar to the previous case this situation is divided into two possibilities. There is asked if the decrease in total receivings forms a barrier.

Does the decrease in total receivings form a barrier? *a) Yes, I want to earn at least as much money as in the current situation.* *b) No, I am happy that I earn more money per hour.*

If the answer is a) then delta will have a negative value. As the receiver wants to make at least as much money in total as in the current situation delta is left unchanged. It is equal to the difference in total receivings between the new and current situation. Delta can be calculated using equation 3.47.

If the answer is b) on the other hand, extra information is needed in order to calculate delta. The willingness to pay for this quantitative effect (increase in receivings per hour) is asked for. The user of the tool needs to answer an additional question.

How much % of the current total receivings are you maximally willing to earn less in the new situation (assuming the new hourly receivings)? = tr%

Delta is positive in this case (at least if the user inputs a value for tr% that does not contradict itself). and can be calculated using formula 3.50.

$$delta_a = \frac{1}{10}\sum_{i=1}^{10}\Big(TR_{a,i,n} - TR_{a,i,c} * tr\%\Big) \tag{3.50}$$

- **Situation 4 (- -): less receivings in new situation & less receivings per hour in new situation**

In this case both total receivings and receivings per hour are higher in the current situation. This obviously forms a barrier for adoption of the new eHealth service. Delta will thus have a negative value and can be calculated using formula 3.51.

$$delta_a = \frac{1}{10}\sum_{i=1}^{10}(TR_{a,i,n} - \frac{TR_{a,i,c}}{hours_{a,i,c}}\ hours_{a,i,n}) \tag{3.51}$$

- **Schematic overview**

Figure 3.7 represents a schematic overview of the different formulas to calculate the receivers' deltas, depending on the value of the gap and the hourly receivings. The formulas inside a green box result in a positive value for delta. The red ones on the other hand have a negative delta, which results into a barrier.

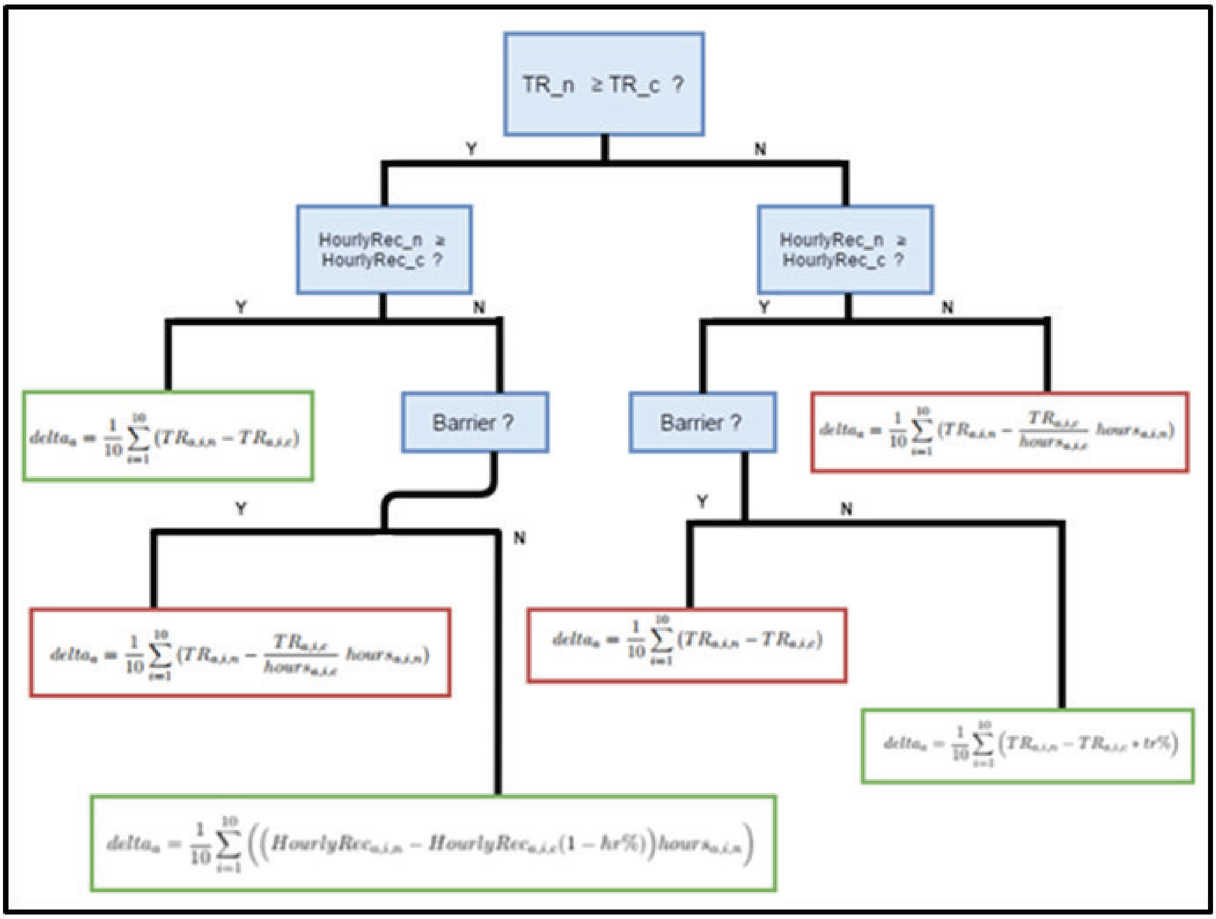


Figure 3.7: Formulas to calculate the receivers' delta depending on the total receivings and hourly receivings

- **General remark**

For actors from the category receivers, the tool will compare both the total receivings and the hourly receivings of the two services. Based on this, delta is calculated and can either be positive or negative. Assume the situation displayed in table 3.5. In the new service this receiver has to work more than eight times as much than in the current situation. But as this actor receives more money in total and more money per hour (situation 1), no barrier is detected and delta is calculated automatically. However, the additional hours will probably form a barrier in practice. The tool will detect this and generate a warning.

	current situation	new situation
total receivings TR [€]	100 000	900 000
total time worked [hours]	3 333	28 125
avg receivings per hour [€/hour]	30	32

Table 3.5: Illustration of a new service in which a certain receiver has to work a lot more

Delta for the eCare provider

The eCare provider does not experience any qualitative effects, neither his time investment is of any interest. As he does not appear in the current situation, his delta would be equal to the financial loss/profit he makes with the new service. For the other actors it is assumed that there is no barrier if the new situation is not worse than the current situation. This has the consequence that these actors are satisfied with a minimal benefit. For the eCare provider this does not hold. As providing the service is his job and thus his income, he will obviously not be satisfied if he e.g. makes 1000 euro per year. Therefore delta cannot simply be equal to the financial loss/profit he makes in the new situation. To handle this there is asked how much profit per year the eCare provider would want to make at least. This is expressed as a percentage gained on his investment. Due to startup costs and market characteristics his earnings will probably be different over the years thus he should take the time horizon into account.

How much profit do you yearly want to make at least (average over time horizon years)? Express in % of gross margin. = $ProfitGoal_{provider}$

With this information the eCare provider's delta can be calculated using formula 3.52. In this formula $\mathrm{TR}_{\mathrm{provider,i,n}}$ and $\mathrm{TC}_{\mathrm{provider,i,n}}$ are used, which have been calculated in section 3.2.7.

$$delta_{provider} = \frac{1}{10}\left(\sum_{i=1}^{10} TR_{provider,i,n} - (1 + ProfitGoal_{provider})\sum_{i=1}^{10} TC_{provider,i,n}\right) \tag{3.52}$$

Total cost of the service: *the gap*

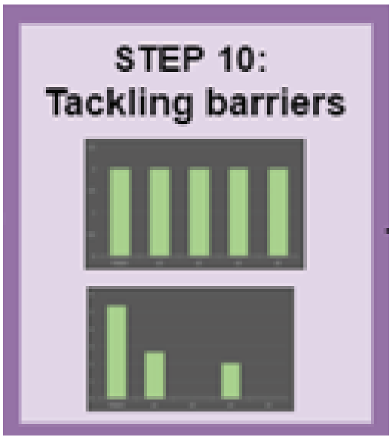
Now that the deltas are calculated for every actor, the total difference between both situations is simply obtained via formula 3.53. When this gap has a positive value, the new service might have the potential to get adopted.

$$gap = \sum_{a} delta_a \tag{3.53}$$

General barriers

Other than the previous barriers (concerning a gap in the business case of the actors), there are also barriers that cannot be identified in this way. A new service can for example be very successful in all aspects, but if no one knows the existence of it, the new service will not be adopted. Publicity is therefore very important and lack of it can be seen as a barrier, which of course cannot be identified with this methodology. This is only one of the many that exist. When introducing a new service one should be careful for these (general) barriers, which are described in section 2.2.3.

3.2.10 Tackling the barriers



In the previous step the delta of every actor is calculated. If for any actor delta has a negative value, a barrier is identified. The actors for which delta < 0 are called *red actors* in this section, while the other actors (delta ≥ 0) are called *green actors*. Obviously in an ideal situation there are no red actors and no barriers need to be dealt with. However, in most cases one or more red actors will show up. In this step the aim is to reallocate the benefits and or costs in such a way that every actor takes profit of the new service. Or better formulated, does not prefer the current care above the new service. There exist different situations and different solutions for the reallocations. The distinction between the situations is made based on being cost-effective or not and having a positive gap or not. The different situations are displayed in table 3.6. After reallocation of the benefits most actors will have a new value for their delta (notation: $deltaNew_a$).

	cost-effective	not cost-effective
gap ≥ 0	2 (++)	1 (+)
gap < 0	3 (?)	4 (- -)

Table 3.6: Possible situations after evaluation of the costs and effects

Cost-effective?

Before the different situations can be handled, the ICER needs to be calculated as then there is known if the new service is cost-effective or not. The denominator, the difference in QALYs between the current and the new situation, is already calculated in step 8. The numerator, the difference in costs between both services, will be calculated in this step. Once again the formula to calculate the ICER is displayed below in equation 3.54. If this ratio is lower than 42 878 € (GDP per capita, Belgium), the eHealth service is cost-effective.

$$ICER = \frac{C_\mathrm{N} - C_\mathrm{C}}{E_\mathrm{N} - E_\mathrm{C}} < 42878? \tag{3.54}$$

But which costs should be included in the terms $\mathrm{C_N}$ and $\mathrm{C_C}$? There can be no double counts included. For example if the patient pays for an eCare service, the developing cost of this service (cost for the eCare provider), cannot be included. There has been chosen to define $\mathrm{C_C}$ (equation 3.55) and $\mathrm{C_N}$ (equation 3.56) as below [€ per patient per year].

$$\begin{aligned} C_c = \sum_a \Big(\Big(\sum_p f_p c_{ap} + ExtraCostPP_{ac} \Big) + \frac{OneOffCostPP_{ac}}{10} * \sum_{i=1}^{10} \frac{TotalNewPatients_i}{TotalPatients_i} \\ + \frac{1}{10} * \sum_{i=1}^{10} \frac{OneOffCost_{aic}}{TotalPatients_i} \Big) \qquad for \quad a \neq provider \end{aligned} \tag{3.55}$$

$$\begin{aligned} C_n = \sum_a \Big(\Big(\sum_k f_k c_{ak} + ExtraCostPP_{an} \Big) + \frac{OneOffCostPP_{an}}{10} * \sum_{i=1}^{10} \frac{TotalNewPatients_i}{TotalPatients_i} \\ + \frac{1}{10} * \sum_{i=1}^{10} \frac{OneOffCost^*_{ain}}{TotalPatients_i} \Big) \qquad for \quad a \neq provider \end{aligned} \tag{3.56}$$

With

$$OneOffCost^*_{ain} = \begin{cases} \left\lceil \dfrac{TotalPatients_i}{capacity_{an}} - \left\lceil \dfrac{\max\limits_{1 \leq j \leq i-1} (TotalPatients_j)}{capacity_{an}} \right\rceil \right\rceil * serviceCost_{an} & \text{if A True} \\ 0 & otherwise \end{cases} \tag{3.57}$$

Where A is *True* if: $\qquad TotalPatients_i \geq \max\limits_{1 \leq j \leq i-1} (TotalPatients_j)$

The total cost is the sum over all actors (except the eCare provider) of three terms. The first term represents the cost of the processes [€ per patient per year], which are the input of steps four and six.

The second term represents the yearly cost per patient per year due to one-time costs for new patients. These costs are only incurred for new patients, so to express *OneOffCostPP* in a yearly cost, these one-off costs are multiplied with the fraction of new patients over the time horizon (default ten years). At last the third term represents the yearly cost per patient that is incurred per certain amount of patients. The term *OneOffCost* is already expressed as a cost per year. To express this as a (yearly) cost per patient it is divided by the total number of patients. Again it is taken as the average over the complete time horizon.

The last term of formula 3.56 can be calculated using equation 3.57. $OneOffCost_{ain}$ cannot be used here because it is calculated using the adoption characteristics. This means that a fraction of the patients is using the current service while the other fraction is using the new service. But for comparing both situations to determine whether or not the eHealth service is cost-effective, this adoption theory should not be applied. To calculate the ICER correctly it is assumed that in the new situation all customer targets use the new service.

Now that there is determined whether or not the new service is cost-effective, different situations, dependent on the value of the gap and ICER, are handled.

Note:
In step 2 of the methodology there was asked for the mortality rate. This is for the current situation. However, there is assumed that in the new situation this mortality stays the same. This of course means that also in the calculations of the ICER no difference is made between the quantity (amount of remaining life years) of both situations. In fact, the indexes in the denominator of the ICER should be multiplied with the remaining life years of the patient (as was already indicated in step 8). But here the numerator of the ICER is a cost per year and in that way no total cost. Multiplying both the numerator and the denominator with the average remaining life years of a patient is thus a *zero sum game* and has no effect on the outcome of the ICER.

Situation 1 (+): gap > 0 & not cost-effective

A new situation that is less expensive but not cost-effective is rather rare. Nonetheless this situation can occur. The current and new situation are compared by the gap, which does not only consist of financial payments, but also of qualitative effects and the cost of time investment. The EQ-5D method compares the total cost with five qualitative effects concerning the quality of life of the patient. If the new situation is more costly in terms of the financial costs and the difference in quality of life for the patient is small, it can for example be that the new service is not cost-effective. If on top of this the other actors also experience benefits and/or spend less time with the eHealth service, this new service is possibly less costly in total than the current one.

As explained before, there will probably be one or more actors who rather prefer the current situation and hereby counter the adoption of the service. An illustrative example that will be used to clarify some reallocation techniques is sketched in table 3.7. The deltas from this table are visualized in figure 3.8. In this example there are three green actors (patient, a2 and a4) and two red actors (a3 and a5).

Actor	Delta (if ≥ 0)	Delta (if < 0)
patient	8	/
a2	4	/
a3	/	-2
a4	3	/
a5	/	-3
total	15	-5
gap	10	

Table 3.7: Data for numerical example of possible reallocations of benefits

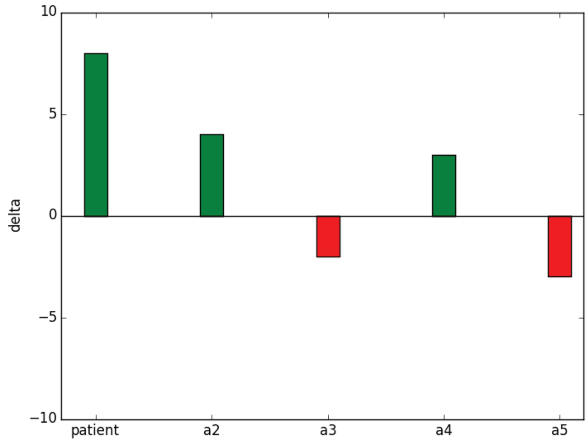


Figure 3.8: Visualization of deltas

The eHealth service from the example clearly has potential as the gap is positive (10). However, there are two actors who do not want to implement the new service because they prefer the current care. Because the gap is positive reallocations of the benefits could offer a possible solution for this. But how will these reallocations be done? In this situation there are different solutions possible.

- **Divide equally**

In this solution approach the benefits from the green actors are reallocated equally over all actors in the new situation. The new delta is the same for all actors and is easily calculated via formula 3.58.

$$deltaNew_a = \frac{gap}{NumberOfActors} \tag{3.58}$$

In this way every actor equally benefits from the new service. Applied on the example one becomes a *deltaNew* of 2 (10/5) for every actor. This new situation is illustrated in figure 3.9a.

- **Red actors break even and divide proportionally from green**

Another strategy that might be followed in this situation is to make the red actors break even. Break even means that *deltaNew* for the red actors will be zero. In that way they are indifferent whether the current or new service is used. The remaining question now is how much to take from which green actor. In this solution approach the benefits that are reallocated from the green actors are proportionally to their delta. The actor that has the greatest benefit with the new service gives the most benefits to the red ones (in absolute terms). *deltaNew* for all red actors equals zero (equation 3.59), while for the green actors it can be calculated using formula 3.60. Note that the sum in the latter equation is the sum of the original deltas from the green actors.

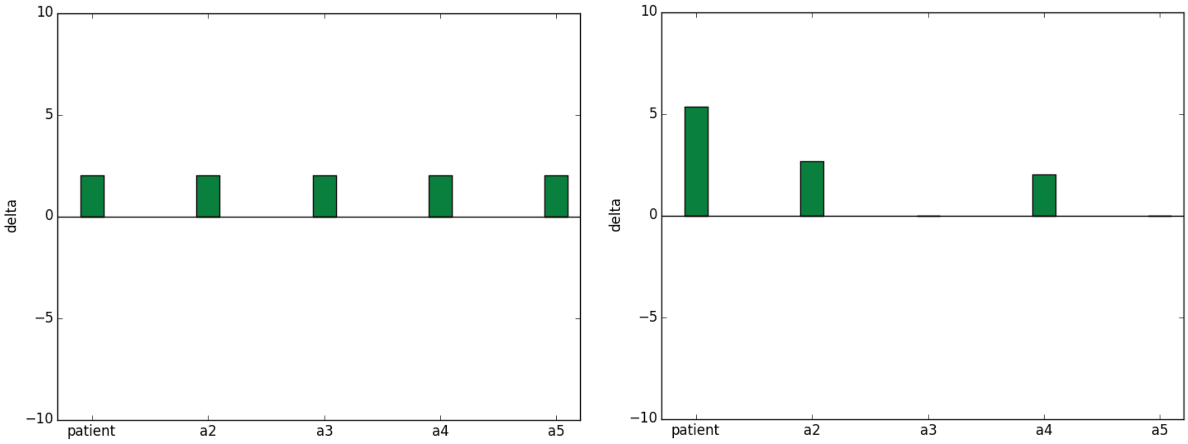
$$deltaNew_{red} = 0 \tag{3.59}$$

$$deltaNew_{green} = gap \frac{delta_a}{\sum\limits_{a \in greens} delta_a} \tag{3.60}$$

The updated deltas are calculated for the example below.

$$\begin{aligned}
deltaNew_{\text{patient}} &= 10 * \frac{8}{15} = 5,333 \\
deltaNew_{\text{a2}} &= 10 * \frac{4}{15} = 2,667 \\
deltaNew_{\text{a3}} &= 0 \\
deltaNew_{\text{a4}} &= 10 * \frac{3}{15} = 2 \\
deltaNew_{\text{a5}} &= 0
\end{aligned}$$

This possible new situation is visualized in figure 3.9b.



(a) Divide equally (b) Divide proportionally

Figure 3.9: Visualization of the deltas after reallocation

- **Reallocation based on financial risk**

A lot of costs show up when developing an innovation. When the innovation is introduced on the market there is often a lot of uncertainty about the outcome. If the innovation is a success, then the investor benefits as he probably gets a share of the revenue. On the other hand, when the new service is introduced and the expected outcome is not achieved, the investor is now the victim as the invested money is (partly) lost. The investor is thus the one who is bearing the financial risk. One could therefore reason that reallocations (after a novel service is introduced on the market) should be based on the financial risk. In the case of mHealth and eCare services, the actor who is bearing the greatest risk is the eCare provider.
If the gap is positive (which is the case in this section) and the eCare provider is one of the green actors and there is at least one red actor (thus reallocations are necessary), one approach is to never take money from the eCare provider to reallocate. If the eCare provider is one of the red actors this means that on average he makes a loss over the time horizon. To reward the provider for the risk he takes, a possible approach is to, after reallocation, let the eCare provider always receive a certain amount of the gap (expressed as a percentage of the gap). The new delta for the eCare provider can then simply be calculated using equation 3.61. *ProviderProportion* represents the fraction of the gap which is reserved for the eCare provider.

$$deltaNew_{provider} = ProviderProportion * gap \tag{3.61}$$

The other fraction of the gap still needs to be divided over the other actors. There are different possibilities to do this. One of them is to divide it proportionally over the original green actors and make the red actors break even. This approach is explained in the previous subsection. This means that the new delta for the red actors is zero (equation 3.62) while the new delta for the green actors can be calculated using equation 3.63.

$$deltaNew_{red} = 0 \tag{3.62}$$

$$deltaNew_{green} = (1 - ProviderProportion) * gap \frac{delta_a}{\sum\limits_{a \in greens} delta_a} \tag{3.63}$$

Note that in both formulas the eCare provider is not included, independent of the sign of the original delta. This means that equation 3.62 is not applicable for the eCare provider and the sum in equation 3.63 is the sum of the deltas of the green actors, excluding the eCare provider. If this approach is used there could exist a situation where the service provider has less benefit than when the pure 'divide proportionally' technique would be used to determine the reallocations. This happens when the sum of deltas from the green actors (without the eCare provider) is smaller than the delta from the eCare provider.

Assume that in the example actor a5 is the eCare provider and that there is defined that he always receives 50 % of the (positive) gap, no matter if he makes part of the red or green actors. If this reallocation method is used the new deltas would be:

$$\begin{gathered}
deltaNew_{\text{patient}} = 0,5 * 10 * \frac{8}{15} \quad = 2,667 \\
deltaNew_{\text{a2}} = 0,5 * 10 * \frac{4}{15} \quad = 1,333 \\
deltaNew_{\text{a3}} = 0 \\
deltaNew_{\text{a4}} = 0,5 * 10 * \frac{3}{15} \quad = 1 \\
deltaNew_{\text{a5}} = 0,5 * 10 = 5
\end{gathered}$$

- **Special situation: insurer green**

In Belgium there is little (or no) competition between the different insurers. They are some sort of passive payment offices from the government. Therefore one can reason that it does not really matter how much more beneficial a new situation might be for them. If the delta from the insurance company is positive and for one or more other actors it is negative, then the first thing one can do is set the delta of the insurer to zero. These benefits can now be divided over the red actors and one of the previously explained methods can be used to reallocate correctly. Of course this only holds if the gap is positive.

Situation 2 (++): gap > 0 & cost-effective

This is obviously the ideal situation: the total cost for all actors is smaller in the new situation and it is cost-effective.

All the techniques that are explained for the previous situation can be used to reallocate the benefits/costs in this situation as the gap has a positive value. On top of that, this situation is also cost-effective. However that after reallocations a viable business case is obtained, it is still possible that one excludes some patients with the eCare service. Because the average patient has a positive delta it does not mean that every patient is able to pay for the service. Health care should be equal and accessible for everyone. As the situation is cost-effective the government can for example help to prevent the exclusion of patients.

There are different ways in which the government can intervene in the value network of digital health services: as a regulator, healthcare payer, digital health platform provider or adoption initiator [34].

If a service is part of a service platform this could reduce the total cost of the service. The government can foresee a national healthcare platform to e.g. facilitate and stimulate sharing healthcare information in a secured way. Service platforms are not the main scope of this master thesis, so this will not be discussed in more detail. The role as a regulator (by assuring quality labels) will also not be handled here.

The government can also act as a healthcare payer by foreseeing reimbursements for certain treatments. Cost-effectiveness is in most cases one of the criteria to determine if a new treatment will be reimbursed or not. As this is the case for this situation (positive gap and cost-effective) the government may act as a payer to cover the delta of one or more red actors and thus dissolve the willingness to pay barrier.

The maximum amount of money that the government can pay yearly is given by equation 3.64. It is equal to the societal willingness to pay, divided by the average remaining life years of the patient using the eHealth service (input value of step 2) and multiplied with the average number of patients per year who use the new service.

$$ReimburseLimit = \frac{42878}{LifeYears} * \frac{1}{10}\sum_{i=1}^{10} Patients_{in} \tag{3.64}$$

In theory the government is maximally willing to pay this amount of money per year. This means that if the sum of the deltas of the red actors is smaller than this *ReimburseLimit*, no other cost reallocations should be executed as the government can cover up for all the identified barriers (negative deltas). However, this would be a very unsustainable solution as the national healthcare expenditures would explode.

A typical situation in which the government foresees reimbursements is when there is a new treatment method for a patient which increases his QOL, but it is too expensive for the patient to pay for it himself. When the new eHealth service is cost-effective there will therefore in the first place be looked to the delta of the patient. If the patient has a negative delta, the government will act as a payer.

A possible strategy that can be followed to determine to who the government can pay first is listed below.

1: Is the patient a red actor? Cover his costs by paying the patients who use the new service by bringing their delta to zero.

2: If the eCare provider has a negative delta he should first of all reconsider different price settings. As the service is cost-effective the government could finance a part of the costs of developing and maintaining the service and bring the delta from the eCare provider to zero.

3: If one of the receivers is part of the red actors the government could foresee incentives to convince them to use the eHealth service. The delta could for example be brought above zero so that these actors actually prefer the new service. After a certain period this incentive could be lowered until delta becomes zero. If now these receivers still use the old care method they can be penalized. The government now acts as an adoption initiator.

4: Cover the cost of remaining red actors.

After the government acted as a payer and there are still red actors, reallocations are again necessary.

Situation 3 (?): gap < 0 & cost-effective

At first sight it seems that the new situation has little potential to get adopted as it is more expensive than the current care. However, the fact that the eHealth service is cost-effective could be very useful in this case. The government can act as a payer for the actors and foresee reimbursements to cover up the gap. But if the gap is just covered and so brought to zero, it would mean that the eHealth service is globally equally good to the current care and thus a unnecessary innovation. So how much will the government cover in this situation?

A theoretically possible solution is to bring all the deltas of the red actors to zero if equation 3.64 is met. The gap will certainly be positive now, but again the government cannot fund limitless. Other more sustainable solutions need to be proposed.

Situation 4 (–): gap < 0 & not cost-effective

When the new situation is more expensive and it is not cost-effective, there is no potential reallocation possible to make the business case viable. If this is the situation, there will be concluded that the new service has no potential for getting adopted.

Practical implementation and feasibility of the reallocations

The more actors that are involved in the reallocation and the more reallocations that need to be performed, the more difficult it gets practically to reallocate costs and benefits. The approaches *divide equally*, *divide proportionally* and *financial risk* involve transactions between all the actors. This makes it very hard to realize in practice. To implement these strategies for reallocation, it is recommended that a central committee gets established by the government. All the actors who have to pay to realize the reallocation will pay this to this central committee. This committee will then make sure that this money is deposited to the right actors.
It is very unlikely that reallocations will happen in this way in practice. A lot of administration and transactions are needed, which result in man hours and thus extra costs (wages). And also, this is not how economics and the markets work.

In many cases the patient will benefit from the new service while a certain care giver (e.g. the general practitioner) is one of the red actors. Assume the situation where a patient uses a telemonitoring service for which he pays a monthly fee to the eCare provider. His QOL increases and this results in less visits to the GP and thus a decrease in the GP's earnings. On top of this the GP needs to do some extra administrative work for which he does not get compensated.

With the previously explained reallocation methods (for example *divide equally*) it is possible that a part of the patient's delta would be reallocated to the GP to cover up his decrease in earnings. This would be very hard to realize in practice as the patient would have to pay the GP just 'because the GP earned more with the previous service'.
But which reallocation methods are realizable in practice? In this situation the eCare provider could be the driving force behind the reallocations. The eCare provider will probably set his prices in a way that after a certain time his profit equals/exceeds its desired value. If his innovation convinces the customers and the aimed market target is obtained, it is very likely that his delta will be positive. He has to sell his product to the market, which in this case are the patients who pay him a monthly sum. But he can also approach the general practitioners and offer them a sum per patient that they threat with the telemonitoring service. If the eCare provider sets his monthly price so that the patient is willing to pay and this is enough to pass a part of it through to the general practitioner they all benefit from the new service. The eCare provider plays a primary role in the success of his telemonitoring service by setting up contracts with physicians. This is a far more straightforward way to reallocate the costs/benefits.

However, this method has been criticized by the National Council of the *'Orde der artsen'*. In their statement they acknowledge the importance of telemonitoring of patients with heart failure and the fact that there is no framework for reimbursements. However, the National Council argues that the financial aspects of the described system can lead to a conflict of interests between the various actors and that aforementioned solution could be in conflict with the deontology. In case that telemonitoring becomes actual, a revision of the funding and a clarification of the legal framework will be necessary [54].
If the need for telemonitoring is concerned, the doctor may ask the patient a reasonable fee for the performance, namely the supervision and response to the alarms. He should inform the patient in advance about the arrangements to be made for alarms or in urgent situations [55].

This makes it clear that innovating in healthcare is hard and requires a work of long breath.

3.3 Conclusion and summary of the methodology

This section described the building and structure of the methodology on which the web tool will be based. This methodology is directed to the person having a innovative idea for a new mHealth or eCare service. Using the designed tool, it can be estimated whether or not this idea is possibly feasible in practice. It should be stated that this methodology provides an indication of the possible success rather than a definitive judgment.

The composed methodology consists of 10 main steps in which there are asked many questions to the user concerning all sort of data. This data concerns both the current situation (the current care) and the new situation (eHealth service + current care). The ultimate goal of this tool is to detect which actors would prefer the new situation and which actors would prefer the current care. If there is at least one actor who prefers the current situation, there is a gap in the business model and possible reallocations of the benefits/costs are suggested so that adoption of the service might be possible.

In figure 3.10 a schematic overview of the methodology is displayed. The blue frameworks represent the steps concerning the input of data. In the first step the various actors are identified. The next step concerns the market characterization. Step 3, 4, 5 and 6 are probably the most time consuming steps: it concerns the description of the different care processes, followed by the input of monetary transactions and time investments.
The seventh step provides a first comparison: for every actor the time and profit is visualized over the time horizon. Step 8 is the last step that really concerns the input of data by the user. In this step the qualitative effects are identified and valued. Now that all the necessary input has been collected, barriers are identified in step 9, followed by suggestions to tackle these barriers in a final step.

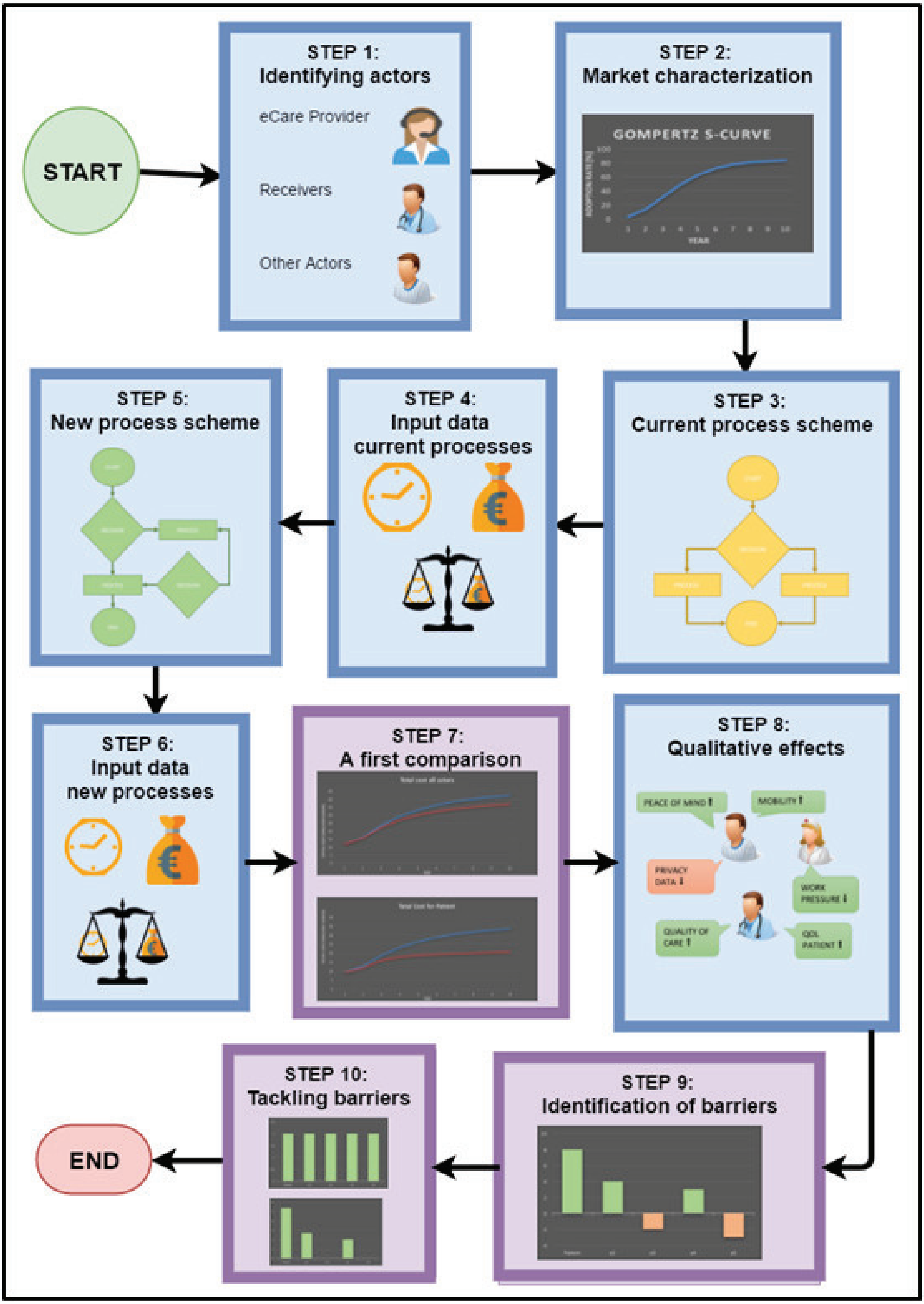


Figure 3.10: Detailed overview of the methodology

Chapter 4

Development of the web tool

The methodology described in the previous chapter is translated into a pre-development validation web tool. This tool will guide the user through the 10-step plan defined in the methodology. The user should fully understand the current situation and possess a sufficient amount of information about it. The same applies for the eHealth service. All the steps run through and all the data asked for in these steps are fundamental to form an accurate judgment about the potential of the innovation. Consequently the reliability of the tool highly depends on the reliability and completeness of the user's input data. Unreliable input will result in unreliable output.

First the used technologies and languages are explained. Subsequently a short summary is provided concerning the implementation of the methodology. Next is discussed how the tool tries to assist the user.

The web tool can be found at the following URL: *http://ecare.evaluation.atlantis.ugent.be/*.

4.1 Web tool technology architecture

The web tool is designed using several technologies and languages:

- HTML5
- CSS3
- JavaScript
- PHP
- MySQL

HTML5 (Hypertext Markup Language 5) is the most recent version of HTML. A HTML-file is used to describe the structure of a web page. It can among other things embed scripts written in JavaScript and style sheets written in CSS (Cascading Style Sheets). A JavaScript-file can respond at run-time on the behavior and content of a web page, whilst a CSS-file defines the presentation and the layout of a web page content. These files can be run and executed at the client-side, on the user's device.

PHP (acronym for Hypertext Preprocessor) is a scripting language executed at the server side, in contrast to JavaScript. One of PHP's main features is its compatibility with MySQL. MySQL is a database system that can be run on a server, it uses standard SQL to access and manipulate databases.

The JavaScript concept AJAX (Asynchronous JavaScript and XML) is used to communicate between the client and the server, or more specific between a JavaScript-file and a PHP-file [56].

PhpMyAdmin is used to access, manage and maintain the database via the web itself. It is a portable web application written in PHP [57].

To summarize, HTML is responsible for the web tool's structure while CSS3 constitutes the layout. JavaScript reacts on the user's behavior and PHP uses MySQL to retrieve and store data from and in the database.

Figure 4.1 depicts an overview of how all these technologies and languages are used in the web tool and communicate with each other to form the desired web page.

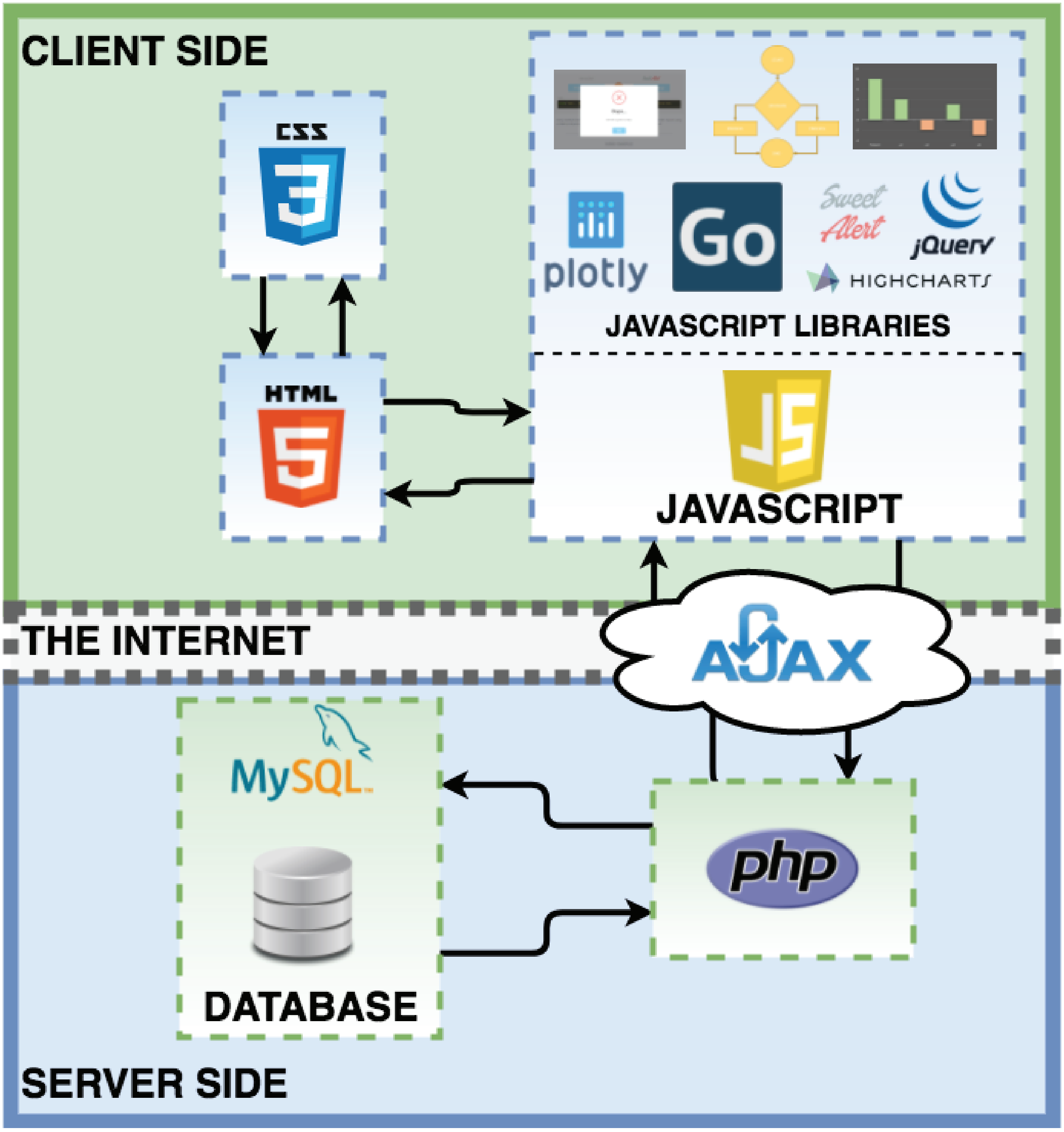


Figure 4.1: overview webtool architecture

The web tool makes use of 5 JavaScript libraries:

- JQuery [58].
- GOJS [59].
- Plotly [60].
- Highcharts [61].
- Sweet Alert [62].

JQuery simplifies the use of JavaScript, it is a "write less, do more" JavaScript library. The main goal of JQuery in the web tool is to simplify the AJAX calls. To draw the process schemes, described in subsections 3.2.3 and 3.2.5, five different options were compared. A summary of the most most important characteristics is given in table 4.1.

	automatic	clear	interactive	easy savable	swimlanes	intuitive	user friendly
MERMAID	+	-	-	+	±	-	±
PLANT UML	+	±	-	+	+	±	+
BPMN	+	+	-	-	+	-	-
GOJS	-	+	+	+	-	+	+
BPMN GOJS	-	±	+	-	+	±	±

Table 4.1: Comparison of the main characteristics between potential process scheme generators

There has been chosen for GOJS, which makes it possible to easily draw and construct the desired process schemes. The JavaScript library plotly generates the bar charts in the web tool, while highcharts is responsible for the graphs. Finally Sweet Alert is used to give the user clear and proper alert messages.

When a web page of the web tool is requested by the user's browser, the server will respond with the corresponding HTML-file. This file is rendered by the web browser. When the browser notices unknown JavaScript-files, CSS-files or image URLs, he will retrieve the corresponding URLs from the server and render these. At the start of every web page visit, some JavaScript functions will be executed with the goal of fetching the needed data from the database for the requested web page. To achieve this, an AJAX-connection is set up. The JavaScript functions define to the PHP-files which data they need. The PHP-files fetch this specified data from the database using MySQL, and send it back to the corresponding JavaScript functions. This process takes approximately zero to five seconds. To assure the user that the web tool is fetching the necessary data a loading symbol is displayed [63]. When all the necessary data is fetched, the symbol disappears and the whole web page is shown. Now the user can interact with it. Depending on his behavior, JavaScript will execute different functions and store all the input data given by the user.
When the user decides to go the next web page, again an AJAX-connection is set up. JavaScript sends all its relevant stored data to specified PHP-files, after which these PHP-files store these data in the database using MySQL. Now the next web page can be loaded in, hence repeating this whole procedure.

4.2 Implementing the methodology

The goal of the web tool is to implement the methodology described in chapter 3.2. Every single step out of the 10-step plan is represented by its own web page. In this section the utility of every web page is briefly discussed.

The web tool's start page welcomes the user and offers him different options (figure 4.2). The user can choose to employ an existing project or start a new project. The existing projects are available as a possible aid for the user of how to correctly input the data. It concerns three cases: a telemonitoring service for CHF patients (CHF), a teleconsultation service for COPD patients after reshospitalization (BRIEF) and an mHealth service with the aim to reduce waiting times (SMART). When opted to manipulate an existing project, the corresponding case is loaded into the web tool. This web page is followed by an introduction page, where some additional side information about the project is entered.

Figure 4.2: Start page of the web tool

After this short introduction the 10-step plan kicks off. The first step, the identification of the actors, lets the user add and remove actors to the project. Next, the user characterizes the market by entering the different parameters. In a third step the process scheme of the current situation is drawn. JavaScript library GOJS is used for the latter. After this, the user enters the corresponding data (money, time, monetary value of time and frequency) for every state drawn in the previous step. Step 5 and 6 have about the same functionalities as step 3 and 4, but this time for the new situation. Step 7 gives a first comparison between the current and new situation using graphs. These graphs are generated by the highcharts JavaScript library. Next, the user estimates the qualitative effects of the new situation relative to the current situation. With all the data retrieved in the previous steps, time and qualitative effects can be converted into money. A final comparison is made for every actor and existing barriers are identified. At last step 10 depicts these barriers and tackles them. The barriers are illustrated by bar charts generated by the JavaScript library plotly.

Every web page of the web tool for the CHF-case is illustrated and discussed in appendix C.

4.3 User assistance

4.3.1 Reducing the margin of error

It is clear that a user must enter a lot of data into the web tool. Therefore it is not unlikely that user-input errors will occur. To reduce the amount of user-input errors, some input restrictions and rules are imposed. Some examples of these restrictions and rules are:

- The actors 'Patient' and 'eCare Provider' cannot be removed from any project.
- An actor's name must be unique.
- Negative input values for money and time are mostly denied.
- When an input field requires a number, only numbers and the decimal mark are allowed.
- Every state (explained in subsections 3.2.4 and 3.2.6) must have a frequency greater or equal than 0.01.

An example illustrates the functioning of these restrictions and rules. The actors 'Patient' and 'eCare Provider' are always present in any project. This means that if a user tries to add an actor with the name 'patient' to any project, the web tool will generate a warning. This warning is illustrated in figure 4.3.

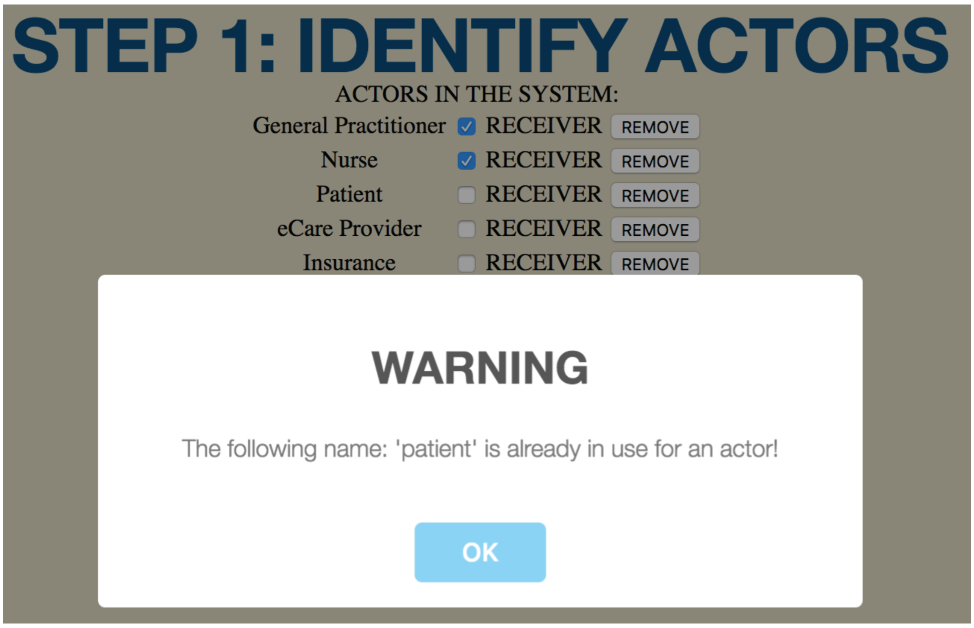


Figure 4.3: Error when an actor with the non-unique name 'patient' is added to the project.

4.3.2 Help-function

To make the web tool more user-friendly every web page has a help button. When this button is pressed, a pop-up window is opened. In this window the user can find the information needed to correctly and completely fill in the corresponding web page. An example of this is depicted in figure 4.4. This shows the help-function for the first step of the tool.

Next to complex elements an information icon is placed. When the user hovers over this icon, a clear explanation about this element appears.

4.3.3 Default values

When starting a new project, it can be difficult for a user to do everything from scratch. To help the user, some default values are provided for certain input data. In the first step (the identification of the actors) a list of common actors in healthcare systems is available. In the second step, where the user characterizes the market, default values are proposed for the different parameters. Step 3 and 5 (concerning the process schemes) give by default simple standard process schemes. And in step 8 a list with some common qualitative effects in healthcare is available.

Figure 4.4: Help-function for step 1: identification of the actors

4.4 Conclusion

In this chapter the development and structure of the web tool was discussed. Now that the methodology is implemented in an online tool, the performance of it can be validated. The next chapter describes how the methodology and tool are tested via case research. Additionally, pros and cons are formulated.

Chapter 5

Analysis

This chapter handles the evaluation of the methodology via case research. Based on the results, critical remarks are formulated.

The telemonitoring service for CHF patients and the patient briefcase, described in section 2.2.4, had a strong influence on the design and development of the methodology. It are quite similar cases with the aim to reduce the amount of hospitalizations. Because of the similarities, the robustness of the tool is tested with another, totally different service that aims to reduce waiting times in healthcare. The methodology is validated via these three cases. They can be consulted on the web tool by any person.

In a second section of this chapter the overall performance of the methodology and web tool is critically evaluated.

5.1 Case analysis

In this section the main results of the CHF case and SMART case are discussed. The focus of the case analysis is on the generated output: barrier identification and dealing with these barriers.

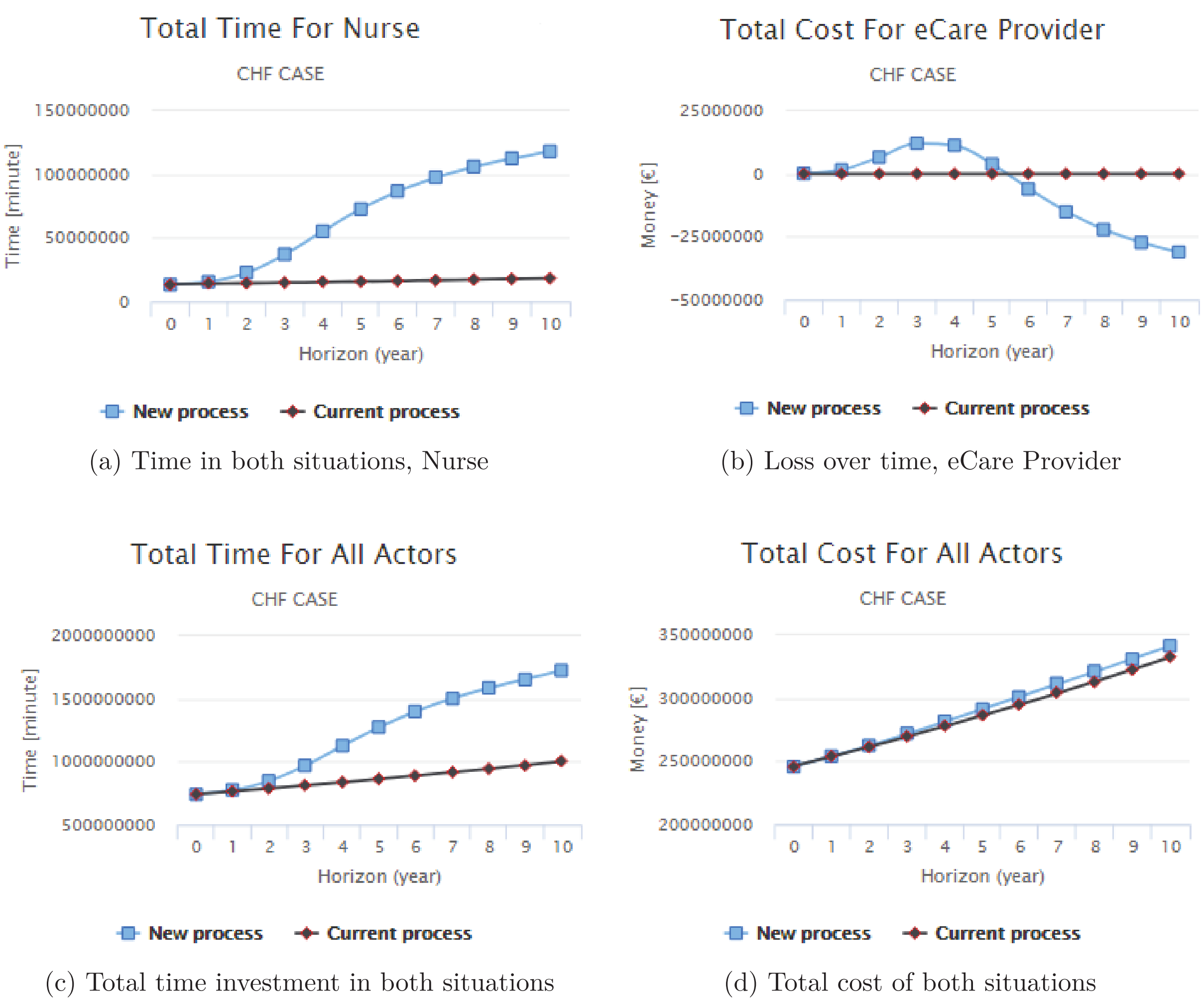
5.1.1 Case 1: Telemonitoring service for CHF patients

To give an overall view of the web tool, every step is depicted and explained in appendix C. It is strongly recommended that the reader first takes a look at this appendix, which focuses on the input. In that way the reader will better understand the care processes for CHF patients and he can consult all the generated output.

A first comparison

After the actor identification, market characterization, making of the process schemes and inputting the data of the processes, step 7 shows a first comparison between the current and the new situation. When examining the generated figures, some things stand out:

1: The nurses have to work a lot more in the new situation (figure 5.1a)
2: The eCare provider will start making profit after about five years (figure 5.1b)
3: The total time investment in the new situation is much larger (figure 5.1c)
4: The eHealth service is more costly (figure 5.1d)



(a) Time in both situations, Nurse

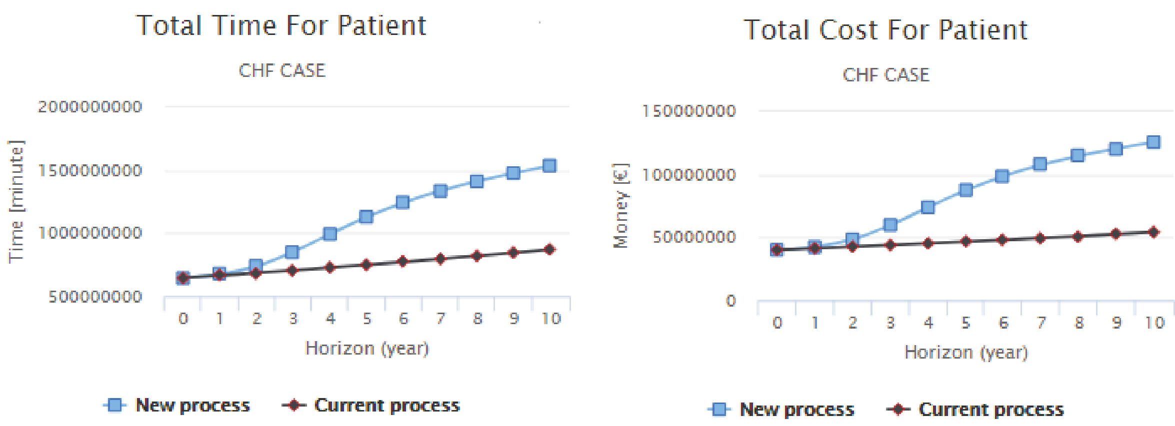
(b) Loss over time, eCare Provider

(c) Total time investment in both situations

(d) Total cost of both situations

Figure 5.1: A first comparison: findings

Apart from these findings, it is also remarkable that with the new service (1) the cost for the patients more than doubles over time and (2) the patient spends more time to the monitoring of his disease (figure 5.2). The eHealth service is primarily aimed for the patient, but is he willing to pay for this additional cost and time investment?



(a) Time (b) Cost

Figure 5.2: Cost and time for the patient

At first sight, following the criterion total receivings/total cost, there are only three of the seven actors who prefer the new situation (table 5.1).

Current service	New service
GP	Insurance
Patient	Nurse
Cardiologist	eCare Provider
Hospital	

Table 5.1: Which actor prefers which service in year 10 (pure financially)

One cannot yet conclude a lot based on this first comparison. To assess the potential of the innovation, the time investment and qualitative effects have to be added to the costs and both situations will have to be compared again. It might however be noticed that the additional time investment of the nurses will probably be problematic.

Barrier identification

In step 9 the qualitative effects and the time investments are taken into account and delta is calculated for every actor. Some results stand out:

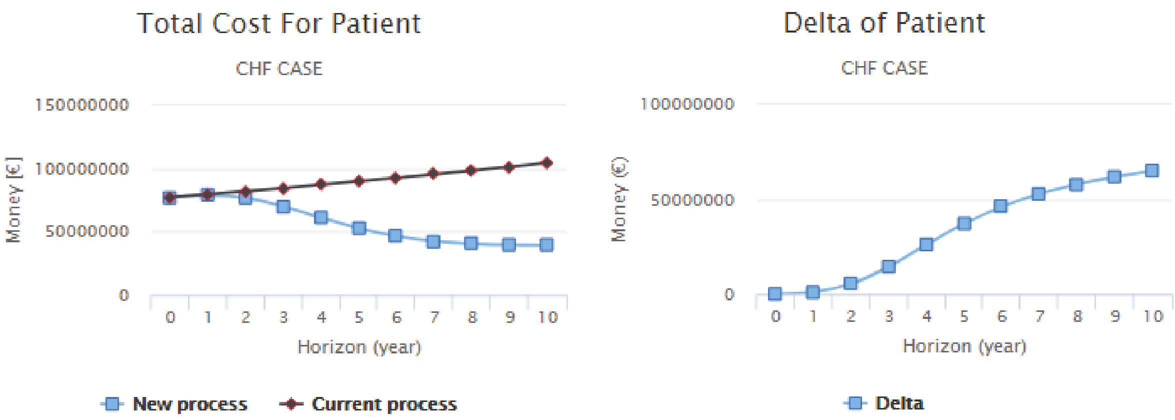
1: The patient now prefers the eHealth service (figure 5.3).

2: Although the average delta for the nurses is positive, the time investment is problematic (figure 5.4).

3: The gap (over the complete time horizon) is positive: 593 million € (figure 5.5).

A big difference with the first overview of step 7 is witnessed for the patient. The reason for this is the influence of the qualitative effects, which are currently estimated high. The patient willing to pay a maximum of

- 365 € per year for an increase in his peace of mind;
- 100 € per year for an increase in his mobility;
- 50 € per year for the increase of knowledge about his condition.



(a) Cost (b) Delta

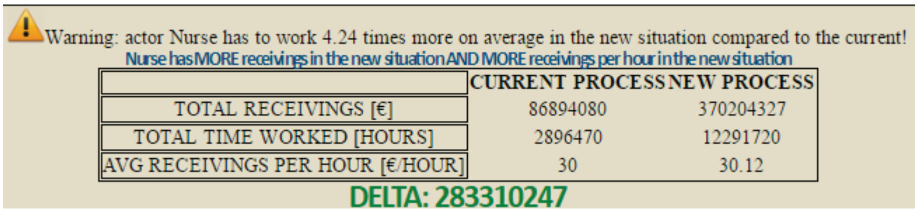
Figure 5.3: Total cost (finacial + time + qualitative effects) for the patient

For the insurer, hospital and eCare provider there are no qualitative effects and no relevant time investments so their total profit/loss is the same as in step 7.

The care givers (GP, nurse and cardiologist) are willing to pay 1 € per patient per year for the increase in QOL. This sum is added to their total receivings. This qualitative effect does however not change the fact that they prefer the current service.

With the eHealth service the nurse spends time to two processes: treating patients in the hospital during their monitoring period and analyzing the alarms of the patients, who are daily monitored at home, followed by a telephone call to inform the patient. Due to the high frequency of the telemonitoring (daily) and the fact that for the moment every patient generates on average one alarm every week, this process is the main reason of the increase in time investment of the nurses.

The nurses have to work on average 4,24 times as much in the new situation. In year 10 this even increases to more than six times as much. As there is no abundance of nurses in Belgium, this will be problematic.



Warning: actor Nurse has to work 4.24 times more on average in the new situation compared to the current!

Nurse has MORE receivings in the new situation AND MORE receivings per hour in the new situation

	CURRENT PROCESS	NEW PROCESS
TOTAL RECEIVINGS [€]	86894080	370204327
TOTAL TIME WORKED [HOURS]	2896470	12291720
AVG RECEIVINGS PER HOUR [€/HOUR]	30	30.12

DELTA: 283310247

Figure 5.4: Visualization of the influence of the time investment and qualitative effects on the total cost

When the (financial) costs of both situations were compared (step 7, figure 5.1d), the new service turned out to be more expensive. However, the value of the time investment and the perception of the qualitative effects have ensured that the new situation has a positive gap: globally the new eHealth service is valued higher. There is one main reason for this: the perception of the qualitative effects for the patient.

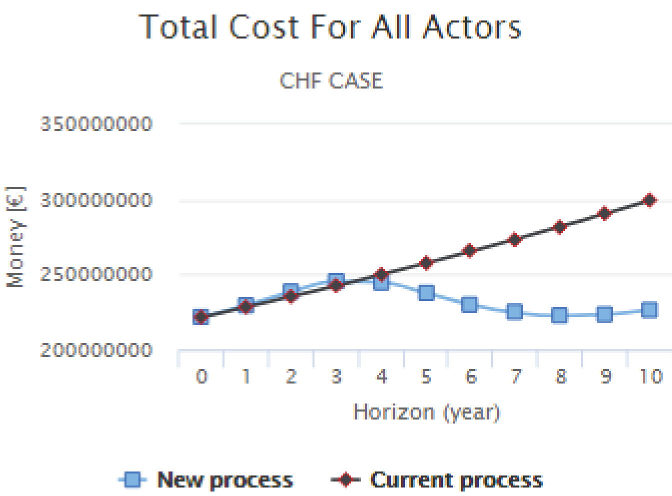


Figure 5.5: Total cost of the service (financial + time + qualitative effects)

Figure 5.6 shows a comparison of step 7 and step 9 for every actor. The blue bars represent the difference in cost between the current and new situation (step 7, money), while the red ones represent the difference in total cost (step 9, money + time + qualitative effects) in year 10. A bar below the horizontal axis means that the current service is preferred. One can see the big influence of the qualitative effects on the total cost of the patient.

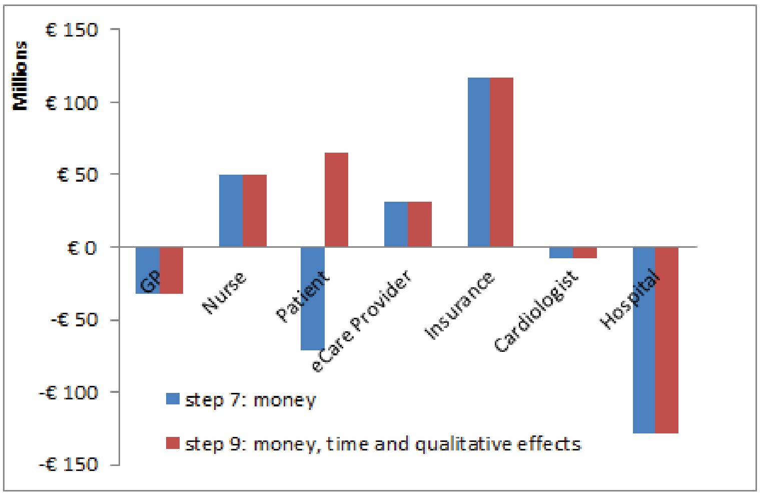


Figure 5.6: Comparison of step 7 and step 9 for every actor

As it is forecasted that there are 256 958 patients in year 10 who use the eHealth service, the patients are willing to pay

$$256\ 958 * (365 + 100 + 50) = 132\ 333\ 370 \text{ €}.$$

This step indicates which actors prefer the current situation and thus form a barrier: the GPs, cardiologists and especially the hospitals (table 5.2).

Current service	**New service**
GP	Insurance
Cardiologist	Nurse
Hospital	eCare Provider
	Patient

Table 5.2: Which actor prefers which service in year 10 (money, time and qualitative effects)

Tackling the barriers

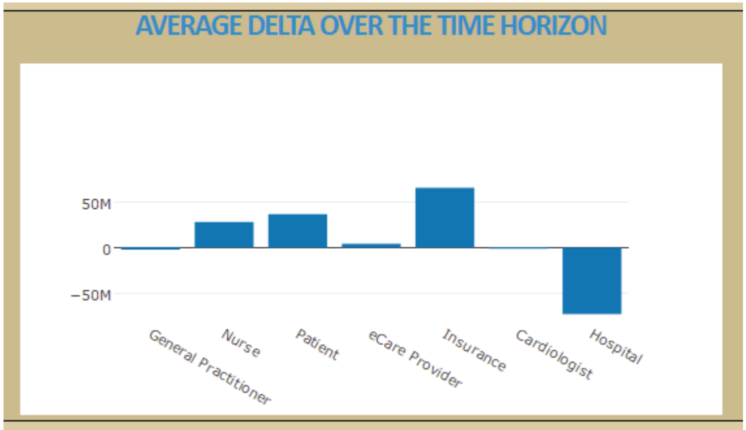
In the tenth and last step the previously encountered barriers are tackled. The average delta for every actor is visualized in figure 5.7b. Two things immediately catch the eye: (i) the insurers benefit a lot from the new service and (ii) the hospitals are by far the greatest victim of the new service if this would be the new situation.

How the barriers are tackled depends on the value of the gap and the ICER. As figure 5.7a reveals, the eHealth service seems to be cost-effective and the gap is positive.

ICER: 79 < 42878

ACTOR	DELTA > 0	DELTA < 0
General Practitioner	/	-1581975
Nurse	25755477	/
Patient	33451953	/
eCare Provider	3893969	/
Insurance	59851639	/
Cardiologist	/	-900570
Hospital	/	-66475810
TOTAL	122953038	-68958355
GAP	53994683	

(a) Summary of the project



(b) Delta for all actors

Figure 5.7: Final results of the telemonitoring case for CHF patients

The fact that the new service is cost-effective and has a positive gap results in various options to cover up the gap in the business case:

1. Reallocations of the costs between the actors mutually.
2: The government can cover up the gap by paying the red actors.
3: A combination of the government acting as a payer and reallocations of the benefits.

For the first possibility the tool provides three different solutions: equal division, proportional division and division based on the financial risk. These are however very hard to realize in practice, as stated in chapter 3.

For the second possibility the tool provides the theoretically maximum limit the government would pay per patient. As this is more than a billion euro and the gap is about 53 million euro, the government can definitely cover all the costs by paying the GPs, cardiologists and hospitals for their loss. This would however be a very unsustainable situation.

The output of the tool stops here. Based on the information provided, the user of the tool can conclude that the methodology indicates that the service has potential to succeed, provided some additional efforts. The main indications are:

- The biggest profit is witnessed for the insurers, while the biggest loss is witnessed for the hospitals.
- The (financial) cost is slightly larger with the eHealth service and is mainly due to the additional working hours of the nurses.
- The additional time investment of the nurses require additional full-time equivalents, which might be problematic
- When the monetary values of time investment and qualitative effects are added, the gap becomes positive. The patient's estimated increase in mobility, knowledge about his own condition and peace of mind are mainly responsible for this.
- To convince the hospital, general practitioner and cardiologist, reallocations are necessary

Additional to this analysis of the telemonitoring service, some things are further investigated. First an elaborated solution is formulated for the reallocations. Secondly the results of a (realistic) change in the input value of a process is examined. At last there is focused on the composition of the total cost of the two situations and on the structure of the costs for the patient. It should be noted that this is done manually by the user.

A possible solution for the reallocations

Firstly the loss for the general practitioner and cardiologist are tackled. The eCare provider charges a monthly fee of 30,44 € to the patient for the complete telemonitoring service. With his current price setting, his average delta equals 3 893 969 €. He is often the driving force behind the success of his innovation: he has to sell the product to the users, in this case the patients. But as they are willing to pay for the telemonitoring service (because it increases their QOL), the eCare provider should focus on convincing the cardiologists (delta of -900 570 €) and general practitioners (delta of -1 581 975 €). If the eCare provider would cover these losses, he would on average still make a yearly profit of 1 411 424 € on top of his desired profit margin, defined as 5 % in step 9. Suppose that the eCare provider goes to the GPs and cardiologists and convinces them to introduce the eHealth service to the patients they treat. For every patient that uses the telemonitoring service (145 275,1 on average over the time horizon of ten years), a monthly sum will then be transacted from the eCare provider (who receives money from the patient) to the GP and cardiologist.

Monthly transaction per patient from eCare provider to GP:

$$\frac{1581975}{145275,1} * \frac{1}{12} = 0,9075 \text{ €}$$

Monthly transaction per patient from eCare provider to cardiologist:

$$\frac{900570}{145275,1} * \frac{1}{12} = 0,5166 \text{ €}$$

This makes the general practitioner and the cardiologist indifferent of which service is used. The eCare provider could also slightly raise the monthly fee so that the GP and cardiologist prefer the eHealth service.

Two barriers are now tackled. The insurer, patient, nurse and eCare provider benefit from the new service, while the GP and cardiologist are indifferent. But the biggest barrier still exists: an average yearly loss of 66 475 810 € for the hospitals. This has two reasons: (1) reduced number of hospitalizations and (2) the wages of the nurses, who have to work a lot more in the new situation.

The hospital plays a major role in the adoption, as they are the one who would implement the new service and pay the nurses for analyzing the monitoring results. The treatment of ill people is a (large) part of the hospital's receiving. In the current context, the hospital has little to no benefits with a more healthy population. This sets the current financing models for hospitals into question. Since there is really no financial benefit to provide this type of services. This calls for the introduction of a (national) financial framework for digital health services.

The biggest 'winners' with the new service are the insurance companies. As the number of hospitalizations reduces, the insurer has less costs (+) and the hospital less receivings (-). An important remark is that the insurance company can be seen as a passive payment office of the government. If the government would act and cover the gap (because the service is cost-effective), it would imply that the profit of the insurer is reallocated over the red actors. So reallocating the profit (which is in fact a saving compared to the current situation) of the insurers comes down to the same as if the government would pay to the hospitals. One could therefore reason that it does not really matter if the money comes from the insurer or from the government itself. The solution proposed is that all the benefits of the insurers in the new situation (savings) are passed to the hospitals. The remaining gap of the hospital (66 475 810 € - 59 851 639 € = 6 624 171 €) is then covered by the government, which is in fact the same actor. This can for example be done through a yearly transaction.

This solution approach is visualized in figure 5.8.

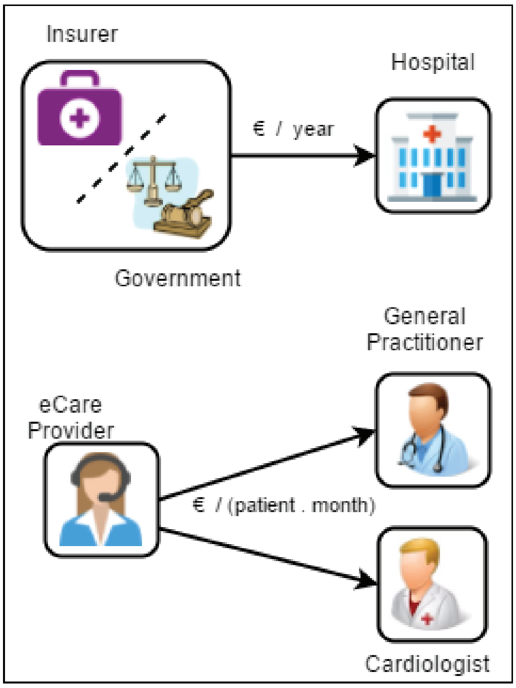
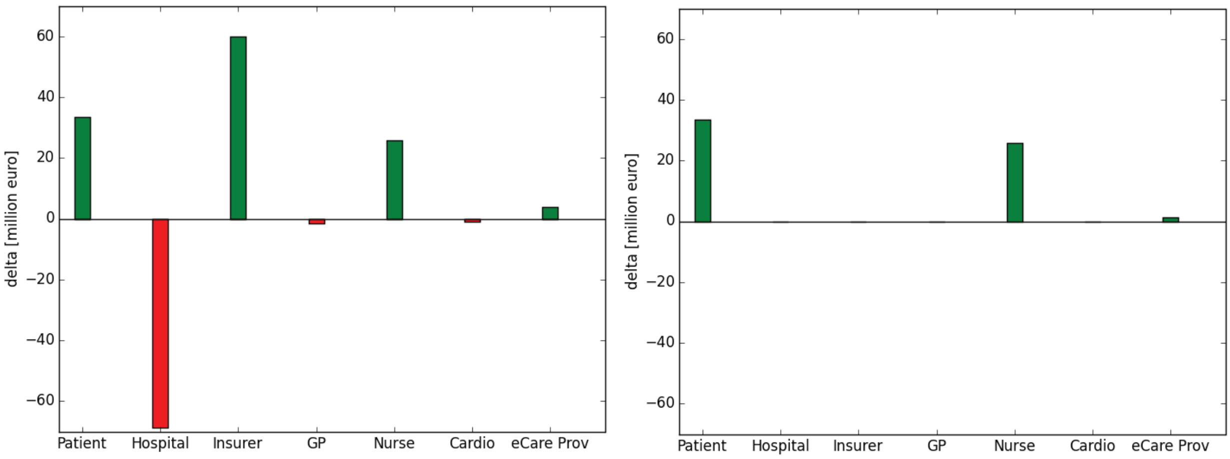


Figure 5.8: Visualization of the proposed reallocation method

The deltas of the actors before and after the reallocations are displayed in figure 5.9.



(a) Before (b) After

Figure 5.9: Delta for all actors: before and after reallocations

This results in three actors who benefit from the eHealth service: the patient, the eCare provider and the nurse. The insurer, cardiologist, general practitioner and hospital are indifferent (table 5.3).

For the general practitioner one could even reason that, with his delta that is now assumed

to be zero, he even benefits from the new service. Assuming there are about 16 000 general practitioners in Belgium, a yearly delta of -1 581 975 € means a yearly loss of about 99 € per general practitioner. Monthly this equal approximately 9 €. As general practitioners often have long working days one could reason that they do not really care for the decrease in consultations of CHF patients [64].
The same reasoning can be followed for the cardiologist, but their decrease in receivings would be about 35 € per month.
These numbers also indicate that especially the hospitals are the biggest victim.

Current service	**Indifferent**	**New service**
/	Insurance	Patient
	Cardiologist	eCare provider
	GP	Nurse
	Hospital	

Table 5.3: Which actor prefers which service after the reallocations

According to the positive value of delta, the nurse benefits from the new service. But it is also stated that there is an enormous increase in the time investment. In the next subsection input values are adapted concerning the time investment of the nurse.

Changing input values

The cause of the large increase in time spendings is the process *CHF nurse analyzes the alarm and contacts patient*.

Currently it is assumed that the average patient generates an alarm once a week and that the nurse spends two minutes to analyze an alarm and six minutes to call and inform the patient. In most cases the CHF nurse judges that the alarm is not serious. The nurse would thus spend six minutes to inform the patient that there is nothing serious going on. Perhaps the nurse only recommends the patient about e.g. his food habits.

Assume now that for non-severe cases the nurse can simply click on a button on the laptop with the monitoring results of the patient, which then sends a certain warning to the patient. This takes about one minute and eliminates the telephone call of six minutes. Assuming that in 75% of the cases a telephone call is not necessary and that an alarm is generated once in ten days per patient (instead of once in seven days) the new input values are:

$$t_{nurse,analyzingalarmandcontactingpatient} = 0,25 * 8 + 0,75 * 3 = 4,25 \text{ minutes}$$

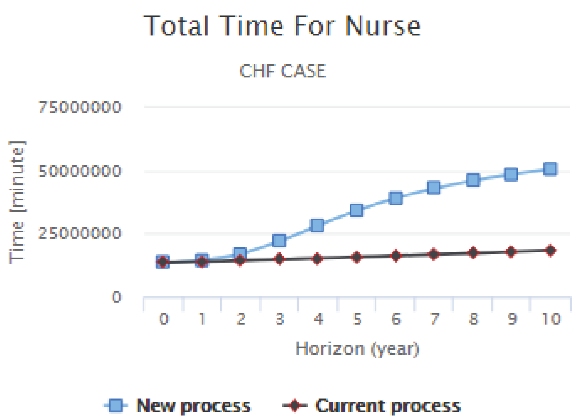
$$t_{patient,analyzingalarmandcontactingpatient} = 0,25 * 6 + 0,75 * 2 = 3 \text{ minutes}$$

$$c_{hospital,analyzingalarmandcontactingpatient} = r_{nurse,analyzingalarmandcontactingpatient} = \frac{30}{60} * 4,25 = 2,125 \text{ €}$$

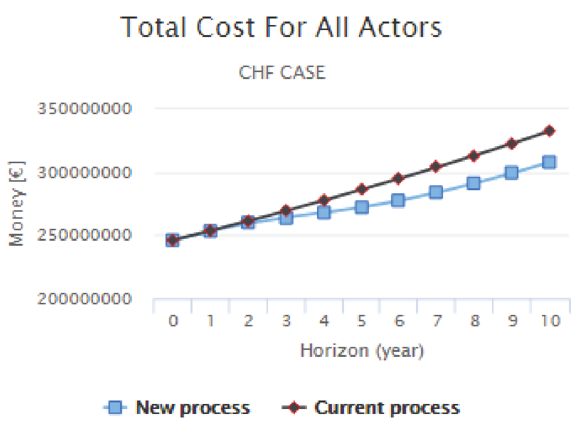
$$f_{analyzingalarmandcontactingpatient} = 36,525 \text{ times per year}$$

These practically realizable changes give remarkable results. Apart from the fact that there is a decrease in the working hours of the nurses (figure 5.10a), the new service now turns out to be less expensive (figure 5.10b). Sheer financially this was not the case before. Adding the monetary values of time investment and qualitative effects again obviously results in a possibly viable business case (figure 5.11).

Apart from these changes, it is fair to assume that in the future the nurse will have to work less than initially predicted. With the increasing capabilities of technology, there will possibly be less false alarms (better measurements) in the future. On top of this, certain tasks of the nurse may possibly be performed by an automated computer system.



(a) Time investment for the nurse



(b) Total cost (sheer financial)

Figure 5.10: Remarkable results of an adjustment in input data for the process *CHF nurse analyzes alarm and contacts patient*

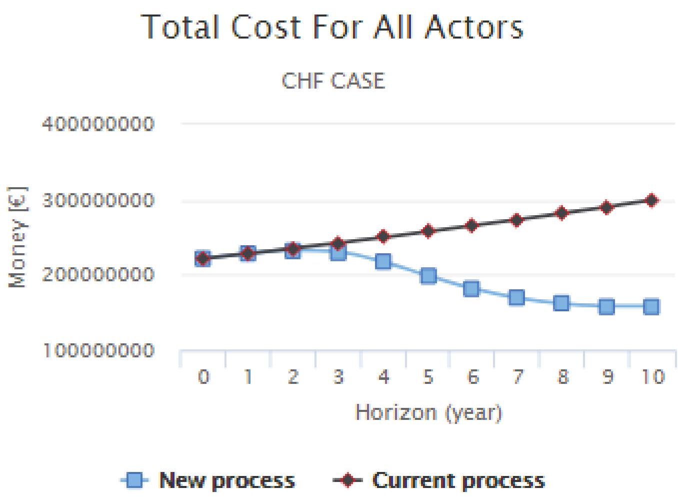


Figure 5.11: The total cost of both situations (money, time and qualitative effects) after an adjustment in input data for the process *CHF nurse analyzes alarm and contacts patient*

This example illustrates that the output is highly dependent on the input data. With this adjustment in the input of the time spendings of a process, the nurses will now have to work maximally about 2,6 times as much. This is a decrease with a factor of more than two, but can however still be a barrier. A possible solution is to involve the general practitioner to the monitoring and analyzing of the alarms, as they spend less time in the new situation.

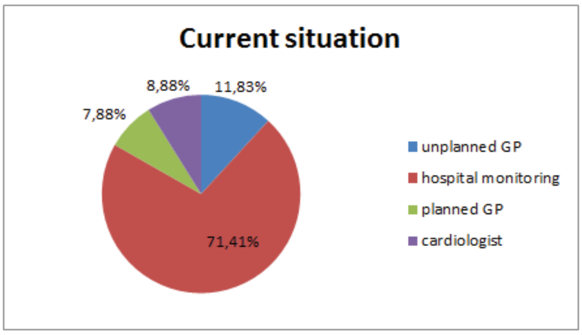
Additional research

The analysis from this section was done based on the output of the tool. It is possible that the user wants to have more information about e.g. the total cost of a certain process. As an example the total cost of the service and the costs of the patients are examined.

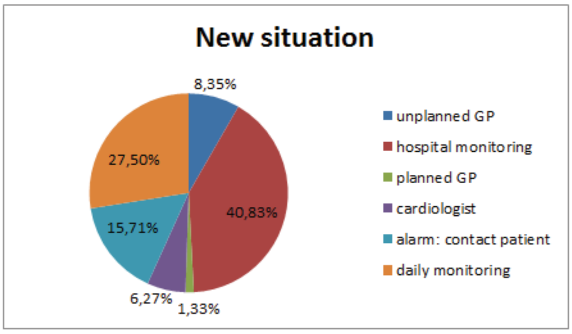
- **Total cost of the service**

As stated before, the costs of treating CHF patients are mainly due to hospitalizations (more than two-thirds of the total cost). To validate this, the share of the various processes in the total cost of year ten is visualized in figure 5.12a, which confirms this: the cost for hospitalizations accounts for about 71% of the total cost in the current situation.

To tackle these high hospitalization costs (which not only result in financial costs but also decrease the QOL of the patient as he has to stay in medical facilities), the potential of a tele-monitoring service is tested with the tool. To have an idea about the share of the various costs in the new situation, the same visualization is displayed in 5.12b.



(a) For the current situation: 332 676 758 €



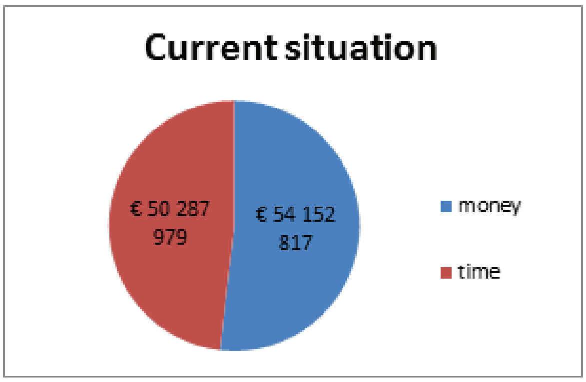
(b) For the new situation: 341 407 886 €

Figure 5.12: Cost of the processes

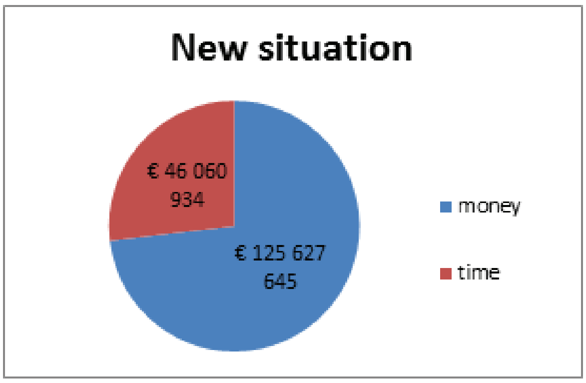
As the frequency of the hospitalization process decreases the total cost of this process decreases (40,83 % of the total cost). The new processes (*daily monitoring* and *analyzing alarm & contacting the patient*) account for 43,21 % of the total cost in the new situation.

- **Cost for the patients**

When the monetary cost of the time investment is added to the pure financial cost, one can see that in the current situation, the cost of the time investment is almost as high as the monetary cost (figure 5.13a, year 10). In the new situation, which requires almost the double amount of time for the patient, the total cost is mainly due to the monetary cost, and less to the cost of the time investment. The cost for the time investment is even less in the new situation. The main reason for this is that in the new situation the time is mainly spent to the daily measurements, to which the patient assigned a very low monetary value (1 € per hour). He feels comfortable with measuring the necessary parameters at home.



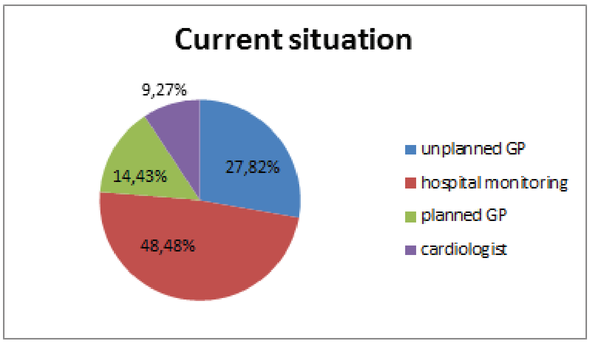
(a) For the current situation: 104 440 796 €



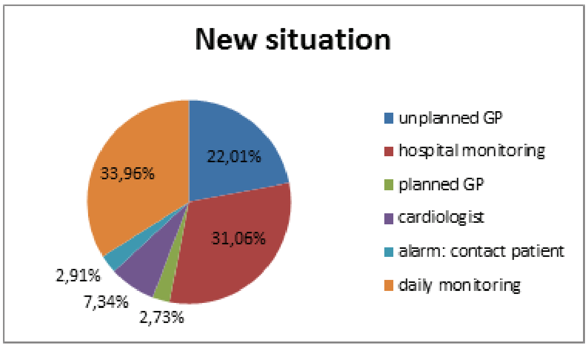
(b) For the new situation: 171 688 579 €

Figure 5.13: Total cost for the patient: monetary cost vs financial cost

The share of the sheer financially value of the various processes is displayed in figure 5.14. This indicates that the new processes of the telemonitoring service are costly for the patient.



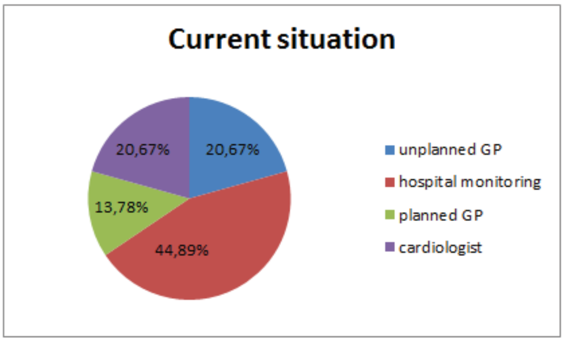
(a) For the current situation: 50 287 979 €



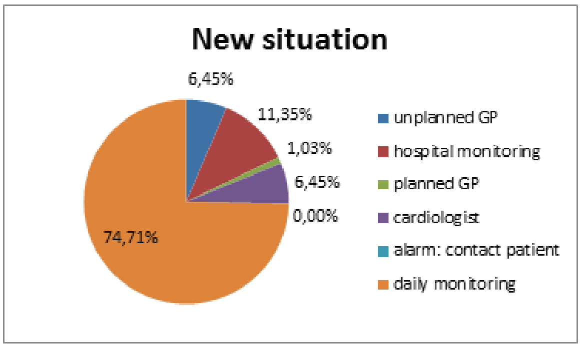
(b) For the new situation: 46 060 934 €

Figure 5.14: Monetary value of time of the different processes for the patient

A closer look to the expenditures of the patient confirms that the daily monitoring (30,44 € per month) is clearly responsible for the higher cost in the new situation (5.15b).



(a) For the current situation: 54 152 817 €



(b) For the new situation: 125 627 645 €

Figure 5.15: Cost of the processes for the patient

In this section the information collected with the tool is analyzed more deeply. There are numerous things that can be further investigated and analyzed: e.g. the distribution of the total time investment, the distribution of the total cost, the distribution of the time investment for a certain actor etc. Some of them may be useful to implement in the web tool in the future.

Conclusion

The web tool processed the input data of the CHF case successfully. Sheer financially, the new service turned out to be more expensive than the current care. However, the monetary values of the time investments and especially the monetary values of the qualitative effects surpass this additional cost and result in a positive value for the gap. It should although be stated that this is in fact a subjective estimation. This case research learned that a (subjective) question like *"What are you yearly willing to pay to experience this effect?"* is fairly easy to answer, be it that there will probably be a lot of variation in the answer, dependent from person to person.

"What is the monetary value of one hour of this process?" turned out to be harder to answer. As the answers will vary and thus cover a certain range, it might be very useful to add a sensitivity analysis to the methodology.

Providing a feature by which the user can answer with a minimum and maximum value on the two questions from above, will give three scenarios: a worst-, expected- and best-case scenario. This can be very important as the CHF case stands or falls with the experienced qualitative effects. If these are e.g. overestimated, the tool can for example wrongly indicate that the gap is positive and the case has the potential to get adopted.

A sensitivity analysis will not only be useful for the time investment and qualitative effects, but it might also come in handy for the input data. In the investigated case, the number of alarms generated per patient is uncertain. A sensitivity analysis could indicate that simply by having less alarms, the barrier of the large time investment of the nurse could disappear.

In the current context, the hospital has no benefits with a more healthy population. This sets the current financing models for hospitals into question. Since there is really no financial benefit to provide this type of services. This calls for the introduction of a (national) financial framework for digital health services.

5.1.2 Case 2: SMART-project

Introduction of the concept

The second investigated case is a proposal around an innovative mHealth service. This proposal tries to tackle one of the biggest frustrations in the waiting room of a general practitioner: the waiting queue. It is not very comfortable, the patient is surrounded with other ill people or people in pain, and most of the time the patient is bored. The main idea of this fictive mHealth service is to replace the ongoing physical waiting line with a virtual waiting line. It will not have a significant change on the health status of the patients, but will improve the queuing process. This innovative service is named SMART.

The idea is analyzed on a conventional general practitioners practice, which has on average approximately 1200 unique patients [65], [66]. Every day the general practitioner works, the practice is open for consultations with an appointment (called fixed consultations) during the first three-fourth of the day and for consultations without an appointment (called free consultations) during the last one-fourth of the day. For a fixed consultation the patient has to call the general practitioner and arrange a time slot. However, for a free consultation the patient does not need to call the general practitioner. Instead the patient has to go to the practice and queue in the waiting room according to the FIFO method. This is a reasonable approach to treat everyone in a satisfying and relatively fast manner. Research provides different numbers about the number of consultations per unique patient each year [67] [65]. An arbitrary value of seven consultations each year is taken into account in this analysis.

With the innovative approach, for every fixed consultation the patient again makes a call with the general practitioner and arranges a time slot. The general practitioner puts this information (the patient's name, his mobile phone number and the agreed time slot) in a program on his computer. Until this point the procedure is similar to the current approach. However now on the day of the appointment, instead of going to the practice on the agreed time, the patient gets an automated notification about the time lag on the general practitioner's schedule. At last a final notification is sent to the patient (depending on the distance between his home and the practice), when it is almost time for his consultation. In this way the patient avoids long queues in the waiting room, if the general practitioner is running behind his schedule. Besides this, in the rare case that the general practitioner is ahead of his schedule, the patient will also be notified. This creates a win-win situation for the general practitioner and his patients.

For every free consultation the patient sends a text message to the general practitioner on the desired day. In this text message the patient specifies the hour from when he is available. The patient will get an automated reply with the first available free time slot that satisfies the implied constraints that day. When all the available time slots of that day are occupied, new incoming text messages will be replied by a text message that informs the patient of this problem. The patient has now 3 options. First of all he can choose to get a free consultation the next available day. Secondly he can call the general practitioner in case of an emergency, maybe the general practitioner can work overtime to treat the patient. Finally the third option is to make a fixed appointment with the general practitioner. Again, using this system, the patient will get a notification when it is almost time for the consultation.

By implying this innovative service it is assessed that emergencies can still be treated, long queuing periods are avoided and patients are more informed. Patients who ignore these notifi-

	worst	realistic	best
average waiting time current process	15	22,5	30
average waiting time new process	10	7,5	5

Table 5.4: Worst-case, average-case and best-case scenario for the SMART project

cations and hereby arrive too late at the general practitioner will be penalized in some form.

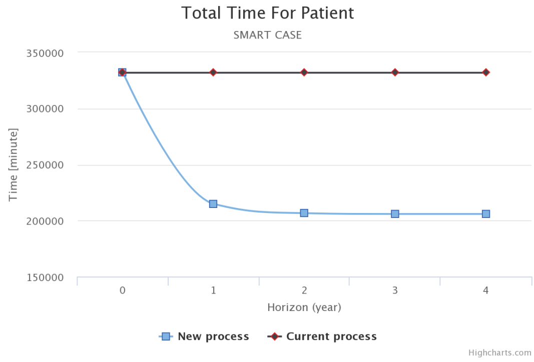
Waiting times vary from practice to practice and from day to day. To cope with this variation, three scenarios are tested on this innovative idea. These scenarios are shown in table 5.4. In the following subsections the average-case situation is discussed deeply. At the end a comparison is made between the gap in the three scenarios and, if necessary, between the reallocation proposals. Four actors participate in the services. The patient itself, the eCare provider, the general practitioner and the insurance company.

A first comparison

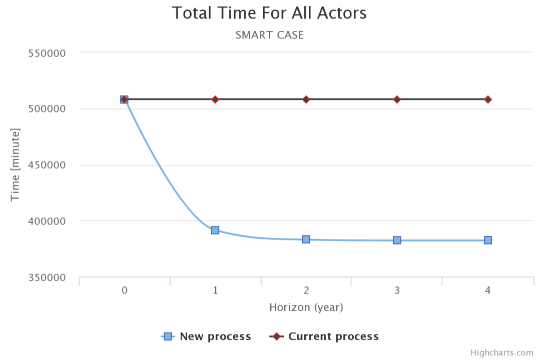
After entering all the input data asked for in the previous steps, a first comparison can be made in step 7. Here, the tool gives an overview of the total invested time and total costs/benefits for each actor. Figure 5.16 depicts the most important results of this step. One should keep in mind that these figures relate to the average-case scenario. Two things stand out:

1. The total time for the patient decreases enormously, as shown in graph 5.16a. The other actors' invested time stays the same in the new situation. Consequently this results in a decrease of the sum of the total time for every actor in the new process. This effect is illustrated in graph 5.16b.

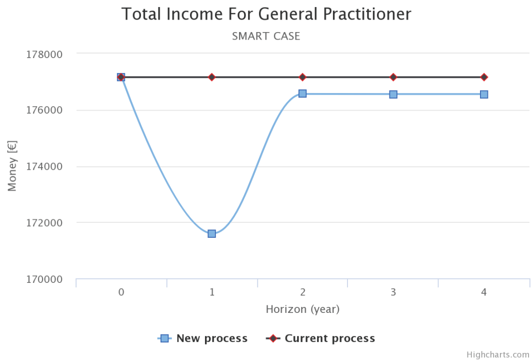
2. The general practitioner pays the eCare provider for the installation costs of the new service at his practice. This results in a decrease of his income, shown in figure 5.16c. Graph 5.16d shows that the eCare provider has less expenses than income. The total cost for all the actors is depicted in graph 5.16e. One can determine by looking only at the financial flows that the new service is more costly than the old service.



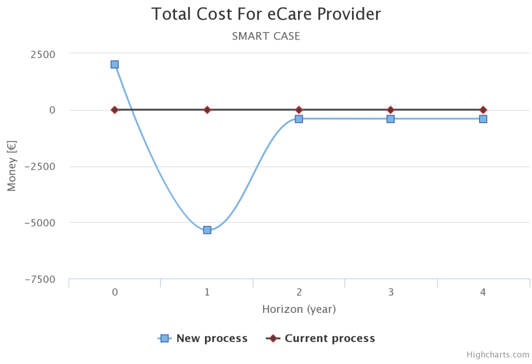
(a) Time in both situations, Patient



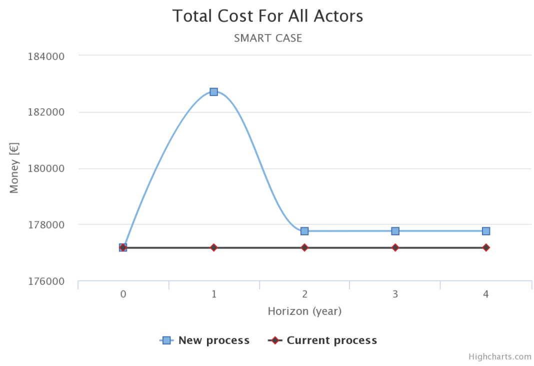
(b) Time in both situations, Total



(c) Income in both situations, GP



(d) Cost in both situations, eCare provider



(e) Cost in both situations, Total

Figure 5.16: A first comparison: average-case scenario SMART-project

Table 5.5 gives an overview of the preferred service for every actor, only considering the criteria of total receivings / total cost. The patient and the insurer are indifferent because the price for a consultation is the same in both situations. The GP prefers the current situation. He has no extra income but only extra costs in the new service (installation and maintenance cost of the software, paid to the eCare provider). The new service is preferred by the eCare provider. His income exceeds his costs.

Current service	Indifferent	New service
GP	Patient Insurance	eCare Provider

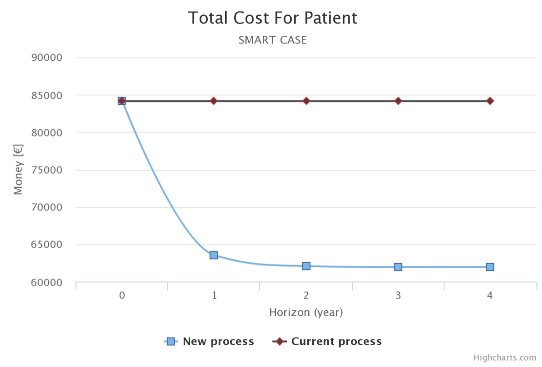
Table 5.5: Which actor prefers which service in year 4 (pure financial)

Barrier identification

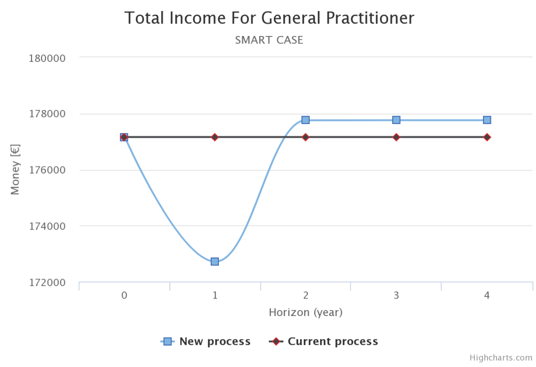
As explained before, step 9 converts the qualitative effects and the time investments into monetary values. For every actor these are added to his total income or total cost. For the insurance companies and the eCare provider this conversion has no effect. Their total income/cost is the same as in step 7. The patients however are willing to pay one euro each year for the increased service satisfaction due to the reduced waiting times. The monetary value of time for a patient in the waiting room is set to ten euro per hour. The general practitioner is willing to pay one euro per unique patient each year for several reasons. Two of them are the patients increased satisfaction of his service and the fact that he has more control over his agenda.

Graph 5.17a and 5.17b show the change in the total income/cost graph for respectively the patient and the general practitioner. The total cost for the patient decreases significantly. This is mainly due to his decrease in waiting time, which was converted into monetary value at the beginning of this step. For the general practitioner a decrease in his profit can be seen after one year, due to the installation costs of the software. The following years his profit increases above the current situation level as a result of his positive qualitative effect, explained in the paragraph above.

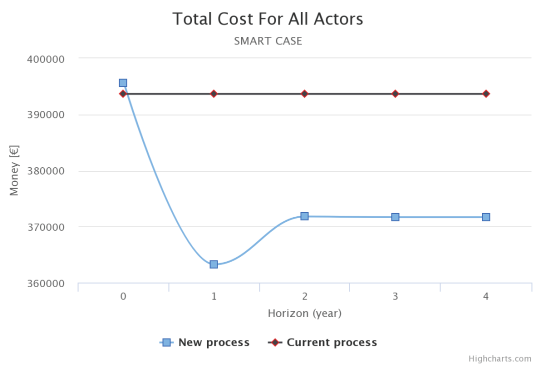
Graph 5.17c illustrates the total cost for all the participating actors. It is clear that the total cost over the time horizon decreases. Comparing this graph with the total cost graph in step 7 (graph 5.16e) shows the effect of the reduced time investments and the positive qualitative effects. In contrast to step 7, one can now clearly determine that the new service is preferred above the current service. However, this not necessarily means that the new service will be adopted. It is very likely that at least one actor will have a negative delta. In that case some reallocations will be needed.



(a) Cost in both situations, Patient



(b) Loss over time, eCare Provider



(c) Loss over time, eCare Provider

Figure 5.17: Identification of barriers: average-case scenario SMART-project

To gain a clear indication of the preferences of each actor, the deltas are calculated. These can be found in table 5.6. As already derived from the graphs, the patient clearly prefers the new situation. The eCare provider also has a slight preference for the new situation. The insurer stays indifferent and the general practitioner prefers slightly the current service above the new service. The negative gap of the general practitioner forms a barrier, which is tackled in the next step.

Actor	**Delta**
Patient	87080
General practitioner	-2646
eCare Provider	4554
Insurance	0
TOTAL DELTA	88988

Table 5.6: Deltas for every actor

Tackling the barriers

Step 10 tries to tackle the barriers found in step 9. First the cost-effectiveness of the new service is checked, which is done by calculating the ICER. The ICER is the difference in total cost between the services divided by the difference in efficacy of the services. However, the health status of the patient stays the same in the SMART-project. In other words, the denominator of the equation will be zero. The cost-effectiveness calculation cannot be used in such a project. The web tool gives a warning about that, shown in figure 5.18. Naturally the tool does not stop here. Even though the ICER of a service cannot be calculated, the service still has potential to be adopted if a positive gap is obtained.

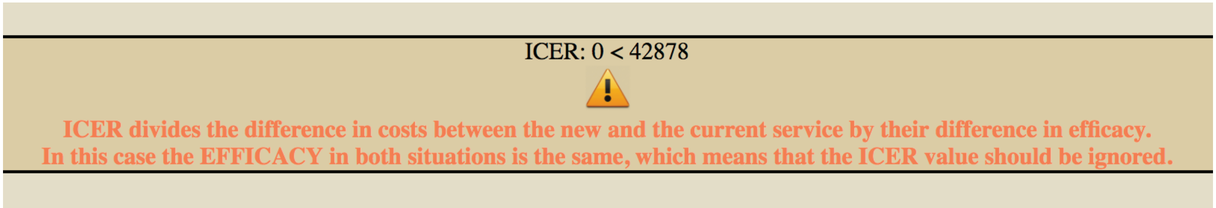


Figure 5.18: Total cost of the service (financial + time + qualitative effects)

The three scenarios (worst-, average- and best-case) explained earlier are compared and analyzed now. Figure 5.19 depicts the average deltas over the time horizon for every actor for the three scenarios (in table and bar chart form). In step 9 was concluded that only the general practitioner forms a barrier in the average-case scenario. The same goes for the worst-case and best-case scenarios. In every scenario a positive gap is obtained. Consequently reallocation methods are proposed.

Before looking at the reallocation proposals, some research is done concerning the critical value of the monetary value of time at the waiting room of the general practitioner for the patient. When the monetary value of the qualitative effect is set to zero, the worst-case scenario still generates a positive gap. Only when the monetary value of time at the waiting room of the general practitioner for the patient is set to 1,01 € or lower, a negative gap is generated. In this case the new service will probably never be adopted. In all the other cases the new service has potential to be adopted, but some reallocation of monetary flows is needed due to the negative delta of the general practitioner.

ACTOR	DELTA > 0	DELTA < 0
Patient	5963	/
eCare Provider	911	/
General Practitioner	/	-1000
Insurance	0	/
TOTAL	6874	-1000
GAP	5874	

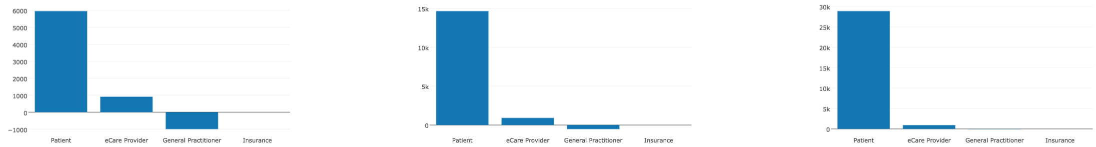
(a) Worst-case

ACTOR	DELTA > 0	DELTA < 0
Patient	14671	/
eCare Provider	911	/
General Practitioner	/	-529
Insurance	0	/
TOTAL	15582	-529
GAP	15053	

(b) Average-case

ACTOR	DELTA > 0	DELTA < 0
Patient	28871	/
eCare Provider	911	/
General Practitioner	/	-58
Insurance	0	/
TOTAL	29782	-58
GAP	29724	

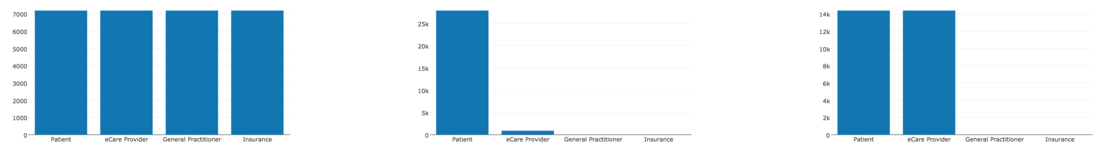
(c) Best-case



(d) Worst-case (e) Average-case (f) Best-case

Figure 5.19: Tables and bar charts of the deltas: SMART-case

The suggested reallocations for the average-case scenario are discussed here. Note that the reallocations suggested for the worst-case and best-case scenarios are very similar. This is because of the positive gaps and the proportionality of the deltas. At first the tool suggests three reallocation proposals. The equally divided reallocation, the proportionally divided reallocation and the reallocation based on financial risk (50% of the gross margin goes to the eCare provider) are shown in figure 5.20a, figure 5.20b and figure 5.20c respectively. To avoid misunderstandings, in every bar chart the bars from left to right represent the deltas of respectively the patient, the eCare provider, the general practitioner and at last the insurance.



(a) Equally divided reallocation (b) Proportionally divided reallocation (c) Division based on the financial risk

Figure 5.20: Three reallocation proposals: SMART-case

The proportionally divided proposal looks odd in this case. The general practitioner and the eCare provider should get a significant part of the total profit, due to their made investments. For the same reason the proposal based on the financial risk is far from optimal, here the GP has again no profit at all. The equally divided proposal appears to be fair. However, one can argue about why the insurer should profit of this new service, because nothing changes at all for him. For this unfair situation the tool provides an extra function. A preferred percentage of the global profit can be reserved for an actor of choice. This is illustrated in figure 5.21.

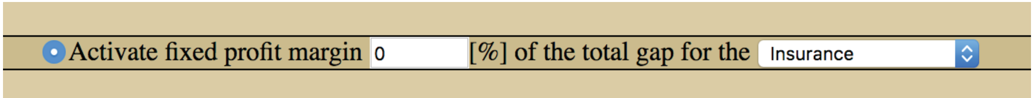


Figure 5.21: Reserve percentage of total profit for an actor of choice

Here, the percentage is set to zero for the insurer. In this way the insurer does not benefit nor does he experience any major setbacks compared to the current service. Or in other words, his delta is set to zero. Activating this button generates two new proposals. The first one based on the equally divided reallocation, the second one based on the proportionally divided reallocation. Logically the second one will be similar to the one without the activation of the button, as a result of the delta of the insurer being zero already in that proposal. In figure 5.22 the new equally divided proposal is shown. This seems to be a very reasonable proposal, all the main actors benefit from the new service.

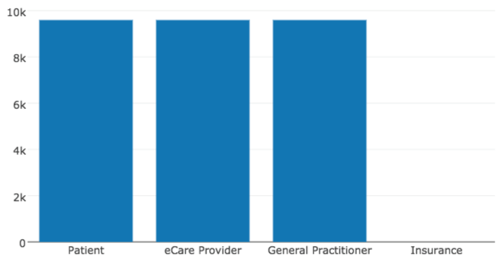


Figure 5.22: Equally divided reallocation proposal: 0% profit margin for the Insurance

Conclusion

The input data of the SMART-project were successfully processed by the web tool. Only one problem came up while entering the data. The methodology does not directly provide an input field for a one-off cost from one actor to another actor, independent of the number of patients. An installation cost (for installing the software at the general practitioner) of 5000 € from the general practitioner to the eCare provider is necessary. This problem was solved by entering the input depicted in figure 5.23. This cost is explained in the one-off costs section of chapter 3.2.4. The monetary value is set to 5 000 € and the number of patients to a very large number, in this case 100 million. This means that the general practitioner has to pay 5 000 € per 100 million patients. By using this simple trick the population independent one-off transaction is correctly implemented.

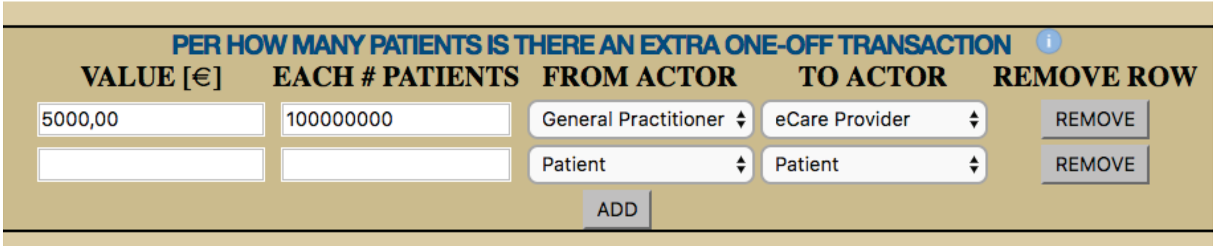


Figure 5.23: solution for the installation cost in the SMART-case

Sheer financially, the new service turned out to be more expensive than the current one. However, the monetary values of the qualitative effects and especially the monetary value of time in the waiting room for the patient surpass this additional cost and result in a positive value for the gap. One should keep in mind that this is a subjective estimation. However the analysis shows that even when the qualitative effects are ignored and the monetary value of time for the patient at the waiting room is set to 1,02 €, still a positive gap is reached. This emphasizes the potential of the project.

The SMART-project showed that improved processes, without any effect on the health status of the patients, can be analyzed and compared with the tool. Only the cost-effectiveness criterion should be ignored. This indicates that the methodology is perhaps also applicable for non-health related projects.

5.2 Evaluation of the methodology

5.2.1 Cost-effectiveness

Section 2.3 described the use of a Cost-Effectiveness Analysis, which makes part of a Health Technology Assessment. The aim of such an analysis is to determine the cost per QALY of a healthcare service. This cost is then compared to the societal willingness to pay. If it is lower than this limit, the service is considered cost-effective. The fact that a treatment is cost-effective can then be used as (one of the) condition(s) to determine if the government should foresee reimbursements for this service. The measure 'what is the monetary value of one life year' is not straightforward and will always be discussable. In this section the use of cost-effectiveness in the methodology is evaluated.

Cost-effectiveness as a measure for reimbursements

The amount of money a government can assign to healthcare is limited. This is one of the reasons why they cannot foresee reimbursements for everything. In the designed methodology, cost-effectiveness is the only criterion used to determine if the government can act as payer. In practice this is just one of many criteria to determine if a certain health intervention should be reimbursed [68]. If the tool states that the new service is cost-effective, one cannot conclude from this that in practice the service will definitely be reimbursed.

The introduction of many new cost-effective healthcare services could be problematic because the budget is limited. It is unlikely that the current reimbursing systems will still be sustainable in the near feature. If many new services are validated with the web tool and seem to be cost-effective one cannot simply assume that the government will act as a payer.

The average remaining life expectancy

In step 2 there is asked for the expected remaining life years of the patient. This is not always an easy question to answer. For example for COPD patients the symptoms and the severeness can be very different from patient to patient. No data was found on the web about the average remaining life expectancy for CHF patients. Based on the mortality rate and the median age of the patients an estimation was made for the remaining life years. This value is then used to determine the maximum amount the government can cover yearly.

Use of the EQ-5D method to determine the index

The EQ-5D method is one way to assess the qualitative effects and determine the incremental cost-effectiveness ratio. When the web tool was tested via case research, it was sometimes found difficult to answer the questions. Especially for the patient briefcase, where pilot projects indicated that the teleconsultation service has a high costs and the qualitative effects for the patients are little. However, patients were satisfied with the service and rather prefer this one (apart from the cost) where they are at home, rather than being hospitalized. With the EQ-5D method there is only asked for five specific effects (mobility, peace of mind,...) with three possible answers for each effect. These three answers are e.g. (approximately equal to) perfect mobility, average mobility, confirmed to bed. With the patient briefcase there is a little increase in the patient's mobility for a few days per year because the patient is at home instead of in a hospital bed. So averaged over a whole year, there is a small increase in his mobility. The same holds for e.g. 'performing daily activities', which is easier at home than in the hospital. But this difference between the two services is too little to say that in the current service the patient has for example 'average mobility' and with the new service 'no problems concerning mobility'. If one would however select these answers, the denominator in the formula of the ICER would increase with a relatively high amount and thus result in a lower value of the ICER. The principle of the EQ-5D method seems good, but it might be valuable to have for example five different answers per question.

5.2.2 Market targeting

In step 2 there is asked to give in the initially targeted number of customers. As the Belgian population is currently growing, in most cases the targeted population will also grow over the time horizon. To estimate the size of the market target in the future years, there is asked to give in a fixed percentage per year, which represents the yearly growth. This method would finally result in an infinitely growing population. For a time horizon of e.g. ten years this will not be a problem. It might however be necessary that in the future this target size is estimated in a different way.

In this step it is also asked to give in the yearly mortality of the patients as a fixed percentage per year. This is however a simplification: for example with chronic heart failure the mortality in the first year following diagnosis is 26% and after five years 50 %.

When estimating the number of customers in each year with the new service, it is assumed that all the patients who do not use the eHealth service, use the current service. Apart from the current care, no other new services are available: it is assumed that there is no competition.

5.2.3 The costs for the eCare provider

Estimating the costs of the eCare provider

Estimating the costs of the eCare provider is an important step. It is highly likely that the eCare provider will be the user of the web tool. If this is the case, there is of course no better person who can estimate the costs for the service. If the latter is not the case, it can be hard to estimate the costs.

Lifespan of equipment

The lifespan of technological parts of a service has not been taken into account in the methdology. In practice equipment has a limited lifetime (e.g. laptops, sensors). After a certain time (e.g. 8 years), often an additional cost to replace the equipment is incurred. The tool does not provide a possibility to give in a one-time cost on a specific moment in time.

Net Present Value (NPV)

The eCare provider probably wants to know from which moment in time his startup costs are covered and he starts making profit. Currently his receivings are compared with his costs, which gives the cumulative profit. This cumulative profit does not take into account the time value of money. To do so and analyze the profitability of a projected investment in time, the NPV can be used. Net Present Value is the difference between the present value of cash inflows and the present value of cash outflows. It is used to analyze the profitability of a projected investment. Generally, an investment with a positive NPV will be a profitable one.

$$NPV = \sum_{t=0}^{N} \frac{CF_t}{(1+r)^t}$$

Where:
t = time of the cash flow
CF_t = cash flow at time t
N = total time period of the project
r = discount rate

It is strongly recommended that in the future the future cash flows are discounted over time. This gives a much better view on the profitability of an investment. However NPV has some uncertainty on its used variables. This can be countered by implying a sensitivity analysis.

Economies of scale

Some costs will not increase linear with the number of customers. Typical, the cost for the first few customers is higher than for the following customers. This is among other things due to the fact that infrastructure can be bought in bulk. These are economies of scale for the eCare provider. The methodology does not provide an input that can handle economies of scale.

5.2.4 Monetary value of time and effects

As already stated in the conclusion of the SMART service and the telemonitoring service for CHF patients, the monetary value of time and the monetary value of qualitative effects are a subjective measure. In both cases, the eHealth service is found to be more expensive than the current care. The willingness to pay for a certain time reduction (e.g. SMART: less waiting) or a time investment in another, more comfortable process (e.g. CHF: additional time investment of daily measurements is preferred over more time spent in the hospital), on one hand and the willingness to pay for qualitative effects (e.g. CHF: patient's increase in peace of mind) on the other, resulted in a positive gap. On the condition that there is a reallocation of the benefits/costs, the methodology indicates that the service has the potential to succeed.

This can however not be assured because the input data are possibly unreliable. In order to assess the value of the time and effects as good as possible, it is recommended that this is personally estimated by the relevant actors and by as many persons as possible. The input value is then the average of the various answers.

It should be noted that before a monetary value is assigned to a qualitative effect, it first needs to be identified. As mentioned in section 2.2.3, the effects of a new eHealth service are often unclear.

It is practically not always achievable to obtain this value-estimation from the actors themselves. As the web tool can be used for a relatively fast assessment of the potential of a (pre-developed) digital health service, it would be very useful if the user can specify a range for the uncertain input data.

5.2.5 Sensitivity analysis

Providing a feature by which the user can answer with a minimum and maximum value on the two questions concerning the monetary value of time and effects, will give three scenarios: a worst-, expected- and best-case scenario. This can be very important as the CHF case stands or falls with the experienced qualitative effects. If these are e.g. overestimated, the tool can for example wrongly indicate that the gap is positive and the case has the potential to get adopted.

A sensitivity analysis will not only be useful for the time investment and qualitative effects, but it might also come in handy for the input data of the processes. In the investigated CHF case the number of alarms generated per patient is uncertain. A sensitivity analysis could indicate that simply by having less alarms, the barrier of the large time investment of the nurse could disappear.

5.2.6 Analyzing the time investment and cost of specific processes

The tool provides a comparison between the current situation and the new situation for every actor in terms of total time investment and total profit/loss. Currently the composition of the total cost for an actor is unknown. If the new situation is for example more expensive, the tool will indicate this. There is however no information provided concerning the reason of this increase. A visualization of the share of the various processes in the total cost for an actor in the current situation, and one for the new situation, would clarify the cause. Enough input data are entered by the user to generate these visualizations.

For every actor, eleven circle diagrams can be generated for the current and the new situation, that each visualize the fraction:

1. to which process his costs go,
2. to which actor his costs go.
3. from which process he gets his income.
4. from which actor he gets his income.
5. to which process his time is spent [min].
6. to which process his time is spent [€].
7. of monetary value of his qualitative effects [€].
8. to which process the sum of all his costs/receivings goes.
9. to which process the sum of all his costs/receivings goes.
10. to which category (money, time or qualitative effects) his total costs belong.
11. to which category (money, time or qualitative effects) his total receivings belong.

In the same way, for every process in the current and the new situation six circle diagrams can be generated, who each visualize the faction:

1. to which actor the costs go.
2. to which actor the income goes.
3. to which actor the time is spent [min].
4. to which actor the time is spent [€].

5. to which actor the total costs belong.

6. to which actor the total receivings belong.

A comparison between the current and new situation can be made, based on these circle diagrams explained above. An example for the total cost (time + negative qualitative effects + costs) of the patient is illustrated in figure 5.24.

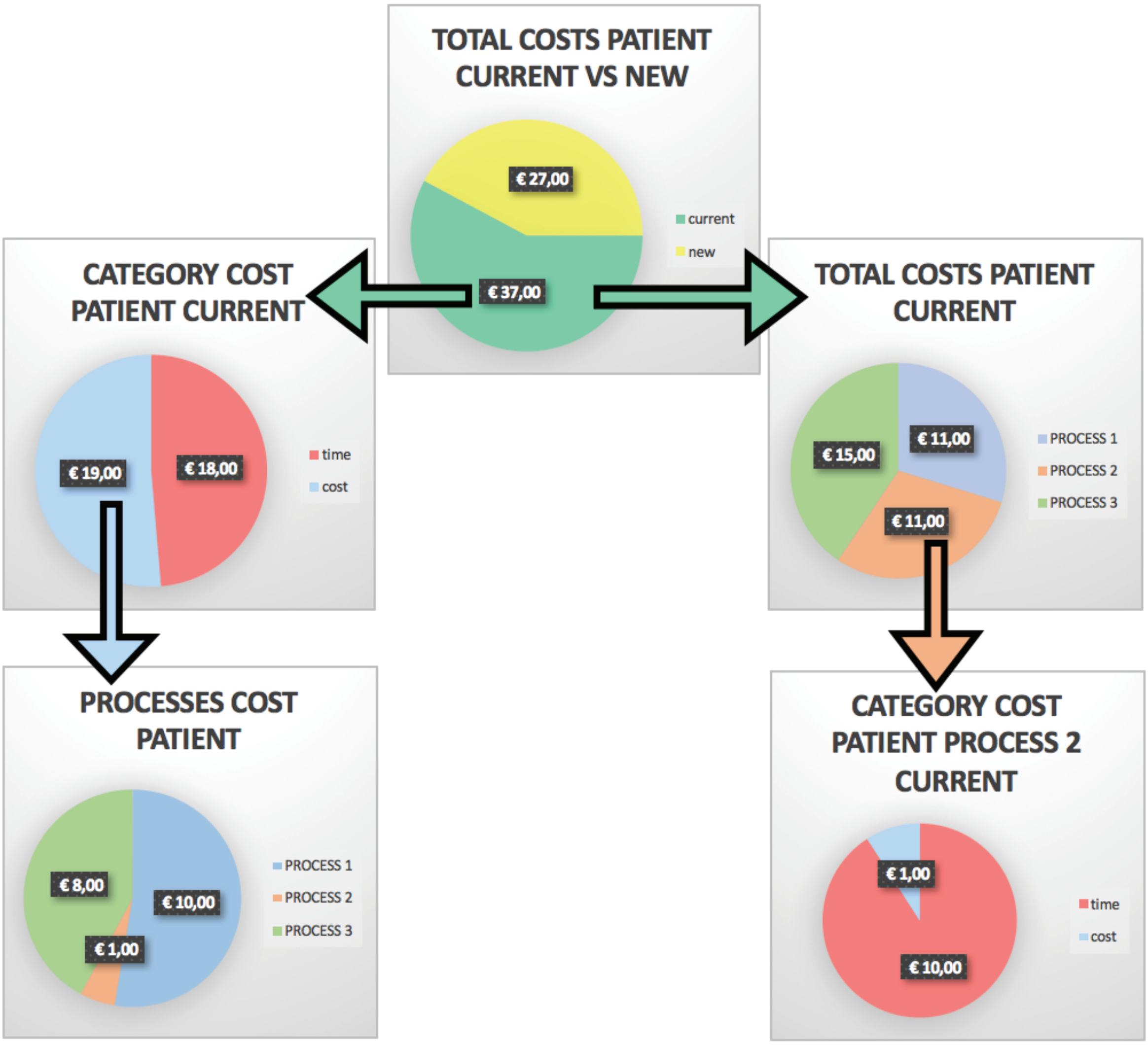


Figure 5.24: Circle diagram of the total cost for the patient (current vs new situation)

5.3 PEST-analysis

The defined methodology considers mostly the financial picture of a service. However, political parameters like regularization and government incentives, economic parameters like inflation rate, legal parameters like health law, etc. are mostly ignored. These parameters could help to see the bigger picture. Therefore it could be interesting to add a PEST-analysis (Political, Economic, Social and Technological), or one of its many variants, to the defined methodology. In this way the tool would be able to take, among others, sociological issues into account.

5.4 Conclusion

In this section the tool has been successfully validated with three cases. The results of this case based research are promising: the tool was able to retrieve input data in a user-friendly way and can assess relatively fast if a new eHealth service has the potential to succeed. The basis is provided for an online validation tool. To improve the current version, a sensitivity analysis can be added. This chapter ends with a list of pros en cons of the web tool, experienced during the testing (table 5.7).

	PROS	**CONS**
1	The tool is well organized, clear and to the point.	More detailed calculations on the input could be performed. For example circle diagrams that indicate the costs of an actor.
2	Every step, the project in progress is automatically saved. This assures that users can develop and analyze their projects at a later time.	A sensitivity analysis could invigorate the reliability of the output of the tool.
3	The required process schemes can be easily drawn and adjusted.	A personal login-interface could be added. In this way users only have access to their own projects.
5	The investigated cases were manually recalculated. It is fair to say that the calculations in the tool are reliable.	
6	When something unusual happens, the tool mostly generates a warning.	
7	The user is assisted by the tool in an intrusive manner. When more information is needed, the user can hover or click on the information icons on almost every web page.	
8	The tool tries to reduce the margin of input errors caused by the user.	

Table 5.7: Positive and negative points of the web tool

Chapter 6

Conclusion and future work

6.1 Conclusion

Driven by an aging population and new costly technologies, eHealth services hold the potential to reduce the healthcare expenditures and increase the quality of care. However, the adoption of these services seems challenging and often fails.

One of the main encountered barriers for adoption is the lack of a financial support/ the unclear business model. Integrating digital health services often require additional efforts from professional care providers (e.g. extra administrative work). As there is currently no clear financial structure or compensation for this, their motivation to adopt and support these services is and will remain low.

Another important barrier is that the added value of eHealth services is unclear. These services will impact more quality of care and quality of life, which is harder to measure and quantify than quantitative effects such as the total cost of a service. Every actor wants to know *'What is in it for me?'* before accepting the new service.

With this motivation, the goal of this master thesis was threefold:

1. Defining a methodology for performing cost-effect and cost-utility analyses of eCare service versus the usual care from the perspectives of the various stakeholders.
2. Identification of potential barriers for adopting the eCare or mHealth service followed by suggestions or opportunities to tackle these barriers.
3. Development of a generic model in the form of an online tool that will allow a) validation of the methodology and barrier identification and b) other users to evaluate an eCare or mHealth service of their interest.

The first two goals resulted in a ten-step plan. The focus during the development of it was to ask for data in a user-friendly way, to process this data correctly (= detect a possible gap in the business models of the various actors) and formulate possible solutions to tackle the previously identified barriers. Every step and method of the methodology is hereby continuously validated using one main case: a telemonitoring service for CHF patients.

This methodology was then successfully translated into an online tool, which can be used by any person that wants to validate an innovative eHealth service. The performance of the tool was tested via three cases. The results were promising: the tool seems robust as no problems occurred while inputting the data, barriers were identified and solutions were provided to tackle these barriers.

It should however be stated that the tool should be used as an assessment of the feasibility of service. No definitive conclusions can be made based on the output of the tool. Subjective measures as the monetary value of time and qualitative effects are used to assess the potential of the eHealth service.

It can be concluded that the goal of the master thesis is accomplished. A methodology is developed and provides the basis for a well-working pre-development validation tool. It might in fact also be used to compare two non-healthcare related services, preferably a new service versus the current one.

6.2 Future work

There is one valuable thing that the tool currently lacks: the possibility to perform a sensitivity analysis. There are after all a lot of input variables which can show variability (e.g. the time spent to a certain process) or that have to be estimated (e.g. the number of customers in a certain year on the time horizon). Allowing to specify the range in which the input variables can vary could result in some valuable insights. In that way the final step would provide a worst, average and best case scenario.

Apart from the sensitivity analysis, the methodology seems to be complete. The structure and mindset seems to be on point. If in the future the methodology/tool would be further developed, it is recommended to focus on the single steps in detail as the bigger picture seems to fit. Some simplifications are made: for example in step 2, where the market target is estimated via a Gompertz-curve, it is assumed that there are only two services available: the current care and the new eHealth service. Every targeted customer uses or the current care, or the eHealth

service. Game theory may be applied.
Another important recommendation for future work concerns the Net Present Value (NPV), which is currently not used. It can be used to estimate the future profitability of the investment of the eCare provider by taking the discount rate into account.

Concerning the web tool itself, a user specific login-interface could be implemented. Now every user can access and manipulate all the existing projects. With a user specific login-interface a user has its own projects with which no one else can interfere if they do not posses the needed credentials. The margin of error can be more reduced in the future, by implementing an expansion of the imposed restrictions and rules.

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Appendix A

Utilities according to the EuroQol 5D profiles

State	Score
11111	1.0000
11112	0.7444
11113	0.3847
11121	0.7641
11122	0.6607
11123	0.3010
11131	0.4241
11132	0.3207
11133	0.2173
11211	0.8170
11212	0.7136
11213	0.3539
11221	0.7333
11222	0.6299
11223	0.2702
11231	0.3934
11232	0.2900
11233	0.1866
11311	0.5300
11312	0.4266
11313	0.3232
11321	0.4463
11322	0.3429
11323	0.2395
11331	0.3626
11332	0.2592
11333	0.1558
12111	0.7651
12112	0.6617
12113	0.3020
12121	0.6815
12122	0.5781
12123	0.2184
12131	0.3415
12132	0.2381
12133	0.1347
12211	0.7344
12212	0.6310
12213	0.2713
12221	0.6507
12222	0.5473
12223	0.1876
12231	0.3108
12232	0.2073
12233	0.1039
12311	0.4473
12312	0.3439
12313	0.2405
12321	0.3636
12322	0.2602
12323	0.1568
12331	0.2799
12332	0.1765
12333	0.0731
13111	0.4262
13112	0.3228
13113	0.2194
13121	0.3425
13122	0.2391
13123	0.1357
13131	0.2588
13132	0.1554
13133	0.0520
13211	0.3954
13212	0.2920
13213	0.1886
13221	0.3117
13222	0.2083
13223	0.1049
13231	0.2280
13232	0.1246
13233	0.0212
13311	0.3646
13312	0.2612
13313	0.1578
13321	0.2810
13322	0.1776
13323	0.0742
13331	0.1973
13332	0.0939
13333	-0.0095
21111	0.7733
21112	0.6699
21113	0.3102
21121	0.6897
21122	0.5863
21123	0.2266
21131	0.3497
21132	0.2463
21133	0.1429
21211	0.7426
21212	0.6392
21213	0.2795
21221	0.6589
21222	0.5555
21223	0.1958
21231	0.3189
21232	0.2155
21233	0.1121
21311	0.4555
21312	0.3521
21313	0.2487
21321	0.3718
21322	0.2684
21323	0.1650
21331	0.2881
21332	0.1847
21333	0.0813
22111	0.6907
22112	0.5873
22113	0.2276
22121	0.6070
22122	0.5036
22123	0.1439
22131	0.2670
22132	0.1636
22133	0.0602
22211	0.6599
22212	0.5565
22213	0.1968
22221	0.5762
22222	0.4728
22223	0.1131
22231	0.2362
22232	0.1328
22233	0.0294
22311	0.3728
22312	0.2694
22313	0.1660
22321	0.2892
22322	0.1858
22323	0.0824
22331	0.2055
22332	0.1021
22333	-0.0013
23111	0.3517
23122	0.1646
23123	0.0612
23131	0.1844
23132	0.0810
23133	-0.0224
23211	0.3209
23212	0.2175
23213	0.1141
23221	0.2373
23222	0.1339
23223	0.0305
23231	0.1536
23232	0.0502
23233	-0.0532
23311	0.2902
23312	0.1868
23313	0.0834
23321	0.2065
23322	0.1031
23323	-0.0003
23331	0.1228
23332	0.0194
23333	-0.0840
31111	0.4426
31112	0.3392
31113	0.2358
31121	0.3589
31122	0.2555
31123	0.1521
31131	0.2752
31132	0.1718
31133	0.0684
31211	0.4118
31212	0.3084
31213	0.2050
31221	0.3281
31222	0.2247
31223	0.1213
31231	0.2444
31232	0.1410
31233	0.0376
31311	0.3810
31312	0.2776
31313	0.1742
31321	0.2974
31322	0.1940
31323	0.0906
31331	0.2137
31332	0.1103
31333	0.0069
32111	0.3599
32112	0.2565
32112	0.2565
32113	0.1531
32121	0.2762
32121	0.2762
32122	0.1728
32123	0.0694
32131	0.1926
32132	0.0892
32133	-0.0142
32211	0.3291
32212	0.2257
32213	0.1223
32221	0.2455
32222	0.1421
32223	0.0387
32231	0.1618
32232	0.0584
32233	-0.0450
32311	0.2984
32312	0.1950
32313	0.0916
32321	0.2147
32322	0.1113
32323	0.0079
32331	0.1310
32332	0.0276
32333	-0.0758
33111	0.2773
33112	0.1739
33113	0.0705
33121	0.1936
33122	0.0902
33123	-0.0132
33131	0.1099
33132	0.0065
33133	-0.0969
33211	0.2465
33212	0.1431
33213	0.0397
33221	0.1628
33222	0.0594
33223	-0.0440
33231	0.0791
33232	-0.0243
33233	-0.1277
33311	0.2157
33312	0.1123
33313	0.0089
33321	0.1320
33322	0.0286
33323	-0.0748
33331	0.0484
33332	-0.0550
33333	-0.1584
Dead	0
Unconscious	-0.0163

Figure A.1: Utilities according to the EuroQol 5D profiles [69]

Appendix B

List with qualitative effects

List for the patient (listed alphabetically)

- access to own file / level of knowledge about own condition: the patient has access to his own file, the patient is clearly informed about the status of his own condition.
- accessibility to care: who fast and easily the patient has access to the necessary care (e.g. trip time).
- amount of medication: the amount of medication taken by the patient.
- average health level in general: the average health level of the patient.
- carrying out daily activities: how good the patient can perform his daily activities (e.g. showering, cooking, ...).
- communication with other actors: the communication with one or more of the actors (e.g. a daily visit from a family care giver).
- freedom of choice: the freedom of choice of the patient
- independence: the level of independence of the patient
- level of knowledge about disease: the patients' level of knowledge about the disease he suffers from in general
- level of pain: the level of pain the patient experiences
- mobility: the level of mobility of the patient
- peace of mind: the patient's peace of mind
- privacy data: the patient's data confidentiality

- reliability service: the patients' experience of the reliability of the service
- safety: the safety of the patient using the service
- satisfaction service: the level of satisfaction the patient has from using the service in general (it can be that the patient does not experience any increase in QOL with a new service, but that he likes the new service; this effect comprises more or less the general experience
- social contact: the patient's contacts with other people
- timeliness of care: how fast the care is delivered

List for the other actors (listed alphabetically)

- need for new/better care: there is need for new or better care
- QOL patient: the patients' quality of life in general
- quality of care: the quality of care in general (safety, timeliness etc.)
- satisfaction of the service: the level of satisfaction the actor experiences with the use of the service
- work pressure: the work pressure experienced with the service

Appendix C

CHF case

In this section the previously described methodology is applied to the case concerning the telemonitoring service for CHF patients, which has been described in chapter 2. Snapshots of every web page of the tool are displayed, with explanation of how to give in the input data correctly. The output (steps 7,9 and 10) is discussed in chapter 5.

Start page

At the first page of the tool, the user is welcomed and gets the option to work on an existing project or start a new project, as illustrated in figure C.1. For the CHF case the user obviously clicks on the CHF-button.

Figure C.1: CHF 0: Start page

Introduction

Now that the user has chosen the project he wants to employ, the screen will display figure C.2. This allows the user to name the project.

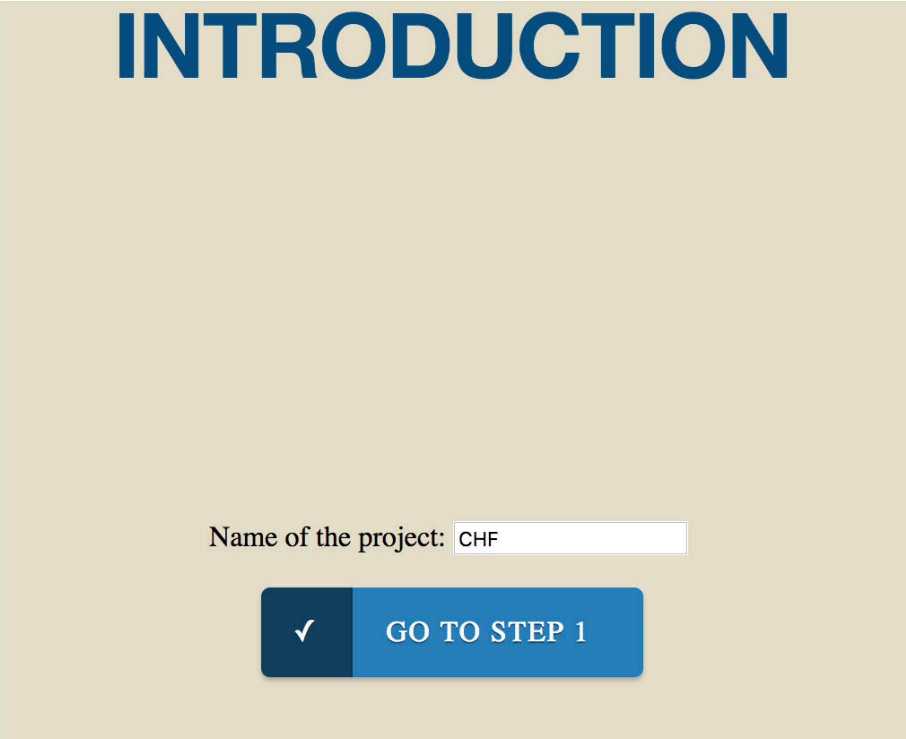


Figure C.2: CHF 0: Introduction

Step 1: Identification of the actors

Apart from the eCare provider (always actor in new service) and the patient (always actor in current and new service), five other actors are selected: the general practitioner, nurse and cardiologist are selected as *receivers*, while the hospital and insurance are part of the *other actors*. This first step is visualized in figure C.3.

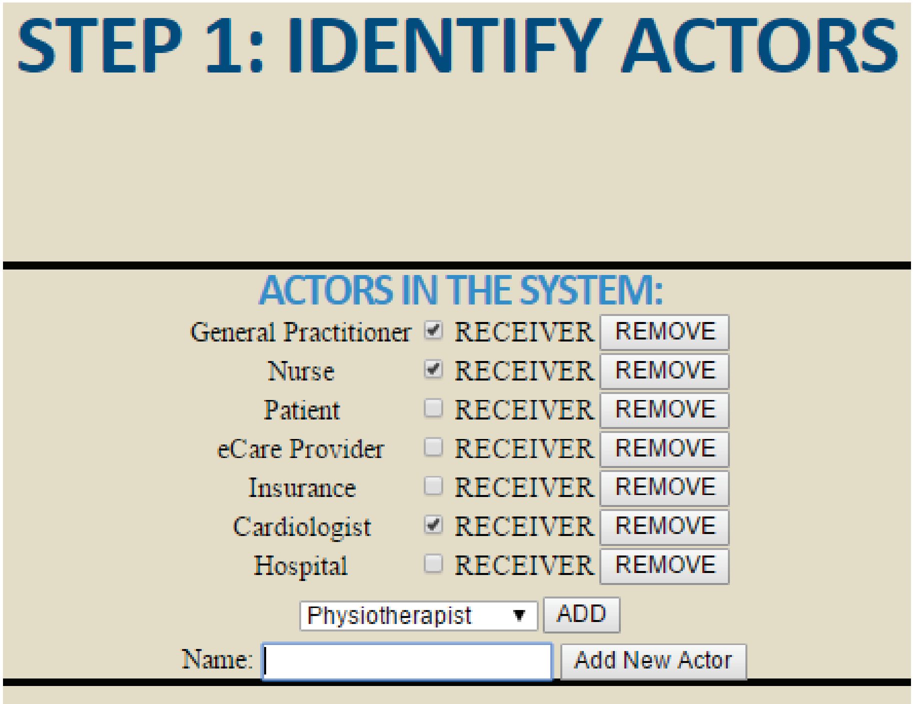


Figure C.3: CHF 1: Actor identification

Step 2: Market estimation

Nowadays there are about 230 000 people in Belgium who suffer from CHF. The median age of CHF patients is 79 years. With the currently aging population the number of patients will keep on increasing. It is estimated that in 2040 the number of patients will have doubled [70]. As there is asked to give in the % increase per year, following calculation should be done:

$$\sqrt[23]{2} = 1,0305955.$$

This means that every year the total number of patients is growing with an estimated 3,05955 %.

One year after diagnosis of CHF the mortality is already 26 % [36]. After five years this mortality is about 50 % [71]. So what should the user choose as mortality rate? As there is asked for the average mortality rate, there has chosen to give in 10 %, which is the average mortality over five years. This means that a simplification is made: the mortality is assumed to have a fixed value. On average, a CHF patient has about five live years remaining from the moment of diagnosis.

The default values for the time horizon (10 years), adoption rate (0,55), inflection point (3,5) and maximum adoption percentage (0,85) will be used to estimate the course of the S-curve.

All these input data are pictured in figure C.4. With this information, all the necessary data concerning the number of patients can be obtained using the formulas from section 3.2. The total number of patients in year i, the number of patients that make use of the current service in year i, the number of patients that make use of the new service in year i, the total number of new patients in year i, the number of new patients that make use of the current service in year i and the number of patients that make use of the new service in year i are calculated internally.

Figure C.4: CHF 2: Market characterization

Step 3: Current process scheme

This step consists of mapping the current situation. What are the different processes the patient can go through? For the case of chronic heart failure the current care method is summarized in the process scheme displayed in figure C.13.

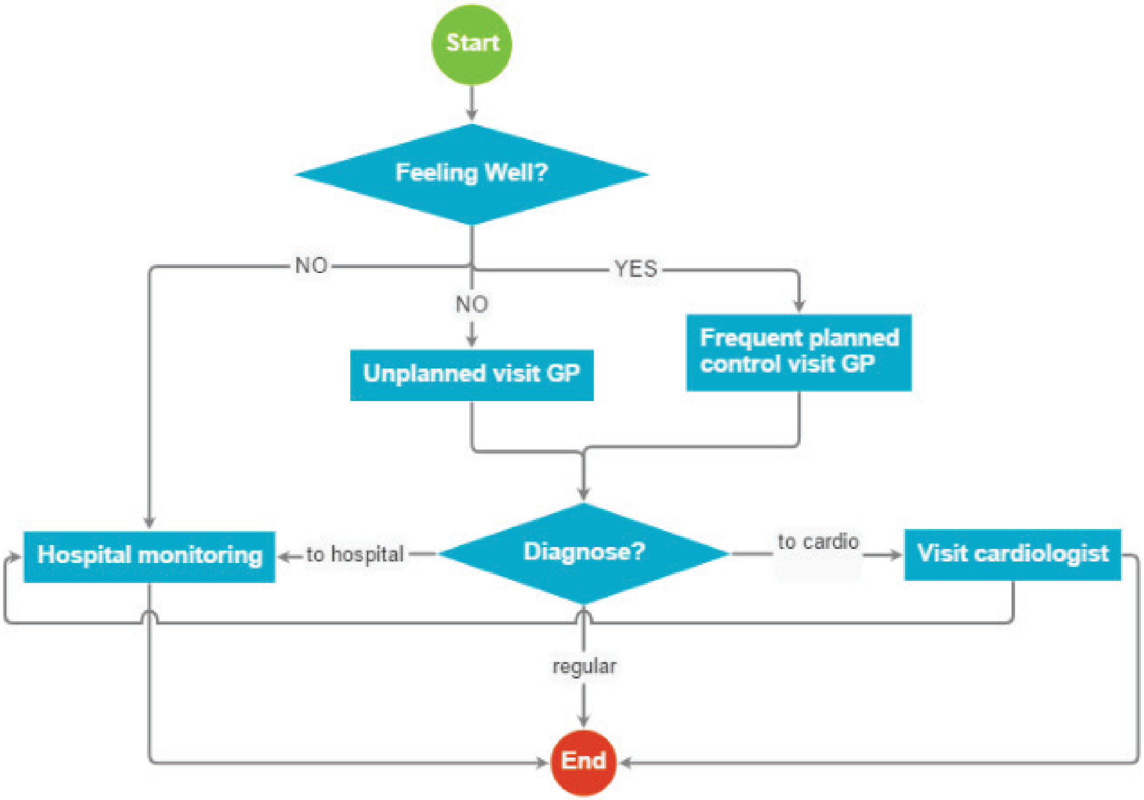


Figure C.5: CHF 3: Current process scheme

The first question that needs to be answered is if the patient is feeling well. If he is, then there is of course no need to suddenly visit the hospital or GP. But because he suffers from CHF, he has planned some frequently planned control visits with the GP to check his condition. If this doctor visit went smoothly, he can go back home afterwards. On the other hand, if the GP finds it necessary he can send the patient to the hospital where he will be monitored for a certain period. Additionally, he can send the patient further to the cardiologist (if he thinks this is necessary).

If the patient does not feel well he has various possibilities. He can go immediately to the hospital, go meet his cardiologist or he can go on an unplanned visit to the GP. Similar as the planned checkup with the GP, the patient can be sent to the hospital or cardiologist by the doctor if necessary.

Note that the processes are related to the disease handled with the eHealth service. A CHF patient who visits the GP because of a broken toe is irrelevant for this case and should not be handled as a visit to the GP. This will be important for the next step, where among other things there is asked for the frequency of the processes.

Step 4: Input data current situation

There are four different processes in the current process scheme: hospital monitoring, unplanned visit GP, frequent planned control visit GP and visit to cardiologist.

When patients are diagnosed with CHF, they often have a schedule of frequent planned control visits to the GP. Usually this happens every three months. Figure C.6 shows the data concerning the process of a frequent planned control visit to the GP. For a planned control visit to the GP there is a flow of money from both the patient and his insurer to the GP. The consultation obviously requires a time investment from both patient and GP. The difference in time for both actors is due to the fact that the patient has to make the displacement to the doctor's office.

The input of the monetary value of time may differ from person to person. With this tool the user should try to estimate what the value is of doing this process one hour less in the future. As the average CHF patient is 79 years old the time value of a process will probably be different from for example a thirty year old.
When a patient has a scheduled control visit with the GP he normally feels relatively well. A young person could therefore probably go to work and could give in the amount of money he would have earned if he worked during the time of the control visit. For a 79 years old person this is different, so that the monetary value of the time investment will be less. The displacement to the doctor's office can however be inconvenient for the patient, who is not very mobile. This approach results in an estimated value of 7 € per hour for this process.
These data are displayed in figure C.6.

CHF patients can of course also visit the GP unplanned if they do not feel well (as a result of their disease). Based on his diagnosis the patient will go back home, to the cardiologist or to the hospital. Figure C.7 shows the data concerning the process of an unplanned visit to the GP. The prices are the same as for a planned control visit. The difference with the planned control visit is that the unplanned visit takes longer for both the CHF patient and for the GP. This is because normally if the patient goes on a planned visit he feels (relatively) well. An unplanned visit means he does not feel well, so it will take longer for the GP to examine the patient. The increase in time for the patient is due to the fact that probably he will have to wait a certain time before it is his turn as now he is not scheduled. Both examination and waiting time are estimated to be 30 minutes. Adding the 30 minutes of the time to get to the doctor results in a total time for the patient of 90 minutes.

It is estimated that a patient is willing to pay 5 € yearly to decrease the time of this process with one hour.

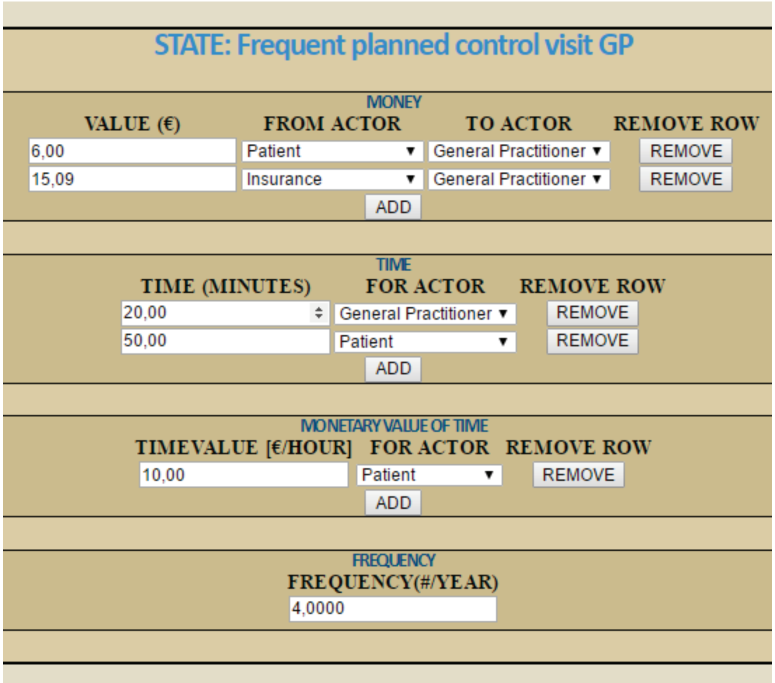


Figure C.6: CHF 4: Data for current process: Frequent planned control visit GP

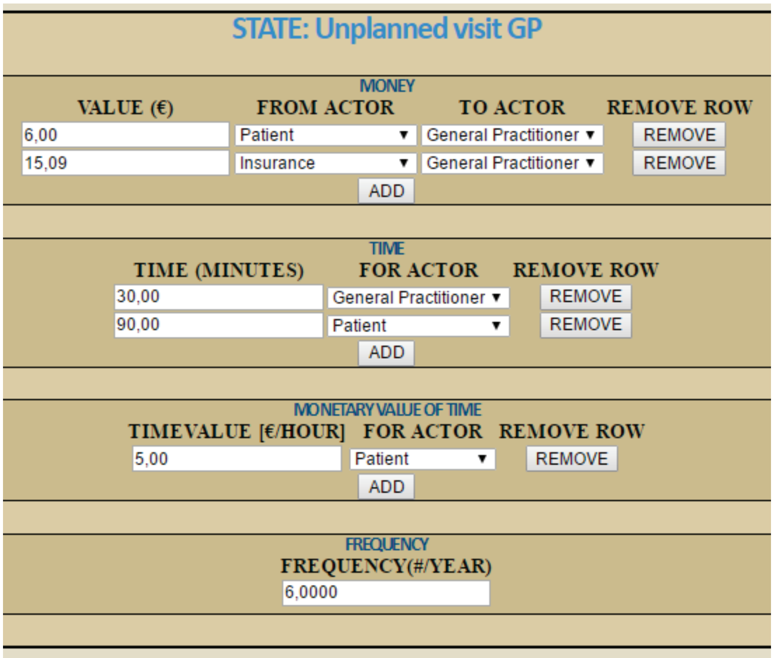


Figure C.7: CHF 4: Data for current process: Unplanned visit GP

The most challenging part of this step is the input of the process of hospitalization, in particular the monetary transactions.

In the hospital the patient gets monitored for a certain number of consecutive days. The most straightforward way to express the frequency of hospital monitoring is in *number of days*. Therefore the unit used for money would be € per day (per patient). As the unit for a monetary transaction defined in the methodlogy is €, one should formulate this process in another way. A simple solution is to express the process as being monitored one day in hospital. The time should thus be 24 hours (for the patient), while the frequency should be the amount of days per year the patient spends on average to hospital monitoring.

First of all the time investment is handled. This process takes 1440 minutes (24 hours) for the patient, while it is estimated that a nurse spends in total 45 minutes per day to one patient (treatment, but also administrative work etc.). Often the patient is examined by a cardiologist to among other things determine the amount and kind of medication. This is estimated as (on average) ten minutes per day.

Patients want to avoid hospitalizations as much as possible. One could ask for the patient's willingness to pay for spending a day in his own home instead of in the hospital. It is estimated that the average patient would pay about maximally 60 € per day to avoid being hospitalized. Thus the monetary value of one hour of the process hospital monitoring is estimated as 2,5 € per hour.

In what follows the monetary transactions and frequency are handled. Data that will be used in this section concerning heart failure hospitalization in 2014 (Belgium) is found online in the national database for medical diagnose [72], while general information about costs concerning hospitalization is found at the website of the *Virga Jesse Hospital (Hasselt)* [73]. What follows are calculations to determine the input data of the process 'hospital monitoring', which is displayed in figure C.10.

In 2014 there were 21 874 hospitalizations in Belgium for heart failure with an average length of twelve days (figure C.8). As there were an estimated 200 000 CHF patients in that year, the average days a CHF patients spends to hospital monitoring per year can be calculates as follows:

$$f_{hospitalization} = \frac{21784}{200000} * 12 = 1,307.$$

These data also allow to calculate the average total cost per day:

$$c_{hospitalization} = \frac{7015,44}{12} = 584,62 \text{ €}.$$

Graad van ernst	Aantal verblijven	% van de verblijven	Gemid. leeftijd	Gemid. gefactureerde verblijfsduur	Gemid. bedrag aan verpleegdagprijs herberekend aan 100%	Gemid. totaal bedrag voor de farmaceutische producten	Gemid. bedrag voor de honoraria	Gemid. totaal bedrag
Mineur	1.290	5,9	75	5,8	2.505,46	51,87	811,25	3.368,58
Matig	9.640	44,3	80	9,3	4.073,66	91,11	1.087,38	5.252,14
Majeur	9.197	42,2	81	14,3	6.394,43	192,54	1.610,99	8.197,95
Extreem	1.657	7,6	80	20,8	9.461,92	656,68	3.430,98	13.549,58
TOTAAL	21.784	100,0	80	12,0	5.370,46	174,63	1.470,35	7.015,44

Figure C.8: Average amount per stay for heart failure (2014) [72]

The total fee for the specialized doctors is 1470,35 € per stay. Which is:

$$r_{specialists} = \frac{1470,35}{12} = 122,53 \text{ € per day.}$$

A closer look to the latter revealed that only a small fraction of this 122,53 € goes to the cardiologist, namely 7,04 €. Radiologists, pneumologists etc. make part of the other specialized doctors who examine a CHF patient and thus receive a certain amount of money. Taking all these different specialists into account would make the case difficult and unclear. The focus of this case research is to map the impact of the telemonitoring service on the main actors, identified in the first step. In particular the impact on the hospitals and cardiologists is of great importance, as literature already revealed that the amount of hospitalizations will drop and thus their receivings will decrease. There has therefore been chosen to assign the honors (except for the cardiologist) to the actor sink (122,53 - 7,04 = 115,49 €).

The hospital receives 462,09 € per patient per day (584,62 - 122,53). This sum is paid by both the patients (small fraction) and the insurer of the patient (large fraction) and consists of many different smaller costs.

The hospital bills all the costs and honors of the hospitalization of the patient. The patient only pays the part that the insurance company does not pay. The price is determined according to the statutory RIZIV regulations.

- RIZIV amount of a performance = legally agreed amount that a healthcare provider (e.g, a doctor, a physiotherapist, etc.) may charge for performing that performance.
- Refund rate of a performance = part of the RIZIV amount reimbursed by the mutual fund.

- Personal share of a performance = Difference of the RIZIV amount and the repayment rate.
- Supplement of a performance = amount charged to the patient on top of the RIZIV amount (eg by doctor's deconvention, by specific questions of the patient's room selection.)

The price also depends on the patient's room selection. If he opts for a single room, he will pay a room supplement and may charge the treating physicians up to a 150% supplement to the fee. This applies to both the performance and the supervisory fees.

How much of does the patient pay and how much the insurer? The total fraction that the patient has to pay himself for the hospitalization is dependent on many things, among others on his hospitalization insurance. E.g. if the patient pays for reimbursable medicines (0,62 € per day and for accommodation costs (42,58 € for the first day and 15,31 € for all other days). this is on average

$$\frac{11 * 15,31 + 42,58}{12} + 0,62 = 18,2 \text{ € per day.}$$

This is only a small fraction of the toal cost. The patient also pays a part of the costs for the doctors (which is in total 122,53 € per day). It is estimated that his share in this sum is about 30 % on average. Adding this cost to the patient's payment to the hospital gives

$$c_{patient} = 23,03 + 36,79(122,64 * 0,3) = 59,82 \text{ € per day.}$$

The receiving of the nurse for treating the patient (calculated using formula 3.8) equals:

$$r_{nurse,hospitalization} = \frac{30}{60} * 45 = 22,5 \text{ € per day.}$$

All the necessary information for the monetary transactions as a result of the hospitalization is now retrieved. How are these payments done in practice? This is illustrated in figure C.9. The patient only receives one invoice for all the costs, which he pays to the hospital. Dependent on the hospitalization insurance of the patient, the patient receives reimbursements from his insurer. The insurer pays also a certain amount immediately to the hospital. A part of the money that the hospital receives goes to the employees (nurses, doctors). In this case the cardiologist is the only identified specialized doctor. The others who participate in the care for the CHF patient are represented by *sink*.

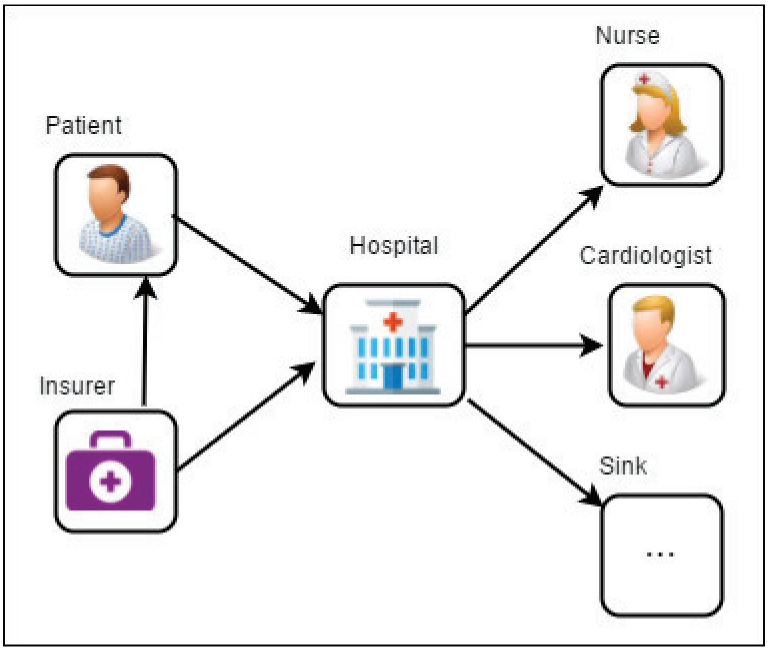


Figure C.9: Hospitalization for heart failure: monetary transactions

There are many ways in which these transactions can be given in with the tool. It is however very important that the sum of the costs of the single actors equals the total cost of the process (584,62 €), as stated in section 3.2.4. Of course the total cost/receiving per actor should also be correct:

$$c_{hospital} - r_{hospital} = -439,59 \text{ €}$$

$$c_{patient} - r_{patient} = 59,82 \text{ €}$$

$$c_{sink} - r_{sink} = -115,49 \text{ €}$$

$$c_{insurance} - r_{insurance} = 524,8 \text{ €}$$

$$c_{nurse} - r_{nurse} = -22,50 \text{ €}$$

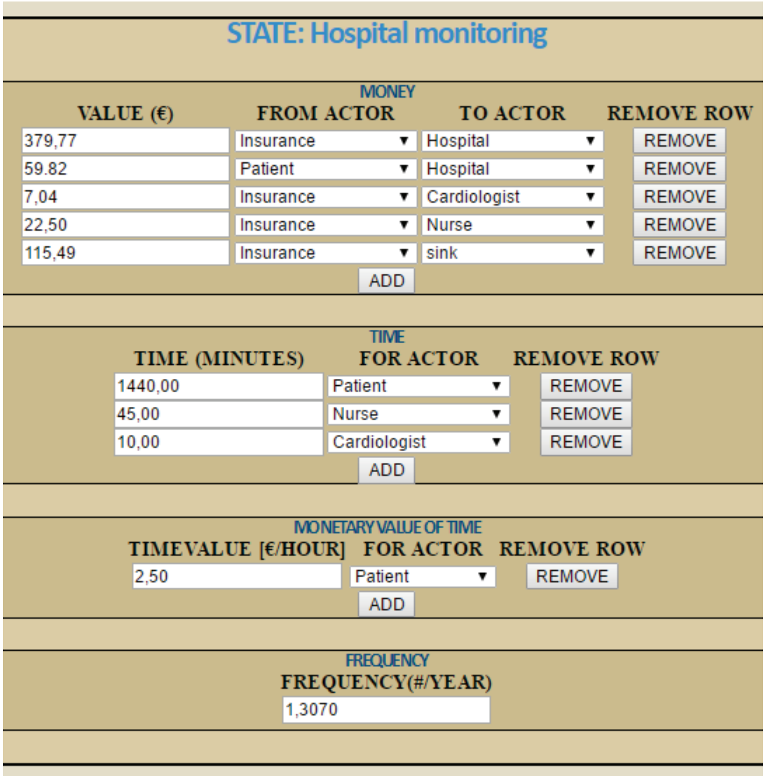


Figure C.10: CHF 4: Data for current process: Hospital monitoring

$$\sum_a Cost_a = 379,77 + 59,82 + 7,04 + 22,50 + 115,49 = 584,62 \text{ €}$$

The last process data that needs to be known concerns the examination by a cardiologist. It is assumed that a CHF patient visits the cardiologist on average three times per year. A consultation with the cardiologist costs 31,69 € and can occur at the cardiologist's office, or in the hospital where he works [74]. For the latter the cardiologist has to pay off a certain fraction of his receiving to the hospital, on average this is about 40 %. Assuming that about halve of the consultations are at the hospital, the average receiving of the hospital per consultation equals:

$$0,4 * 0,5 * (31,69) = 6,34 \text{ €}.$$

The patient's cost for one visit equals 12 €. The remaining part of the cost is then paid by the insurer. A consultation takes on average half an hour. For the patient a traveling time of half an hour is added. It is estimated that the average patient would assign a monetary value of 5 € per hour for this process.
All this information can be found in figure C.11.

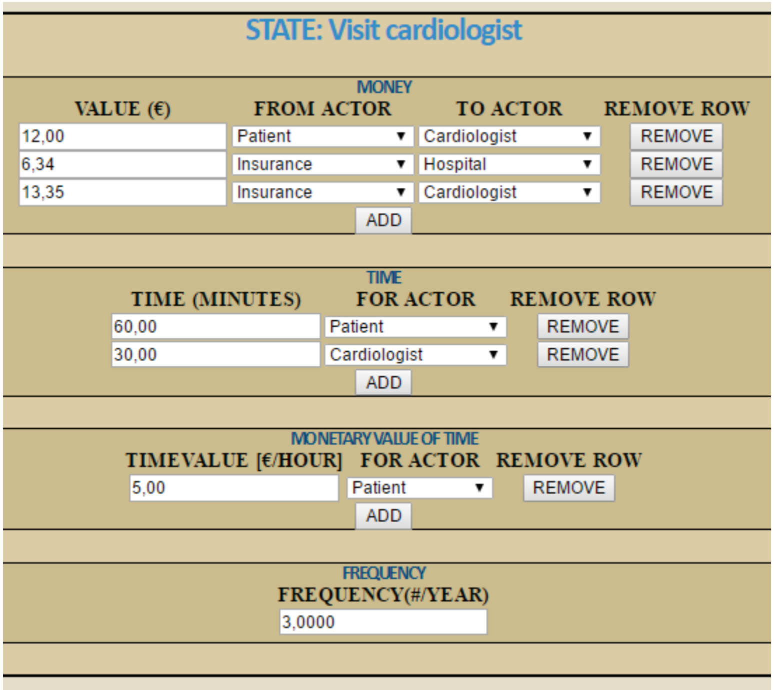


Figure C.11: CHF 4: Data for current process: Visit cardiologist

There are no one-off costs, nor are there extra costs (figure C.12).

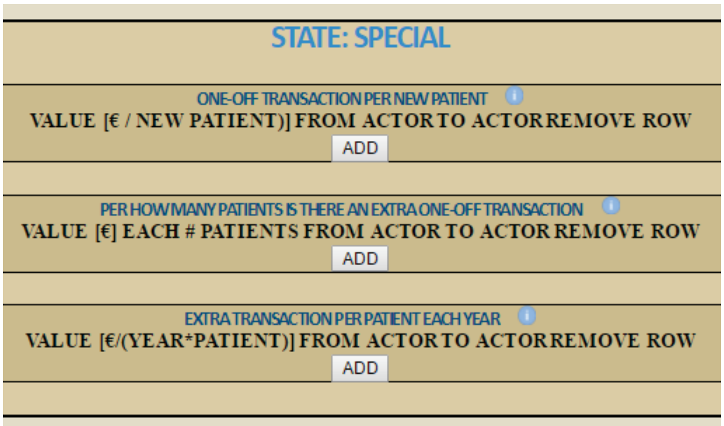


Figure C.12: CHF 4: One-off transactions in the new situation

Step 5: New process scheme

In the new process scheme one can find three processes that are also present in the current process scheme: unplanned visit to the GP, hospital monitoring and a visit to the cardiologist. The planned frequent control visits to the GP is replaced with the daily monitoring process, which refers to the independent daily measurement of the patient of its blood pressure, heart rate, weight and ECG (electrocardiography). The results of these measurements are sent immediately to the heart failure nurse. If some parameters are measured out of their bounds, an alarm is triggered. The heart failure nurse analyses this alarm and takes action by contacting the patient. If it is a false alarm (or little adjustments need to be taken) the patient is informed and can be at ease. However, if hospitalization seems necessary the patient goes immediately to the hospital.

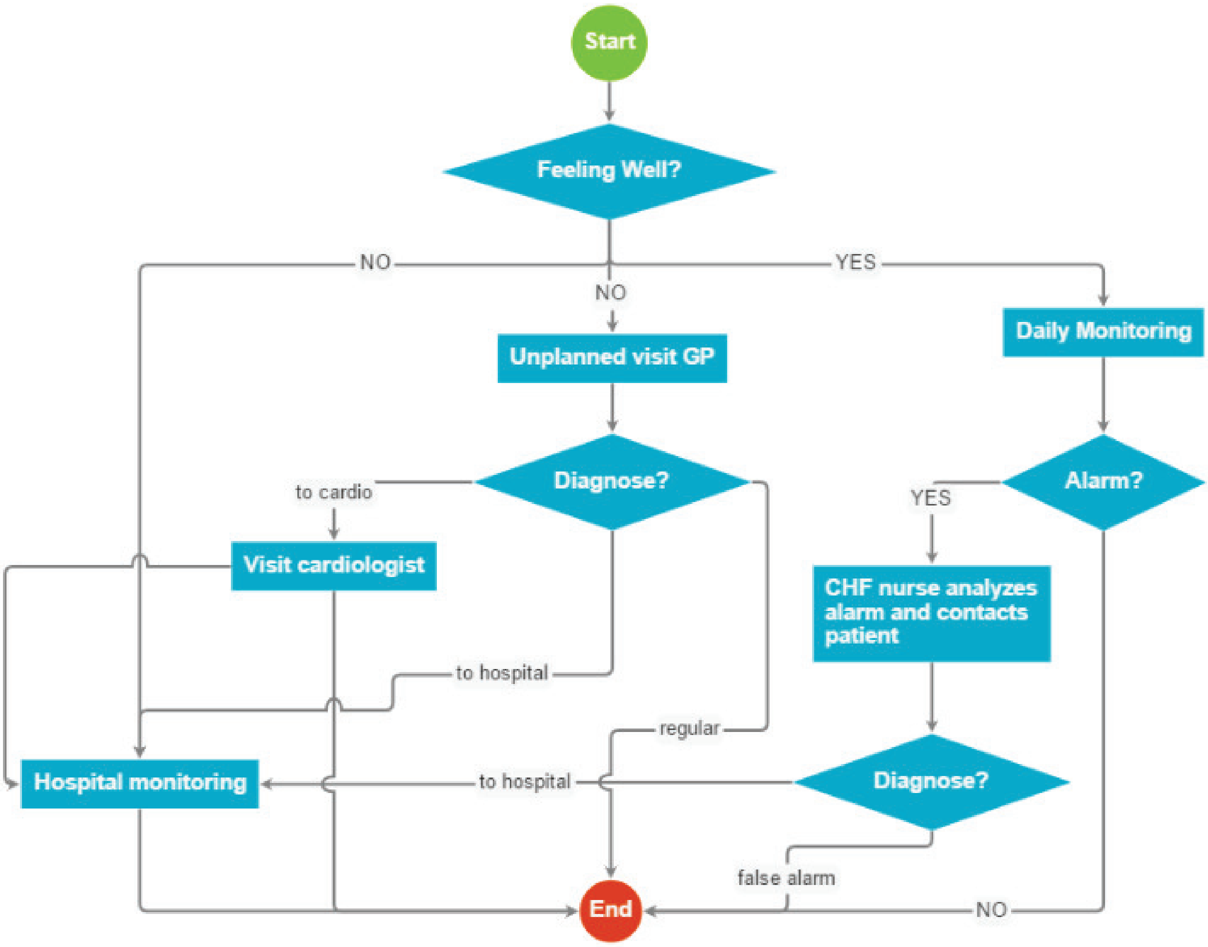


Figure C.13: CHF 5: New process scheme

Step 6: Input data new situation

About two third of the costs of treating chronic heart failure patients in Belgium is due to the monitoring periods in the hospital. When the number of days spent in the hospital can be reduced the total cost for treating CHF patients can decrease a lot. The insurance companies pay the biggest part of the hospital bill. So they have great benefits if there are less hospitalizations. Apart of the potential in cost-savings, less hospitalizations strongly increase the QOL of the patient, who wants to avoid the hospital as much as possible.
The eHealth service therefore focuses on reducing the amount of (re)hospitalizations. A lot of projects result in a reduced (re)hospitalization rate when telemonitoring is used [38]. There is estimated that for the new eCare service hospitalizations can be recuded with about 50 %.

In the new process scheme, there are five processes. Three of them are also identified in the current situation: *hospital monitoring*, *unplanned visit GP* and *visit cardiologist*. The two new process are *daily monitoring* (which makes the *frequent planned control visit GP* unnecessary with the eHealth service) and *CHF nurse analyzes the alarm & contacts patient*. For the first three processes the input data will be the same as in step 4 except for the frequency, so this will not be explained again. They are displayed in figure C.14, C.15 and C.16.

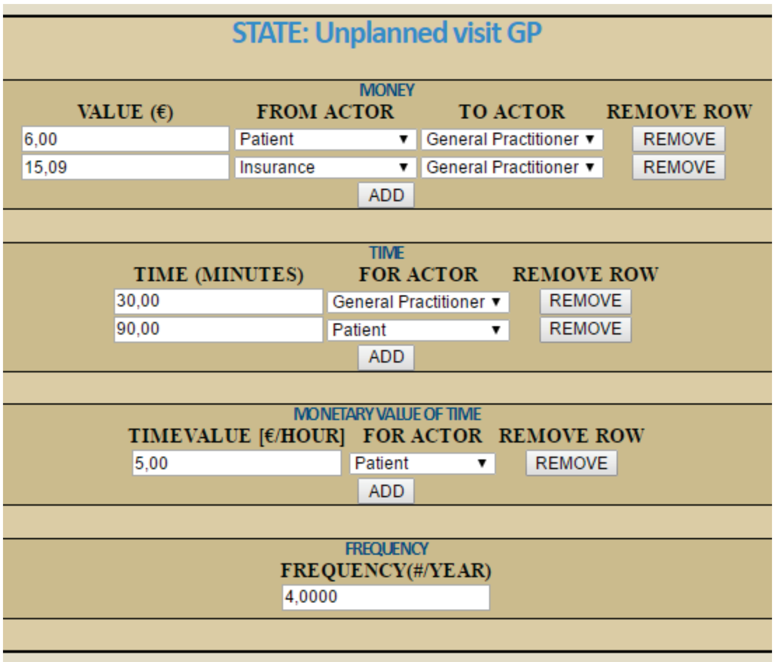


Figure C.14: CHF 6: Data for new process: Unplanned visit GP

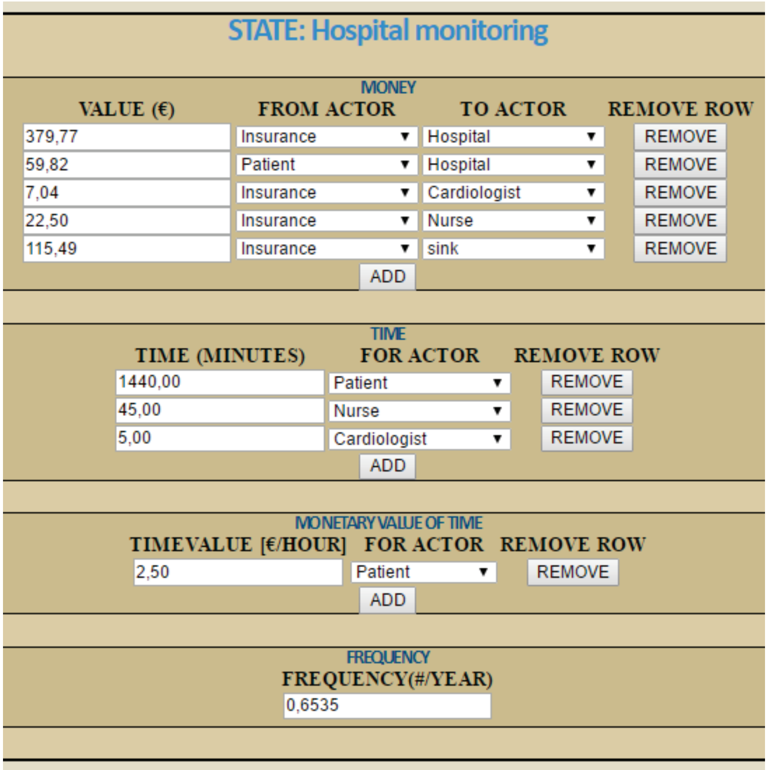


Figure C.15: CHF 6: Data for new process: Hospital monitoring

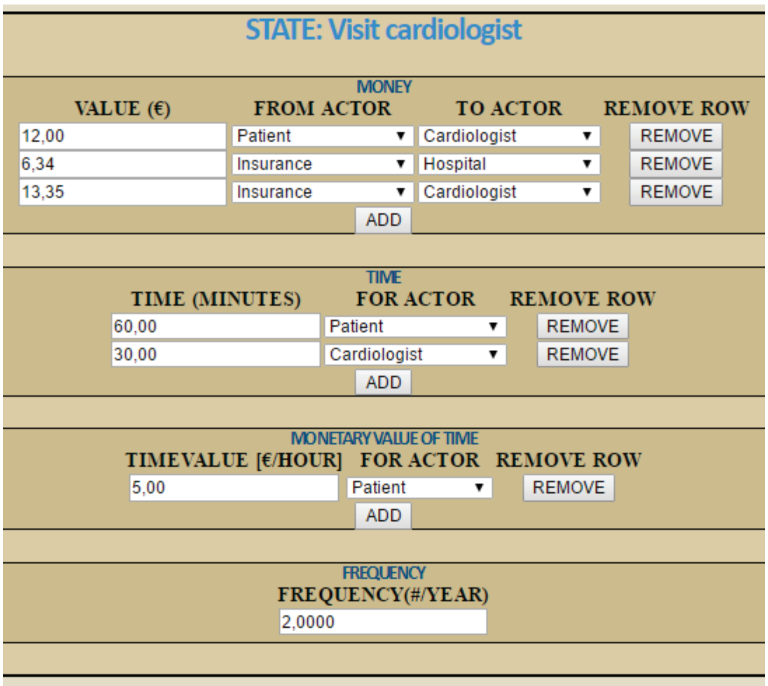


Figure C.16: CHF 6: Data for new process: Visit cardiologist

The input data for the daily monitoring process is displayed in figure C.17. The eCare provider charges a monthly cost to the patient for the use of the telemonitoring service: 30,44 € per month (one euro per day). The process takes about ten minutes for the patient. As the patient at home during the process the monetary value of time is estimated very low: 1 € per hour.

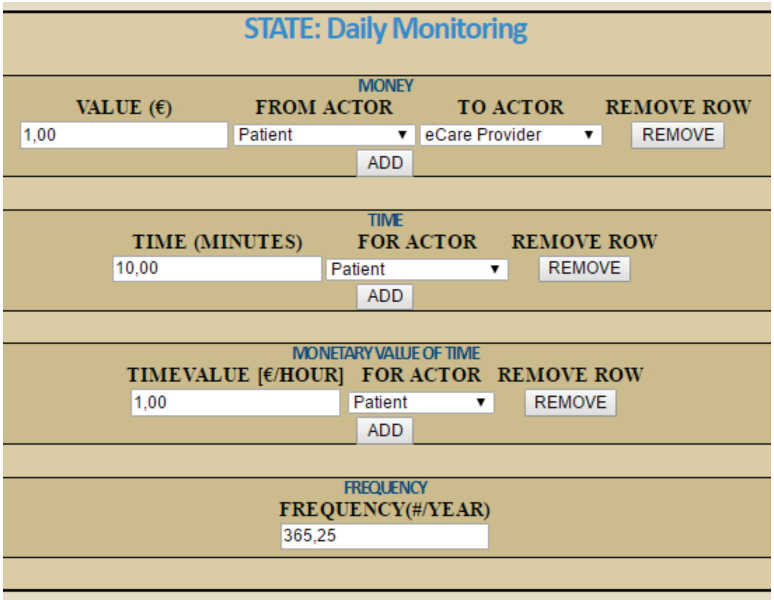


Figure C.17: CHF 6: Data for new process: Daily monitoring

The input data for the process of analyzing the alarm and contacting the patient is displayed in figure C.18. If the measurements are out of bounds, an alarm is generated. The CHF nurse will interpret this alarm, which takes about two minutes. After an alarm is generated, the nurse contacts the patients by telephone to inform the patients. This conversation takes about six minutes. If the nurse is not sure about the alarm the cardiologist may be contacted. This is rather rare but can also happen. It is estimated that the cardiologist's opinion is needed in 5 % of the alarms (takes two minutes). So on average he spends 0,1 minutes per alarms (2 minutes time per 20 alarms). There is approximately one alarm per week per patient, which is equal to 52,18 alarms per year.

The payment of the working hours for the nurse are calculated using formula 3.7:

$$c_{hospital,analyzingalarm} = r_{nurse,analyzingalarm} = \frac{grosshourwage}{60} * t_{ap} = \frac{30}{60} * 8 = 4€.$$

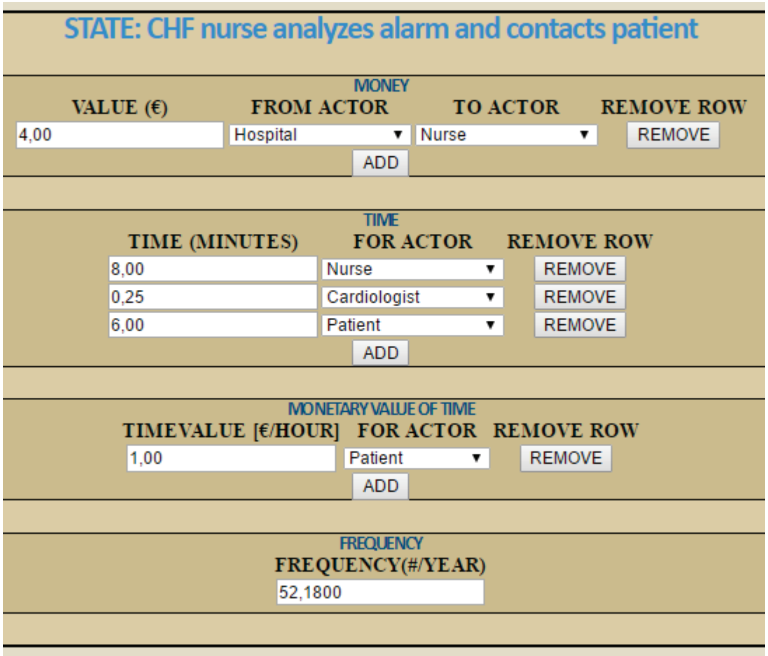


Figure C.18: CHF 6: Data for new process: CHF nurse analyzes alarm and contacts patient

In the hospital the nurses can interpret the measurements from the patient on a computer. This computer is provided by the eCare provider, with all necessary soft- and hardware. The cost for one unit is 2 000 € for the hospital. It is estimated that about 300 patients can be monitored with this one-off investment. Further there are no extra costs or one-off costs (figure C.19.

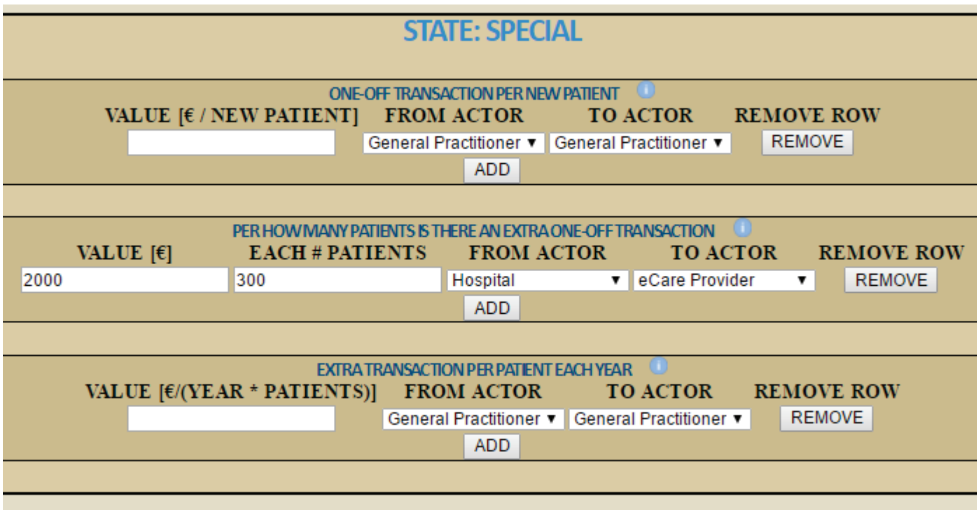


Figure C.19: CHF6: One-off transactions in the new situation

The last input of step 6 is maybe the most difficult to estimate of all the input data, especially if the user of the tool is not the eCare provider himself. The costs are split into five categories. Costs can be a one-time payment, they can be ongoing, they can be population dependent, they can be population independent etc. The estimated costs are displayed in figure C.20.

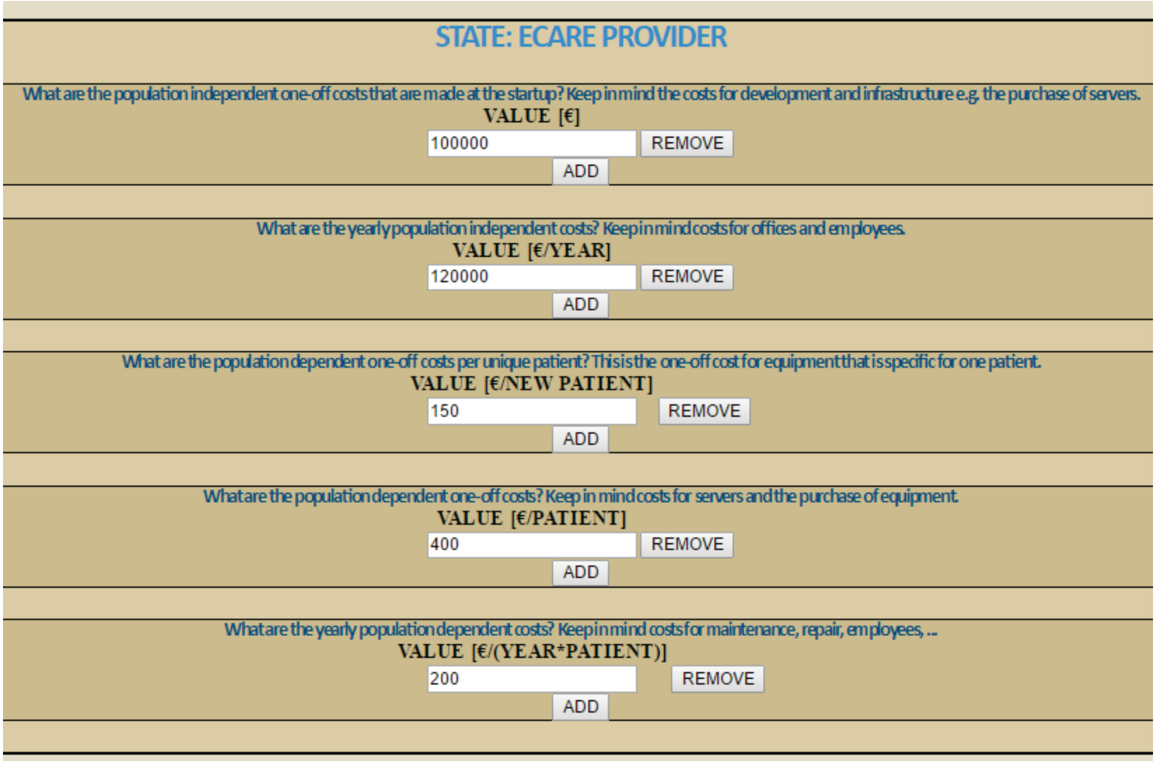


Figure C.20: CHF 6: Estimated costs for the eCare provider

The first cost represents costs for among others the purchase of servers and man hours for development. This one-off cost has an estimated value of 100 000 €.

The second cost group represents the yearly population independent costs: just as the cost from above it does not matter if there is one customer or if there are 10 000 customers, this yearly ongoing cost will be the same. It is estimated that, independent of the amount of customers, three employees are needed, each resulting in a cost of 36k per year (108k in total). The price of their office is estimated to be thousand euro per month. This makes a total of 120 000 €.

Next are the one-off costs per unique patient. It represents the cost for devices that are devoted to one patient and cannot be used in the future for another patient. With the telemonitoring service the patient pays a monthly sum to the eCare provider which covers everything for the patient. The service is offered as a parcel. The patient does not need to pay a lump sum in the beginning for the equipment. It is assumed that, when a patient deceases (or for some reason stops with the telemonitoring service), the provider company will pick up the equipment at the patients' home and it can be used for other patients. However, not everything can be reused, which results in an estimated cost per new patient of 150 €.

Servers have a limited capacity, which means that they make also part of the population dependent (one-off) costs. Mostly this cost is expressed as a cost per certain amount of new customers (for example 2000 € per 1000 new customers). This would result in a cost of 2 € per patient (2000/1000).

There are also costs that do not need to be made for every unique patient. These are one-off costs that are incurred per additional patient. If for example there were 1000 patients in the beginning of year i, 50 patients died during year i, and 50 new patients start using the service, than there is no cost of this category incurred (note that there would be a cost for 50 patients in the cost category above this one). Cost of buying servers (which have a limited capacity) are also included in this category. It is estimated that the telemonitoring service is required a population dependent one-off cost of 400 € per patient.

At last there are the yearly population dependent costs. Typical costs belonging to this category are for the maintenance of the servers and also for employees. The latter is necessary because per certain amount of customers probably an extra employee is needed. This cost is estimated as 200 € per patient per year.

Step 7: A first comparison

This step gives a first overview of

- the cost of both situations for every actor
- the time investment in both situations for every actor
- the total cost of both situations
- the total time investment in both situations

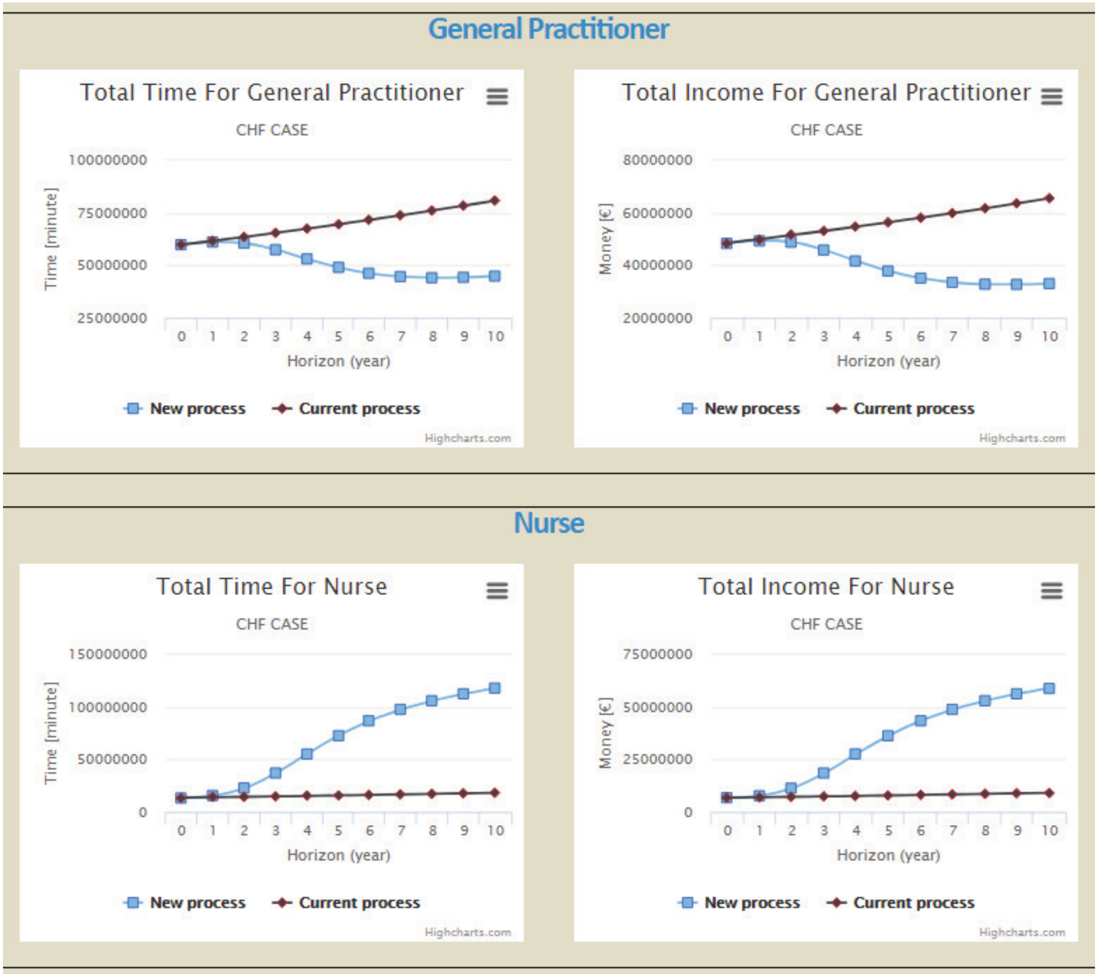


Figure C.21: CHF 7: Time and Profit over time horizon for GP and Nurse

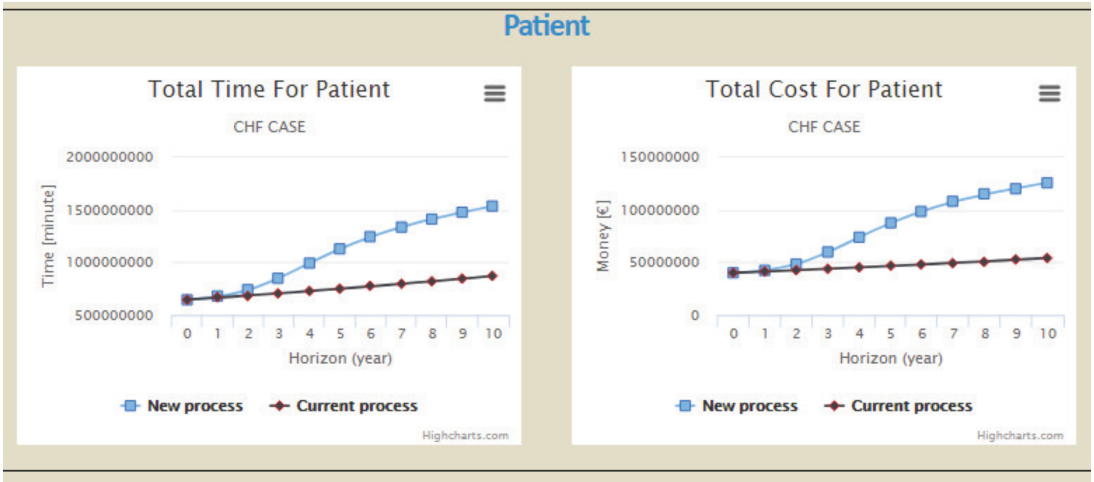


Figure C.22: CHF 7: Time and Profit over time horizon for Patient

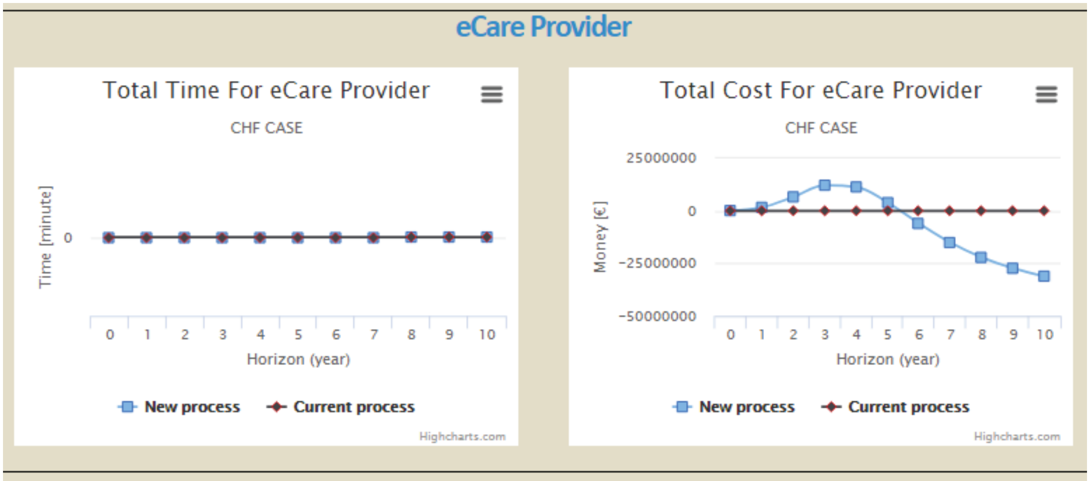


Figure C.23: CHF 7: Time and Profit over time horizon for eCare Provider

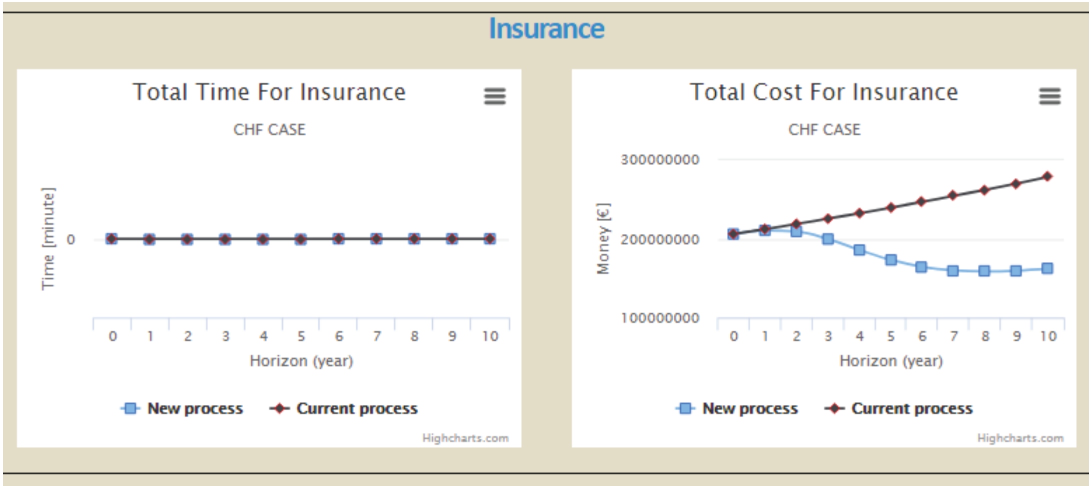


Figure C.24: CHF 7: Time and Profit over time horizon for Insurance

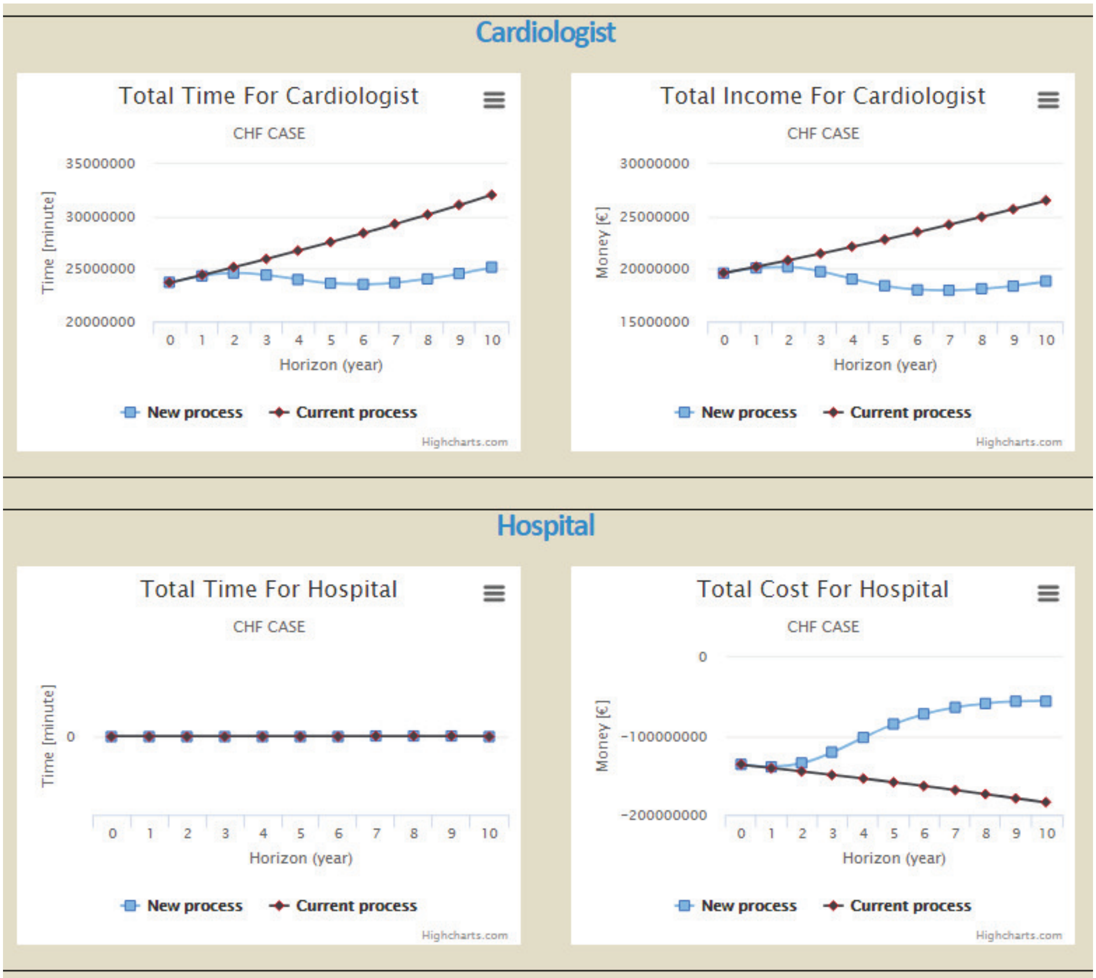


Figure C.25: CHF 7: Time and Profit over time horizon for Cardiologist and Hospital

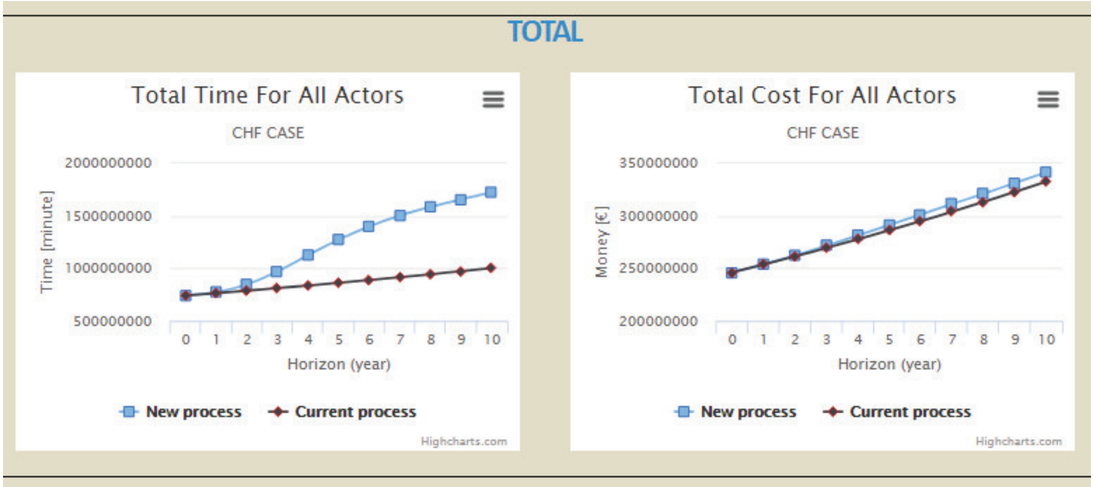
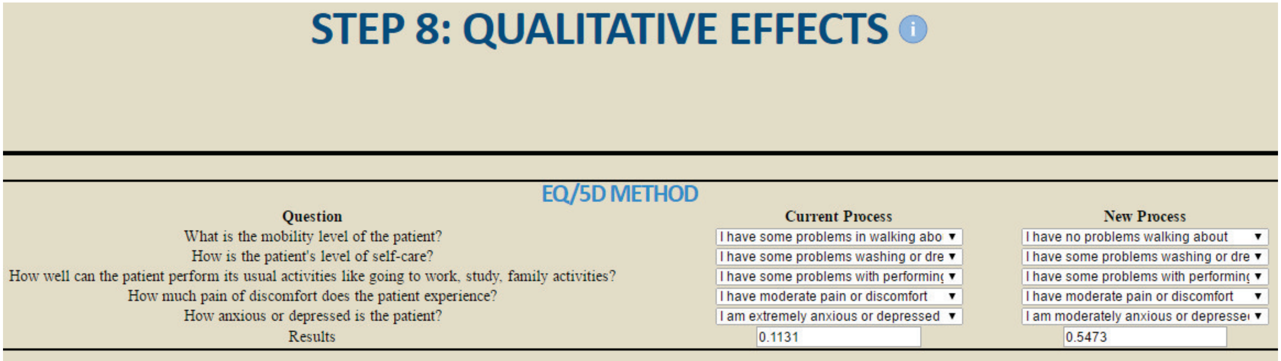


Figure C.26: CHF 7: Total Time and Profit for all actors

Step 8: Qualitative effects

The patients qualitative effects can be estimated using the EuroQol 5D method. In that way indexes are calculated, which on their turn are used in the denominator of the ICER formula. The results of the EQ-5D method for both current and new situation can be found in figure C.27.


STEP 8: QUALITATIVE EFFECTS

EQ/5D METHOD

Question	Current Process	New Process
What is the mobility level of the patient?	I have some problems in walking abo	I have no problems walking about
How is the patient's level of self-care?	I have some problems washing or dre	I have some problems washing or dre
How well can the patient perform its usual activities like going to work, study, family activities?	I have some problems with performin	I have some problems with performin
How much pain of discomfort does the patient experience?	I have moderate pain or discomfort	I have moderate pain or discomfort
How anxious or depressed is the patient?	I am extremely anxious or depressed	I am moderately anxious or depresse
Results	0.1131	0.5473

Figure C.27: CHF 8: Estimating the qualitative effects via the EQ-5D method

The score for the current situation is 22223 which results in an index of 0,1131 (see figure A.1). With the telemonitoring service the level of self-care, usual activities and pain/discomfort stay the same. On the other hand there is an increase in both mobility and peace of mind (anxiety). This results in a score of 12222, which corresponds to an index of 0,5473. This is an increase of the index with a factor of almost five. Note that the decrease in the level of anxiety contributes for the biggest part in this difference of the indexes. If the score would have been 12223, so only a difference in the level of mobility, than the index would have been 0,1876.

Using these values for the effects the denominator of the ICER can be calculated. In step 9 the numerator will be calculated so that the ICER can finally be determined.

$$ICER = \frac{C_{\mathrm{N}} - C_{\mathrm{C}}}{0,5473 - 0,1131}$$

This second part of this step consists of identifying the qualitative effects of the new service for all the actors and assign a monetary value to it. Choose for every actor the qualitative effects where there is a difference in current and new situation and give both situations a score going from -3 to +3.

The qualitative effects for the patient are the easiest to determine C.28. The patient's level of knowledge about his own condition, his mobility and his peace of mind increase.
One could possibly add 'usability of the service' as the patient will need to work with ICT and

this could possibly be difficult for (older) people. However, this new eCare service requires very little knowledge about ICT so it is chosen to not select it.
The monetary values of these effects are chosen high. The patients are especially willing to pay for the increase in peace of mind.

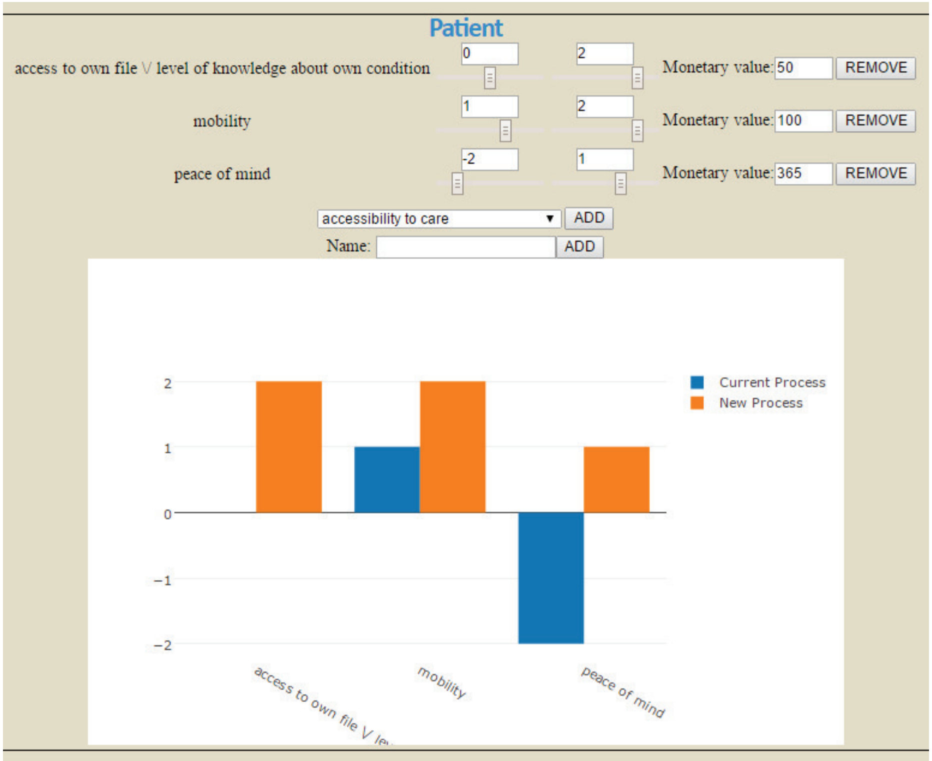


Figure C.28: CHF 8: Qualitative effects for Patient

For the other actors it might be less straightforward to choose the qualitative effects. With the telemonitoring the quality of life of the patient clearly increases. From a human perspective it is the goal from care givers to improve the quality of life of the patient. It gives them (hopefully) satisfaction. For all care givers (nurse, GP, cardiologist) there is chosen to select QOL for the patient. It is estimated that they would yearly pay one euro per patient for this increase in QOL (figure C.29, C.30, C.31).

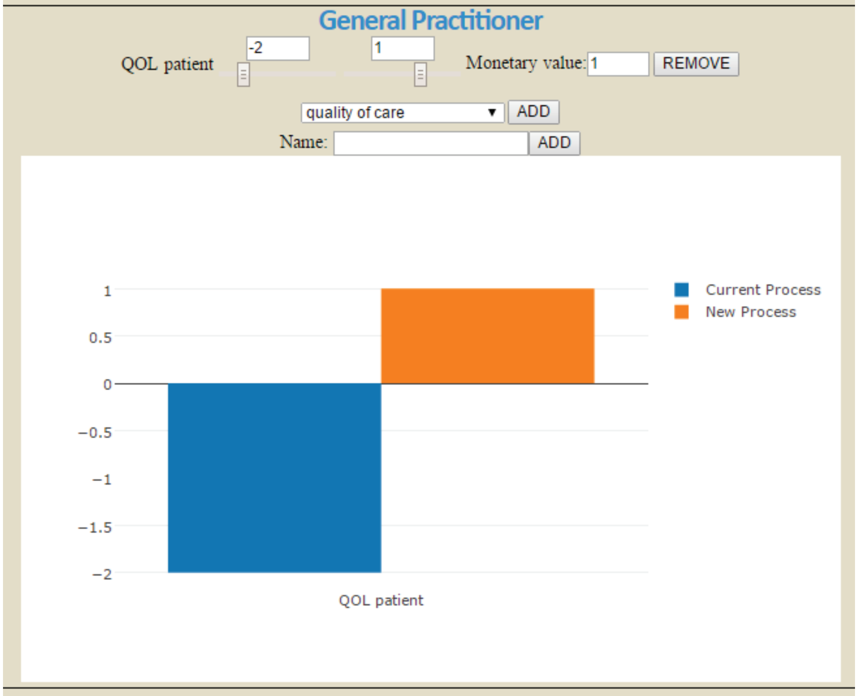


Figure C.29: CHF 8: Qualitative effects for General Practitioner

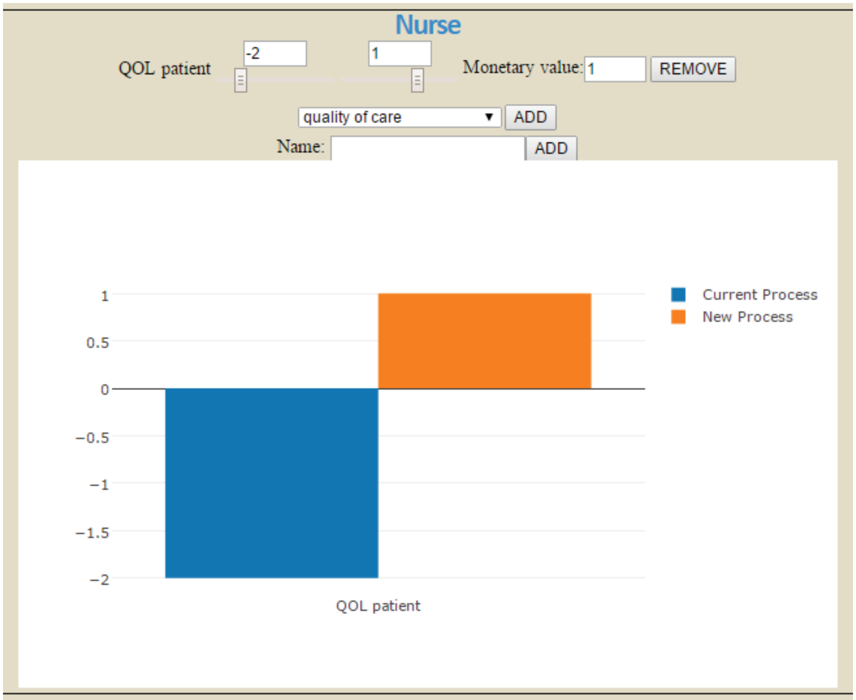


Figure C.30: CHF 8: Qualitative effects for Nurse

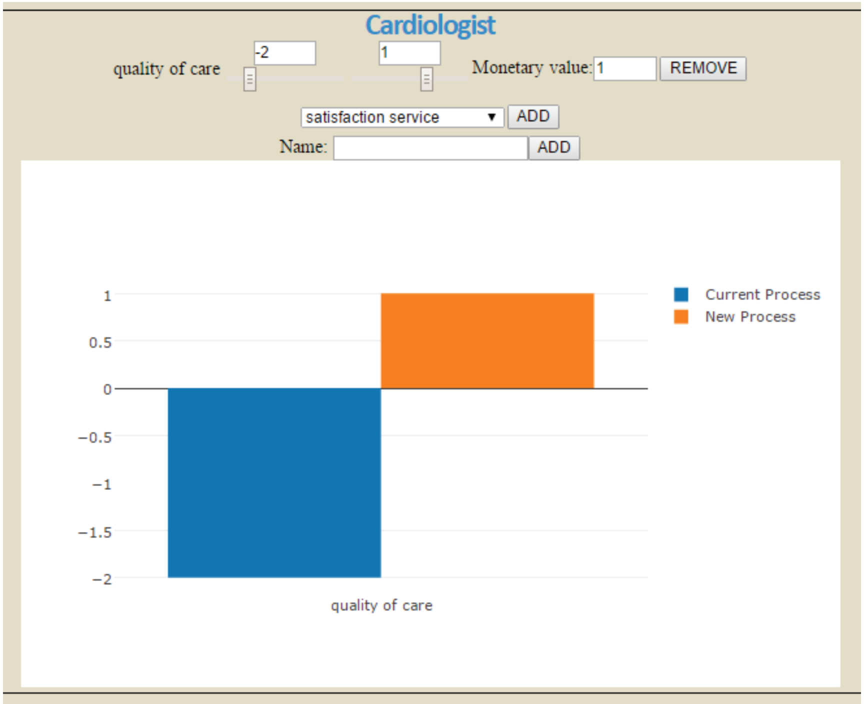


Figure C.31: CHF 8: Qualitative effects for Cardiologist

Step 9: Influence of time and qualitative effects: identification of barriers In this step the monetary values of the time investment and the qualitative effects are added to the financial cost/receiving. Delta is calculated for every actor.

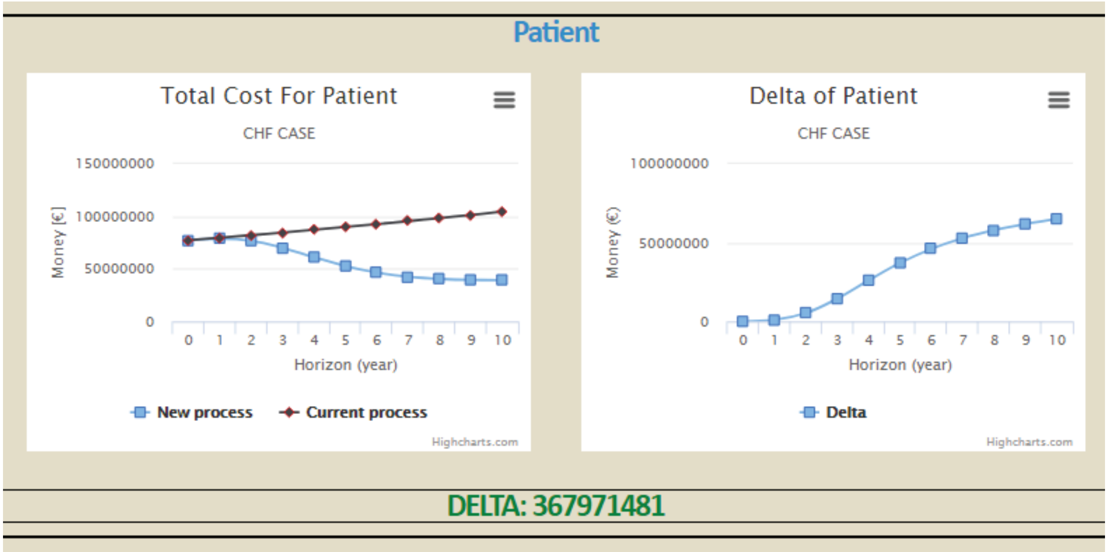


Figure C.32: CHF 9: Total Profit and delta for Patient

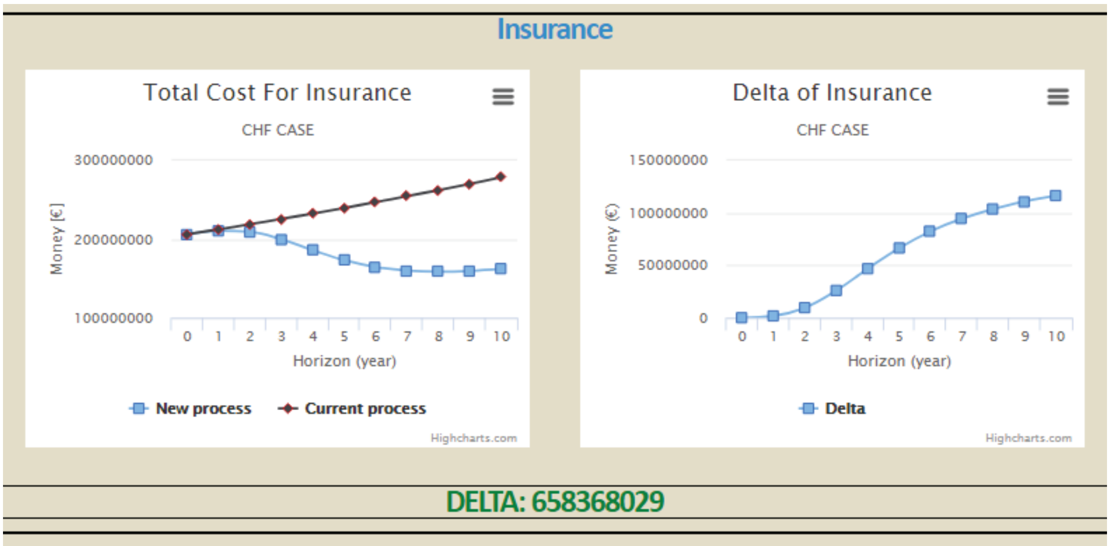


Figure C.33: CHF 9: Total Profit and delta for Insurance

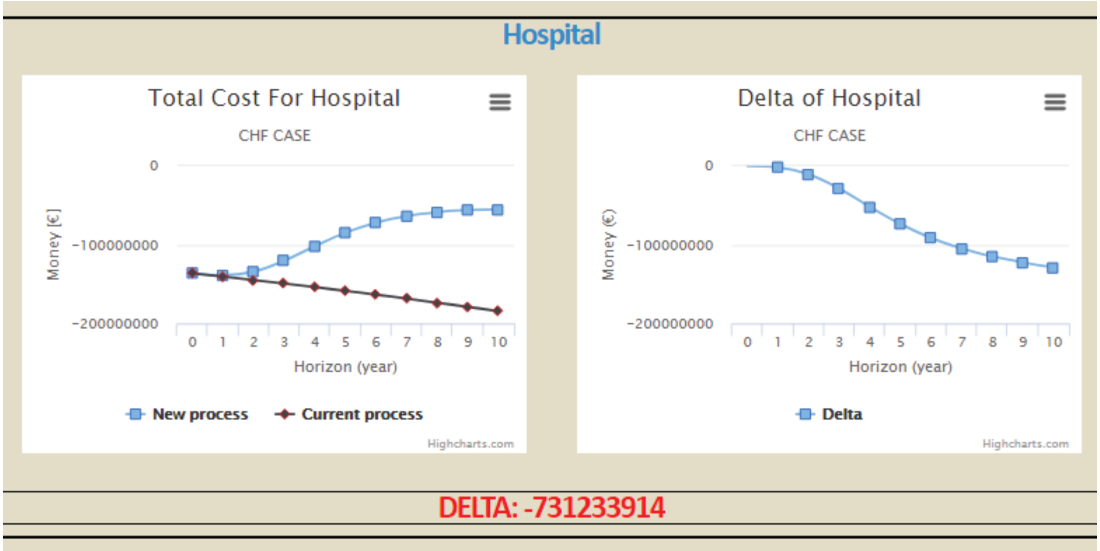
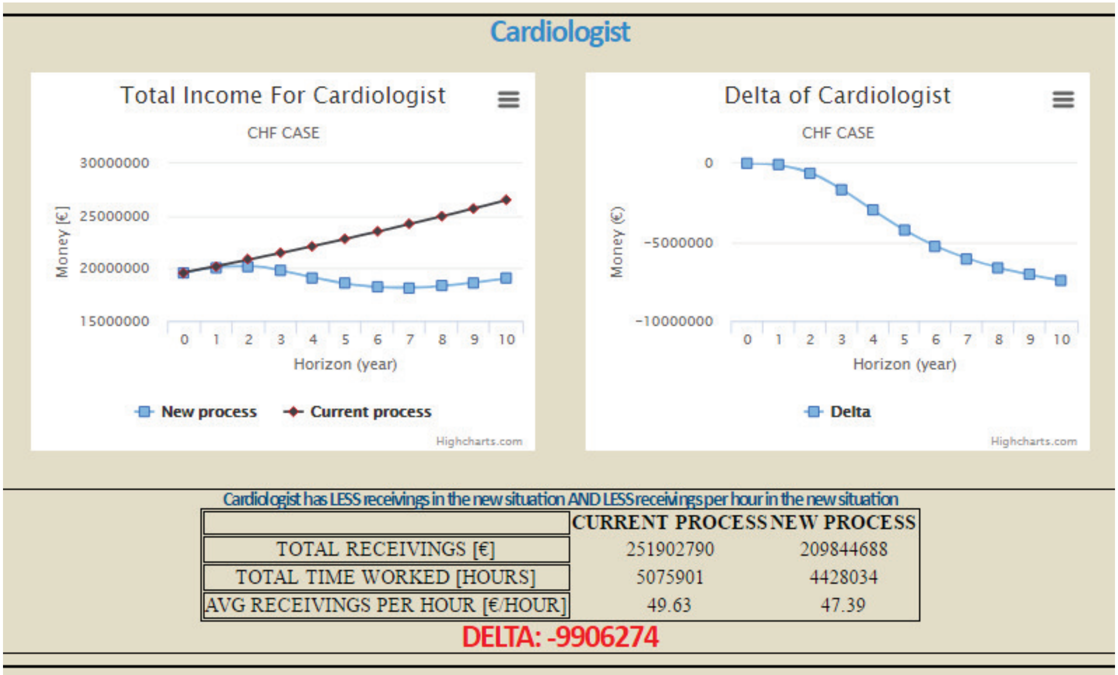


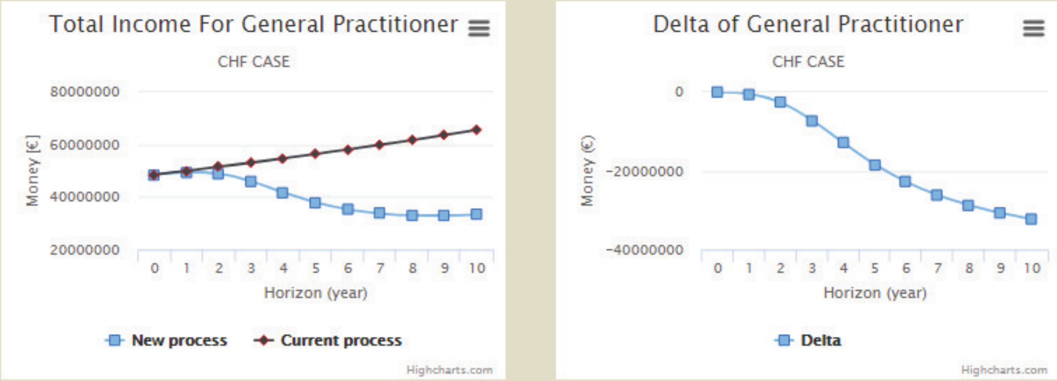
Figure C.34: CHF 9: Total Profit and delta for Hospital



	CURRENT PROCESS	NEW PROCESS
TOTAL RECEIVINGS [€]	251902790	209844688
TOTAL TIME WORKED [HOURS]	5075901	4428034
AVG RECEIVINGS PER HOUR [€/HOUR]	49.63	47.39

Figure C.35: CHF 9: Total Profit and delta for Cardiologist

General Practitioner



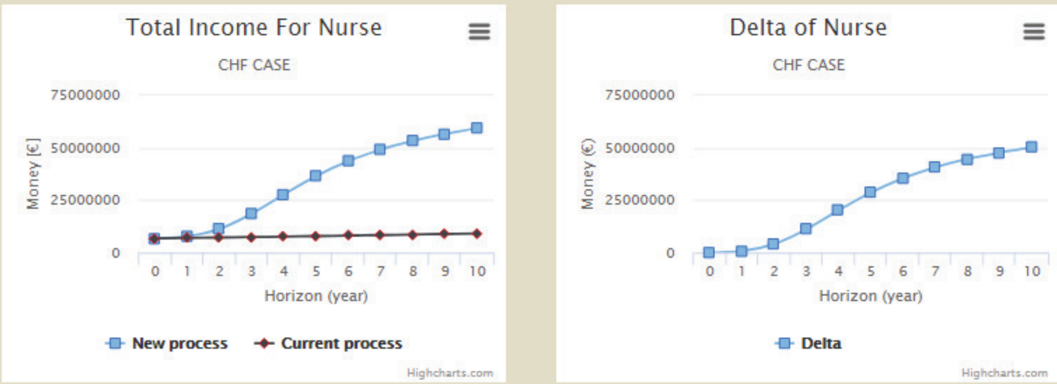
General Practitioner has LESS receivings in the new situation AND LESS receivings per hour in the new situation

	CURRENT PROCESS	NEW PROCESS
TOTAL RECEIVINGS [€]	623173020	440794532
TOTAL TIME WORKED [HOURS]	12804251	9414496
AVG RECEIVINGS PER HOUR [€/HOUR]	48.67	46.82

DELTA: -17401734

Figure C.36: CHF 9: Total Profit and delta for General Practitioner

Nurse



⚠ Warning: actor Nurse has to work 4.24 times more on average in the new situation compared to the current!

Nurse has MORE receivings in the new situation AND MORE receivings per hour in the new situation

	CURRENT PROCESS	NEW PROCESS
TOTAL RECEIVINGS [€]	86894080	370204327
TOTAL TIME WORKED [HOURS]	2896470	12291720
AVG RECEIVINGS PER HOUR [€/HOUR]	30	30.12

DELTA: 283310247

Figure C.37: CHF 9: Total Profit and delta for Nurse

For the eCare provider one should enter the profit he wants to make. This is expressed in % gross margin. There has been chosen to input a value of 5 %; the eCare provider is satisfied with a return of 105 % on his investment. As one can see that he has a positive delta, it means that he makes more profit than this percentage.

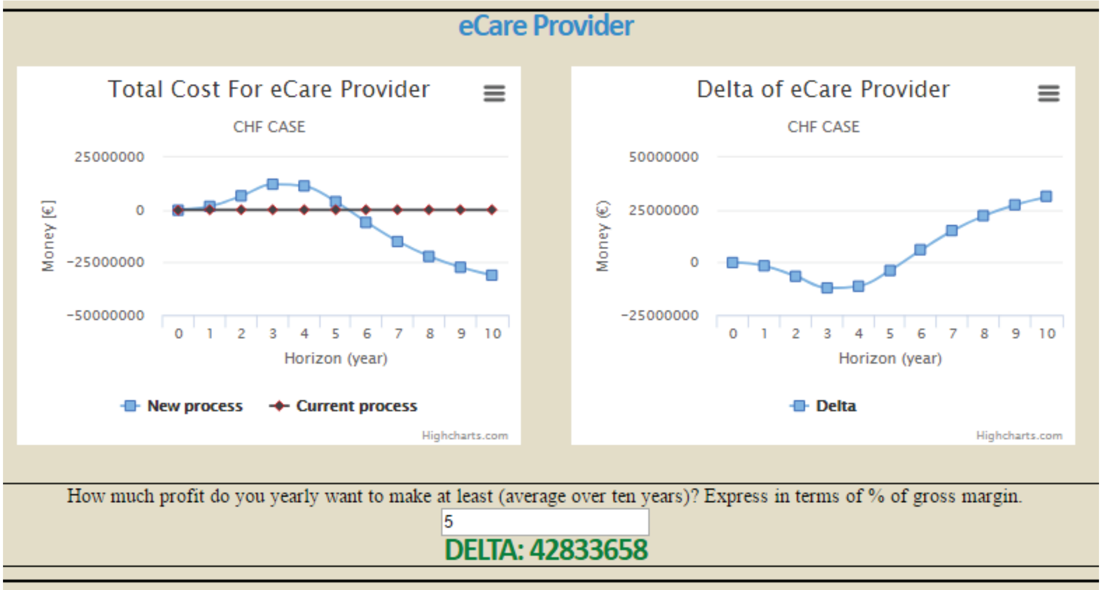


Figure C.38: CHF 9: Total Profit and delta for eCare Provider

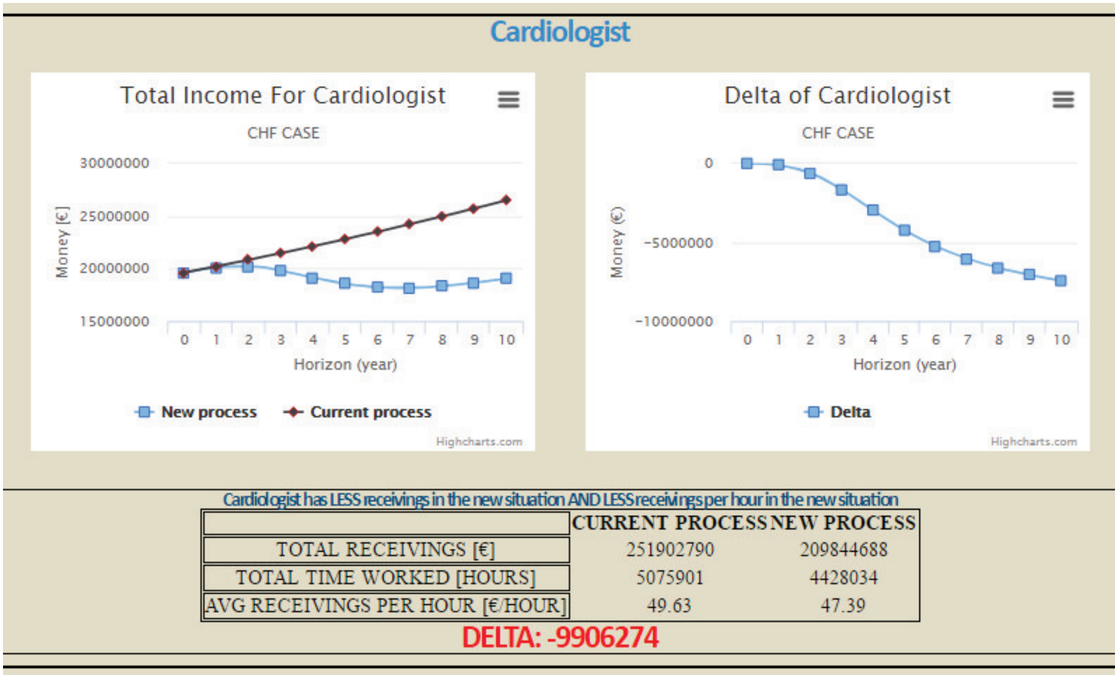


Figure C.39: CHF 9: Total Profit and delta for Cardiologist

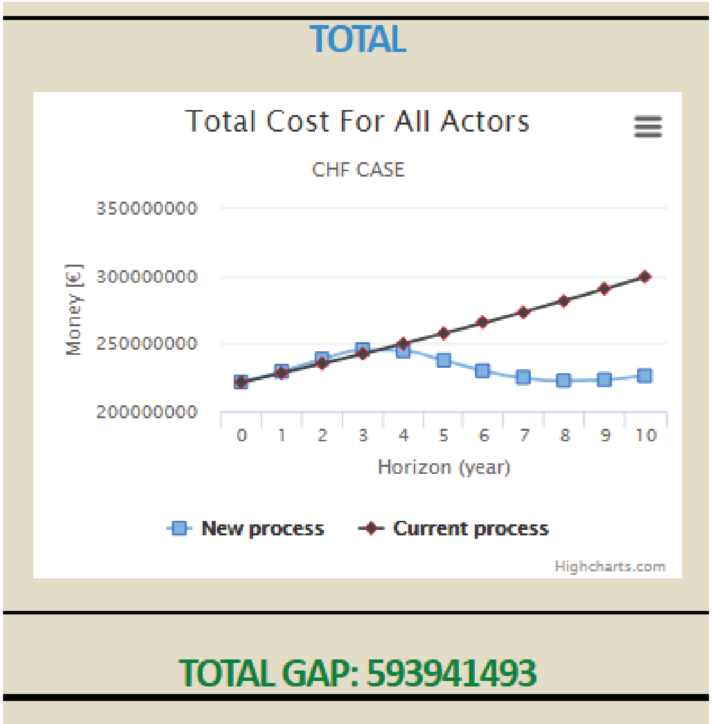
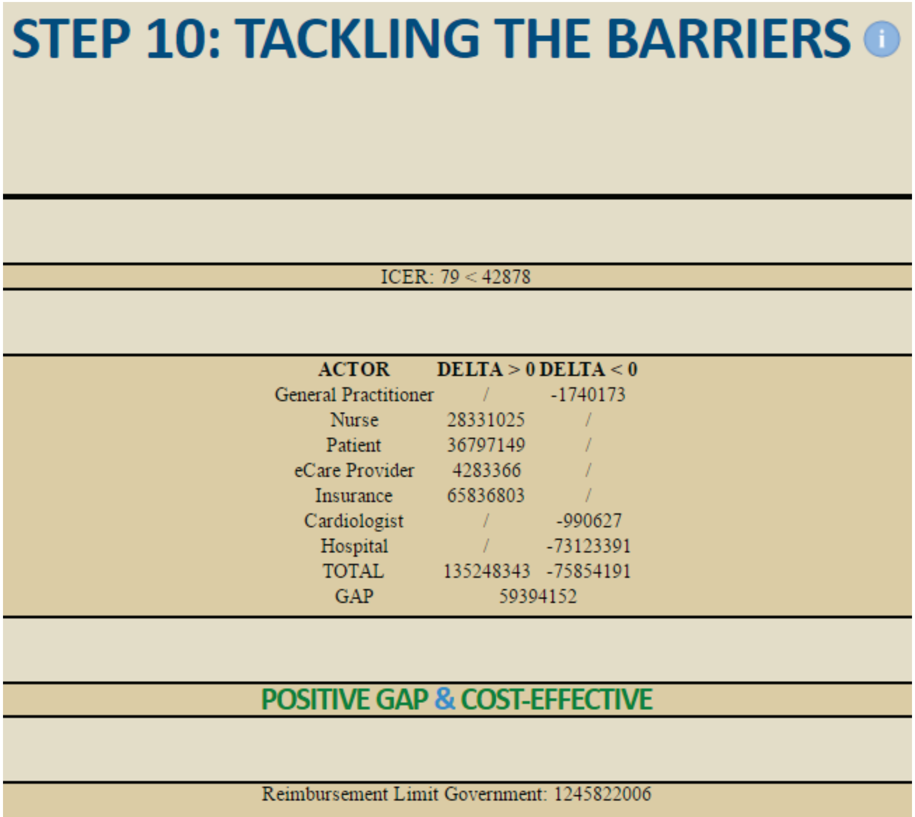


Figure C.40: CHF 9: Total Cost of the service

Step 10: Tackling the barriers

At last, a summary of the project is shown with some possible reallocation solutions.


STEP 10: TACKLING THE BARRIERS

ICER: 79 < 42878

ACTOR	DELTA > 0	DELTA < 0
General Practitioner	/	-1740173
Nurse	28331025	/
Patient	36797149	/
eCare Provider	4283366	/
Insurance	65836803	/
Cardiologist	/	-990627
Hospital	/	-73123391
TOTAL	135248343	-75854191
GAP	59394152	

POSITIVE GAP & COST-EFFECTIVE

Reimbursement Limit Government: 1245822006

Figure C.41: CHF 10: Final results

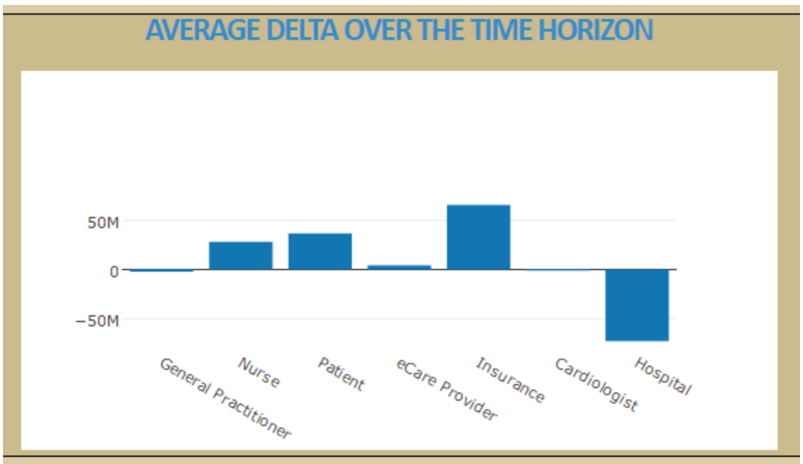


Figure C.42: CHF 10: Deltas for all actors

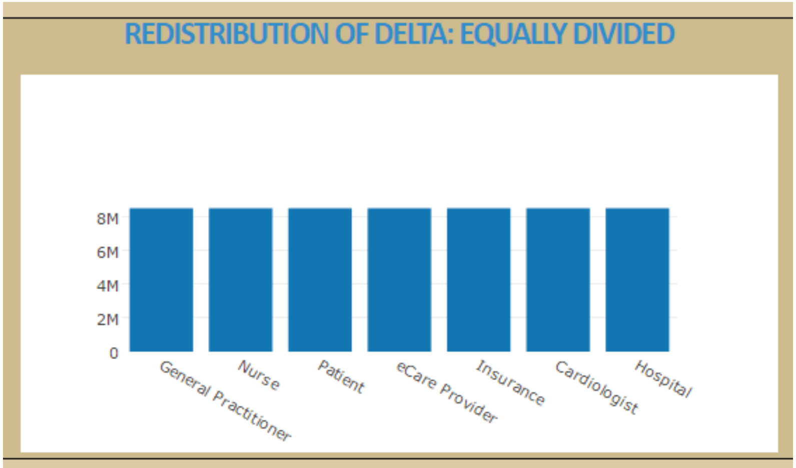


Figure C.43: CHF 10: Tackling the barriers: reallocation based on divide equally

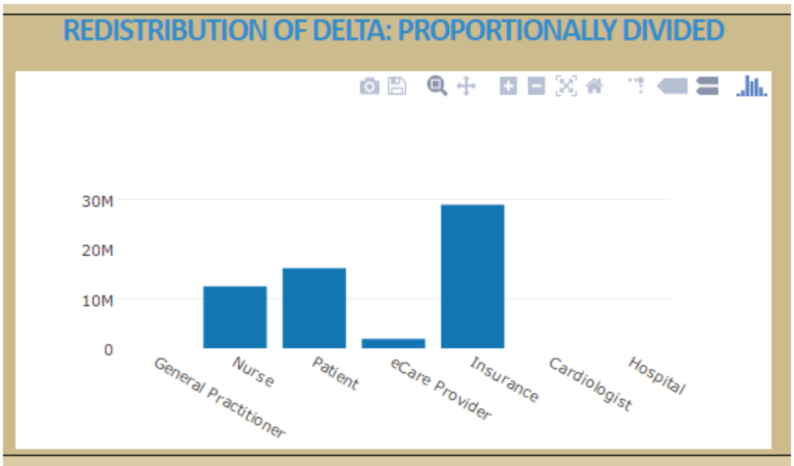


Figure C.44: CHF 10: Tackling the barriers: reallocation based on divide proportionally

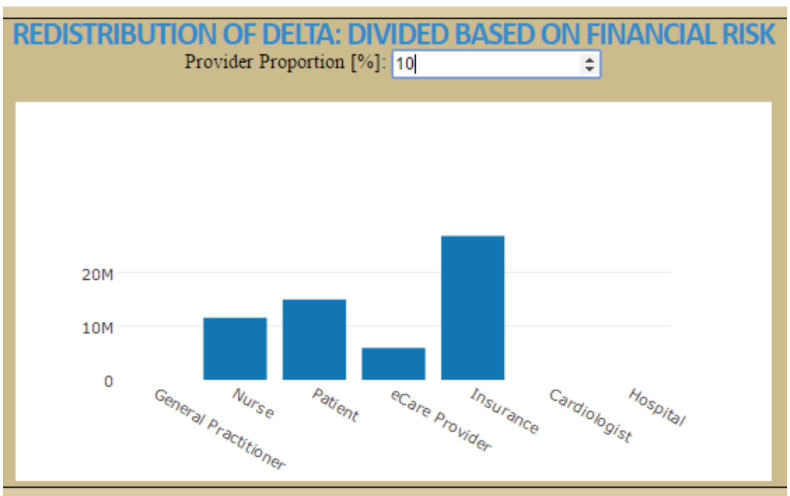


Figure C.45: CHF 10: Tackling the barriers: reallocation based on financial risk