Analyse van de impact van ICT-gebaseerde slimme diensten met behulp van een techno-economische evaluatiemethodologie

Assessing the Impact of ICT-Enabled Smart Services Using a Techno-Economic Evaluation Methodology

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Genegen groet,

Frederic Vannieuwenborg
Gent, juni 2017

Table of Contents

List of Figures

List of Tables

List of Acronyms

0 – 9

2G	Second Generation
4G	Fourth Generation

A

AAL	Ambient Assisted Living
ADL	Activities of Daily Living
API	Application Programming Interface

B

BAN	Body-Area Network
BAU	Business As Usual
BLE	Bluetooth Low Energy
BPMN	Business Process Model and Notation

C

CapEx	Capital Expenditure
CHF	Chronic Heart Failure

D

DES	Discrete Event Simulation

E

eCP	eCare Platform
ERP	Enterprise Resource Planning

F

FTE	Full Time Equivalent

G

GDP	Gross Domestic Product
GP	General Practitioner
GSM	Global System for Mobile communications
GTM	Go-To-Market

H

HIS	Hospital Information Systems
HVAC	Heating, Ventilation and Air Conditioning

I

IAAS	Infrastructure-As-A-Service
ICT	Information and Communication Technology
IoT	Internet of Things
ISM	Industrial, Scientific and Medical
ISP	Internet Service Providers

K

KPI	Key Performance indicator

L

LPWAN	Low-Power Wide-Area Network
LTE	Long-Term Evolution

M

MAAS	Mobility-As-A-Service
MCU	Micro Controlling Unit

N

NPV	Net Present Value

O

OECD	Organization for Economic Co-operation and Development
OpEx	Operational Expenditure
OTA	Over-The-Air
OWL	Web Ontology Language

P

PAS	Personal Alarm System
PAAS	Platform-As-A-Service
PAN	Personal-Area Network
PEST	Political, Economic, Social and Technological analysis

PI	Performance Indicators
PSU	Power Supply Unit

Q

QALY	Quality Adjusted Life Year
QoL	Quality of Life
QoS	Quality of Service

R

RFID	Radio-Frequency Identification
RIF	Rule Interchange Format
RPM	Remote Patient Monitoring

S

SAAS	Software-As-A-Service
SCADA	Supervisory Control And Data Acquisition
SCP	Smart Care Platforms
SDK	Software Development Kits
SMS	Short Message Service
SWOT	Strengths, Weaknesses, Opportunities and Threats

T

TE	Techno-Economic

V

VAS	Visual Analog Scale

W

WAN	Wide-Area Network

Samenvatting
– Summary in Dutch –

Onze omgeving wordt alsmaar ‘slimmer’. Vele objecten, producten en diensten, zowel voor persoonlijk als niet-persoonlijk gebruik, worden naar een hoger niveau getild door integratie van ICT-functionaliteiten. Dit laat dergelijke producten en diensten toe informatie te verzamelen over de context waarin ze gebruikt worden, deze te communiceren, er zich aan aan te passen en erop te reageren. Deze op ICT-steunende slimme diensten dragen bij aan de omschakeling van vele productgerichte industrieën en ondernemingen naar een dienstgerichte structuur. Deze trend, ook bekend als ‘servitization’, wordt mogelijk gemaakt door nieuwe evoluties op het gebied van Internet of Things (IoT) en clouddiensten. Zowel IoT- en clouddiensten bieden veel nieuwe opportuniteiten gaande van betere inzichten in de eindklant, meer toegevoegde waarde, hogere kosten-effectiviteit en nieuwe soorten inkomstenstromen zoals recurrente inkomsten i.p.v. een eenmalige inkomst. Verschillende applicatiedomeinen zoals slimme zorg (bv. diensten voor valpreventie en het volgen van de patiënt op afstand), slimme woningen (bv. Nest, een zelflerende thermostaat die energieleveranciers toelaat je verwarmingsinstallatie aan- of af te schakelen), Industrie 4.0 (bv. automatisch monitoren van machineparken voor preventief onderhoud), slimme voorzieningen (bv. slimme elektriciteitsmeters), slimme steden en slimme transportdiensten (bv. slimme containers) groeien aan een sneltempo door de vele potentiële voordelen van deze slimme diensten.

Maar, integreren van deze slimme diensten brengt veel uitdagingen en onzekerheden met zich mee voor zowel de betrokken actoren, de gebruikers en de maatschappij in haar geheel. Zo moeten bijvoorbeeld nieuwe samenwerkingsverbanden geformuleerd worden, zijn er nieuwe en ongeteste inkomsten-modellen en dienen er investeringen gemaakt te worden. Dan is er nog de vraag hoe de operationele processen geïmpacteerd zullen worden en wat het effect van regelgeving is, of net het gebrek eraan? Dergelijke onzekerheden kunnen in sommige gevallen leiden tot een terughoudende houding en kunnen zelfs resulteren in barrières voor adoptie van de slimme dienst.
Zo is er in de zorgsector, afgaande op onderzoeksresultaten en verklaringen van de Orde der Geneesheren, een terughoudendheid te bespeuren omwille van gebrek aan financiële structuren, hierdoor is de adoptie van slimme zorgdiensten vaak laag. Ook in andere domeinen zoals slimme woningen en slimme

transportdiensten kunnen bezwaren rond data privacy en data eigenaarschap leiden tot een vertraagde adoptie van nieuwe diensten.

Om inzicht te krijgen in de totale impact van dergelijke slimme diensten en om economisch haalbare voorstellen te formuleren, dienen deze zorgvuldig geëvalueerd te worden. Om dit te doen, stellen we binnen dit proefschrift een methodologie voor om de multi-dimensionale impact van slimme diensten te kunnen evalueren.

Vooreerst focussen we op de impact die slimme diensten hebben op de manier waarop ondernemingen dienen samen te werken of competitie aangaan. Dit start met het analyseren van het waardenetwerk, wat inhoudt dat de verschillende actoren en hun rollen of taken binnen het volledige proces van waardecreatie worden geïdentificeerd, alsook de uitwisselingen van waarde tussen de actoren (bv. financiële waarde versus specifieke dienstverlening). Waardenetwerk-analyse verschaft inzichten hoe toegevoegde waarde wordt gecreëerd en laat toe om potentiële hiaten en moeilijkheden voor een duurzaam waardenetwerk te identificeren. Een duurzaam waardenetwerk beschrijft een constellatie waarbij alle betrokken actoren individueel profiteren en daardoor verder zullen bijdragen binnen het waardenetwerk. Indien dit niet het geval zou zijn, dan zal het waardenetwerk niet duurzaam zijn en daarmee ook niet haalbaar in zijn huidige vorm.

Om te weten of de betrokken actoren al dan niet zullen profiteren van integratie van de slimme dienst, moet de totale impact op hun business model worden geïdentificeerd en geëvalueerd. Slimme diensten kunnen niet enkel de bedrijfsmodellen en -processen impacteren, ze leiden ook tot additionele investeringen en nieuwe inkomstenstromen. We beginnen met het identificeren en beschrijven van de toegevoegde waarde en impact op de bedrijfsstrategie, dewelke kan zijn: toegenomen marktaandeel, aantrekken van een nieuw type klanten, een dienstenuitbreiding of een totaal nieuw aanbod naar de klanten toe. Vervolgens worden de huidige operationele processen ontleed om de impact van de slimme dienst op de verschillende processtappen en –taken te kunnen identificeren. Simulatiemethodes zoals discrete event simulatie worden aangewend om de effecten van de slimme diensten na te gaan op vooraf gedefinieerde kritieke prestatie-indicatoren (KPI) van de operationele processen. Het kwantificeren van zowel de impact van de KPI's, maar ook van kwalitatieve effecten zoals gemoedsrust, verbeterde mobiliteit en een verminderd angstgevoel laat een economische analyse van de slimme dienst toe. Daartoe is het ook van belang de investeringen en operationele kosten te modelleren. Op basis van deze gegevens kunnen scenario- analyses en techno-economische evaluaties ons leiden naar optimale uitrolstrategieën of naar mogelijk technische alternatieven.

Nadat voor elke betrokken actor de impact in kaart is gebracht en gekwantificeerd is, dient de haalbaarheid van de slimme dienst in het algemeen, haar waardenetwerk constellatie en de individuele bedrijfsmodellen geëvalueerd te worden. Door hun innovatieve en disruptieve karakter kunnen sommige slimme diensten geteisterd worden door verschillende barrières die een grootschalige uitrol verhinderen. Via PEST-analyses (politiek, economisch, sociaal en technisch) worden de barrières gedetecteerd. Een duurzame slimme dienst volgt niet enkel uit het feit dat de actoren een positieve impact ervaren, of omdat de waardenetwerkconstellatie haalbaar lijkt, maar ook uit het feit dat er geen signifancte PEST-barrières meer aanwezig zijn. Rekening houdend met potentiële barrières en eventuele tekortkomingen in de bedrijfsmodellen van de individuele actoren kunnen richtlijnen voor verbetering en haalbare vermarktingsstrategieën voor de slimme dienst geformuleerd worden.

De belangrijkste bijdragen van dit proefschrift zijn het formuleren en valideren van de voorgestelde methodologie evenals het beschrijven en toepassen van verschillende simulatie- en techno-economische modellen op verschillende use cases. Zo toont de waardenetwerk-analyse voor integratie van een eCare platform, die als doel heeft om de communicatie en samenwerking tussen zowel de patiënt en diens informeel en professioneel zorgnetwerk te faciliteren maar tegelijkertijd ook verandering in dagelijkse levensstijlpatronen van de patiënt monitort, dat een grootschalige uitrol nog momenteel verhinderd wordt door verschillende barrières (bv. de technische complexiteit voor ouderen, gebrek aan standaarden, bezorgdheden rond privacy en een gebrek aan financiële structuren). Het onderzoek geeft aan dat deze barrières te uitdagend zijn om in een beweging te overbruggen. Daarom wordt een migratiepad voorgesteld waarbij de verschillende eigenschappen en mogelijkheden van dergelijk eCare platform stapsgewijs worden vrijgegeven voor verschillende actoren, om zo tot volledig patiëntgeoriënteerde zorg te komen. Uit analyse van de bedrijfsmodellen van de verschillende betrokken actoren blijkt dat thuiszorgorganisaties een voordeel kunnen halen uit gebruik van dergelijke eCare platformen omdat deze de huidige administratieve processen sterk kan vereenvoudigen. De directe kosten voor zorgplanning en zorgfacturatie kunnen met 38% gereduceerd worden na implementatie van het eCare platform. Daarnaast zal dit ertoe leiden dat er veel tijd van de zorgprofessionals vrijkomt wat kan resulteren in meer kwalitatieve zorg.

Vervolgens wordt een discreet event simulatiemodel voorgesteld om de impact van een ontologie-gebaseerd verpleegster-oproep systeem te evalueren op de operationele processen binnen een zorgafdeling. Het ontologie-gebaseerde verpleegster-oproep systeem neemt verschillende context variabelen (bv. type van alarm: vraag naar zorg of vraag naar hoteldiensten, de relatie met de patiënt, en de agenda van de verpleegkundige staf) in overweging bij het toewijzen van alarmen aan specifieke stafleden. Acht verschillende scenario's waarbij het nieuwe systeem wordt ingezet worden vergeleken met prestaties van huidige traditionele verpleegster-oproep systemen. De performantie van het systeem wordt gemeten aan de hand van verschillende KPI’s, zoals: balans in werklast, maximale wachttijd vooraleer een oproep beantwoord wordt, aantal doorverwezen oproepen en afgelegde afstand per shift. Wanneer de KPI’s van zowel het traditionele systeem vergeleken worden met deze van het ontologie-gebaseerde oproep systeem, wordt duidelijk dat de laatste kan bijdragen tot een verbetering van de operationele performantie binnen bepaalde scenario's. De aanpak via het discreet event simulatiemodel is daarom geschikt voor managers die de potentiële impact willen nagaan van nieuwe slimme diensten op hun operationele processen.

IoT is een belangrijk element van veel slimme diensten. Maar het integreren van IoT-functionaliteiten zoals monitoren van de context en aansturen van actuatoren (bvb. moter, luidspreker, elektromagneet) heeft een impact op de kostenstructuur van het bedrijfsmodel. Zo beïnvloedt de keuze van het type netwerktechnologie niet enkel de kosten voor hardware, firmware en middleware, maar kan het ook impact hebben op de operationele kosten zoals bv. de kosten voor tele-communicatie of batterij vervangingen. Beide types kosten kunnen een significante impact hebben op de kostenstructuur, zeker bij een grootschalige uitrol. Om IoT-ontwikkelaars en dienstenleveranciers te ondersteunen bij het keuzeproces voor een geschikte IoT-netwerktechnologie wordt een twee-staps methode voorgesteld. In een eerste stap wordt op basis van mismatchen tussen enerzijds de technische eigenschappen van de netwerken en functionele en technische vereisten van de dienst anderzijds (bv. maximale lengte van bericht, bereik, maximale zendfrequentie) de lijst van IoT-netwerktechnologieën (bv. LoraWAN, Sigfox, BLE, satellietcommunicatie, GSM en LTE) ingekort. Daarna worden in een tweede stap de totale kosten inzake een bepaalde technologie met elkaar vergeleken. Dit bevat onder andere de kost voor netwerkuitrol, kosten voor netwerkonderhoud, hardware kosten, kosten voor batterijvervangingen, en kosten voor tele-communicatie. Dergelijke techno-economische aanpak stelt dienstenleveranciers en IoT-ontwikkelaars in staat om de meest economische en technisch haalbare netwerktechnologie te kiezen.

Tot slot wordt de multi-actor evaluatie-methodologie toegepast op verschillende eCare diensten om de toegevoegde waarde ervan voor de verschillende actoren te identificeren en te vergelijken. Dit omvat niet enkel het kwantificeren van de impact op kost- en inkomstenstromen, ook worden kwalitatieve effecten zoals verhoogde gemoedsrust en kwaliteit van leven in het algemeen meegenomen. Wanneer deze bevindingen worden gecombineerd met geïdentificeerde PEST-barrières voor de betrokken actoren, kunnen potentiële lacunes in de bedrijfs-modellen gedetecteerd worden die mogelijks kunnen leiden tot niet-duurzame waardenetwerken. Daarnaast laat de methodologie toe om, vertrekkende van de grootte en het type barrière, algemene richtlijnen te formuleren om naar een duurzame oplossing toe te werken. Dergelijke richtlijnen en suggesties kunnen bijvoorbeeld zijn: de service abonnementskosten zou met bedrag X verminderd moeten worden, de kwalitatieve effecten van de service zijn te laag, of de initiële investering voor de patiënt is te hoog.

Summary

Our environment is becoming ‘smarter’. Many objects, products and services both for personal and non-personal use are being taken to a next level due to the integration of ICT-functionalities. This allows these products and services to collect information of the context they are used in, and to communicate, adapt and act on this information. These ICT-enabled smart services have been contributing to the migration of many product-centered industries and businesses towards a service-centered structure. This trend, also known as ‘servitization’, is driven by new capabilities and evolutions in the fields of Internet of Things (IoT) and cloud-services. Both IoT- and cloud enabled services open up a lot off new possibilities ranging from better customer insights, increased added value, increased cost-effectiveness and new types of revenue streams. Several application domains such as smart health and care (e.g. fall prevention and remote patient monitoring services), smart homes (e.g. Nest, a self-learning smart thermostat that allows energy provider to control your heating system), Industry 4.0 (e.g. machine monitoring services for preventive maintenance), smart utilities (e.g. smart electricity meters), smart cities and smart mobility (e.g. smart container monitoring) are growing at fast pace due to the potential benefits smart services hold.

But, integrating these smart services comes with many new challenges and uncertainties for the involved actors, the users and the society as a whole. For instance new types of collaborations with other business actors need to be formulated, there are new and untested revenue models, and new investments have to be made. Also, how will the operational processes be affected and what about the effect of regulations or lack thereof? These uncertainties lead sometimes to a reticent attitude, or can even result in barriers for adopting the smart service. In the care sector for instance, research and statements of representatives of associations of physicians indicate that a lack of financial structures fuels reluctance, and therefore adoption of smart care services has been low. Also in other application domains such as smart homes and smart mobility there can rise concerns about data privacy and ownership, which can result in a lowered adoption of the new service.

To gain insights in the overall impact of smart services and in order to create or formulate a viable and economic offer, they need to be evaluated very well. To do so, in this dissertation, we propose a methodology to evaluate the multi-dimensional impact of smart services.

First, we focus on the impact a smart service has on the way business actors must collaborate, co-operate or compete with each other. This starts by analyzing the value network, which comprises the identification of involved actors, their tasks or roles within the complete value offer and the value exchanges between these actors (e.g. monetary vs. specific services). Value network analysis provides insights in how added value is created and allows identification of potential threats or gaps for a sustainable value network. A sustainable value network is a constellation in which all the involved actors receive value in such a way they benefit individually and therefore will further contribute in the value network. If this is not the case, the value network will become unsustainable and non-viable in the current setting.

In order to know if the involved actors will or will not benefit from integrating the new smart service, the total impact on their business model needs to be identified and evaluated. Smart services can not only affect the individual business strategy and the business processes, but also lead to additional investments and potential revenue streams. We start with identifying and describing the added value and impact on the business model, which can be an increased market share, attracting a new type of customer, a service extension or a completely new offer for their customers. Next, current operational processes are broken down to identify how smart services will impact current process steps and task. Simulation methodologies such as discrete event simulation are used to model the effects the smart service has on predefined key performance indicators (KPIs) of the current operational processes. Quantifying the impact of these KPIs, as well as quantifying qualitative impacts such as increased peace of mind, increased mobility and less anxiety, allows economic analyses of the smart service. To do so, also the required investments or capital expenditures and operational expenditures need to be modelled. Scenario and techno-economic analyses then can guide us to the most optimal deployment strategies and feasible technical alternatives.

At last, when the impact for each actor involved is described and quantified, we can evaluate the overall viability of the smart service, its value network and the individual business models. Due to their innovative and disruptive characteristics, smart services often face many barriers for large scale deployment. These barriers can be identified via PEST-analyses (political, economic, social and technological). A sustainable smart service not only is a result of the positive impacts on some of the involved actors' business models, nor on the viability of the complete value network but also of the lack of broader PEST-barriers. Taking into account all potential barriers and potential gaps in the business models of individual actors, guidelines and viable go-to-market strategies for the smart service can be formulated.

The main research contributions of this dissertation are the formulation and validation of the proposed methodology and the description of the simulation and techno-economic models used via case research.

First, the value network analysis for the integration of an eCare platform, which aim is to facilitate the communication and collaboration between patients and both the formal and informal care providers, whilst monitoring changes in daily patterns and lifestyle of the care receiver, shows us that there are currently many barriers for large scale deployment (e.g. technological barriers for elderly, lack of standards, privacy concerns, lack of financial structures). The analysis indicates that these barriers are too large to tackle at once. Therefore a migration path is presented to release the features and capabilities of the eCare platform in several steps in order to achieve complete patient-centric home care delivery. When analyzing the business models of the involved care providers, it has become clear that home care organizations could benefit from such an eCare platform because it simplifies administrative tasks. The direct costs for both the care scheduling and billing processes could be reduced by 38% by implementing such a smart eCare platform. In addition, a significant amount of time of the care personnel could be freed up for providing more qualitative care.

Next, to evaluate the impact of an ontology-based nurse call system on the operational processes of the care department, the care staff and patients, a discrete event simulation model is presented. Such an ontology-based nurse call system takes into account a set of context-variables such as trust relationships, type of call (e.g. alert, care request, request for hotel services) and current agenda of the nurse staff when assigning a call to a specific staff member. Up to eight different implementation scenarios of an ontology-based nurse call system have been compared with traditional nurse call systems. The performance of the system is measured via different key performance indicators (KPI) such as workload balance, maximum waiting time before answering a call, number of redirected calls, and distance walked per shift. Comparing the KPIs of both traditional nurse call systems and an ontology-based nurse call system shows that the latter can result in increased operational performance in specific scenarios. This DES modelling approach therefore proves to be useful for managers to determine the potential impact of smart services on the operational processes.

IoT is a major enabler for smart services. But introducing IoT-functionalities such as context monitoring and controlling actuators (e.g. motor, speaker, electro magnet) has an impact on the cost structures of the business models. The choice of the network technology influences not only the hardware, middleware and firmware cost, but also affects operational expenditures such as the costs for telecommunications and battery replacements. Both types of costs have a significant impact on the cost structure of a smart service provider, certainly in case of large scale deployments. To guide IoT-developers or service providers in choosing an appropriate IoT-connectivity technology for their service, a two-step methodology has been proposed. The first step narrows down a wide set of different network technologies (e.g. LoraWAN, Sigfox, BLE, Satellite based communications, GSM and LTE) based on mismatches between the technical characteristics of the networks and the required functionalities of the service (e.g. data payload size, maximum transmission frequency, range). In a second step, the total costs of the remaining IoT-connectivity alternatives are compared. This includes network deployment, network maintenance, device hardware costs, battery replacement, and tele-communication fees. This techno-economic approach allows smart service providers to choose the most economic and technically feasible network technology.

At last, we present a multi-actor evaluating methodology that identifies and compares the added values and impact of various eCare services for the involved actors. This not only includes the quantification of the impact on the revenue and cost structures, but also of qualitative impacts such as increase in peace of mind and overall quality of life (QoL). Combining these benefits with the identified PEST-barriers for the involved actors provides insights in potential gaps in the business models which could lead to unsustainable value networks. In addition, the methodology also presents high level guidelines based on the type and magnitude of these barriers in order to be able to formulate a viable smart service offer for the involved actors. These guidelines or suggestions for improvement include for example: the service subscription cost should be lowered by a certain amount, the qualitative added value of the service should be increased or the upfront investment is too high.

1
Introduction

"In today's climate, it's best to assume that most business models, even successful ones, will have a short lifespan."
- Alexander Osterwalder

This first chapter introduces readers to the broad concept of smart services and their impact. In Section 1.1, the scope and definition of smart and smart services is provided. Next, both domains of Internet of Things (IoT) and Cloud services are introduced in Section 1.2 as enablers for smart services. What is meant by 'impact and effects of smart services' is discussed in Section 1.3. Section 1.4 provides an overview of the different application domains of smart services. Then, Section 1.5 lists the research challenges followed by a description of the research approach to tackle these challenges (Section 1.6). A complete outline of this work is provided in Section 1.7, along with its contributions. At last, all publications resulting from this research work are listed in Section 1.8.

1.1 Smart services

It cannot remain unnoticed any longer, in many sectors traditional economic models are making place for alternative approaches. Think of Uber, the company that is deploying a transportation network by connecting riders and drivers via their mobile application. They are turning the traditional taxi business into a shared economy model in which people who own a car and have a driving license can become independent drivers in just a few clicks. Another great example is Nest, the self-learning thermostat that allows energy providers to remotely control your HVAC-system (heating, ventilation and air conditioning) when for instance demand for energy is spiking. Next, Heidelberg, a manufacturer of high-end printing systems has been integrating sensors into their machines to remotely monitor the performance. This not only results in more cost-effective maintenance processes for Heidelberg but also allows offering a complete performance service towards their customers, including alerts on maintenance or consumables and performance optimization. Also in in the care sector, there are many examples of innovative smart services trying to seek their way into the market. Fall-detection systems, smart pill-boxes, health monitoring applications and telecare platforms to enable remote diagnoses, are just a glimpse these smart care services.

It seems that many product-centered business are migrating to a more service-oriented industry by supercharging their traditional services or products with a layer of ‘smartness’. Due to their innovative characteristics and the speed these smart services are getting introduced with, it is not always clear what the effects of these services are on the way business actors collaborate, how they affect their business cases and processes and what the value of these smart services is for end customers.

Therefore, in this dissertation, we propose a methodology to evaluate the multi-dimensional impact of smart service. This includes the effect on the way enterprises co-operate, collaborate or compete and the effects on their individual business models, processes and cost and revenue structures. Doing so, potential barriers and challenges for smart service adoption can be identified as well as some guidelines to tackle these issues are proposed.

1.1.1 What is Smart?

These days, so many services or products of so many different sectors are called 'smart' that the term has already lost its buzz-value for marketers and has become just a vague reference to a technical characteristic. There are many definitions out there to describe what a smart product is. Often these definitions vary depending on the perspective of the writer. End users for example can define things as smart things if they can be managed remotely. Researcher on the other hand will consider a product smart when it adapts by learning from the context it is used in. For others, a thing becomes smart when there is a microprocessor embedded in it. The latter has nowadays maybe become a too simplistic definition since microprocessors could be embedded in almost everything ranging from toys, electronic cigarettes to self-driving cars. Many definitions focus on products whilst many of these are often only an enabler for providing smart services.

In this dissertation the definition of smart services, formulated by Aschbacher [1] has been used. *"Smart services are technical systems that are intentionally implemented in products or services for the purpose of meeting specific tasks, especially in the area of IT-based services. They are characterized by connectivity (synchronous, asynchronous) with a technically suitable service infrastructure, which can enable agile responsiveness based on pro-activeness, self-learning abilities and effectiveness."*

The most important characteristics of smart services include the ability for data communication, the ability for data interpretation, the ability to transform this data into knowledge and the ability to act upon that.

Data is King maar is het echt zo smart als alles parallel loopt, Met tijd zullen we hiernaar toe gaan, maar we zijn er nog niet (bvb healthcare)

1.2 New technologies enabling smart services

The evolution of smart services has been strongly driven by various emerging technological trends in information and communication technologies (ICT). Driven by an increasing global demand, technological progress has opened a numerous set of new opportunities whilst market and technological competition has been increasing. Following areas of technological progress have been important enablers for smart services:

1.2.1 **Internet of Things (IoT)**

The network of physical objects ('Things') that are identifiable, communicate via the internet about the sensed context characteristics of the environment they are in, and possess actuation abilities is referred to as the Internet of Things. IoT forms the bridge between the physical world and its virtual state by communicating the Thing's physical state or context and allowing to actuate in the physical world based upon virtual decisions. This opens a complete set of new business opportunities in various sectors. For instance sensors can measure vibrations on shafts of big machines and alert operators to perform preventive maintenance tasks when these vibrations exceeds thresholds.

The high-level generic architecture of smart services or IoT-enabled services can be described via a four layered model [2] (Figure 1-1) which includes 1) information generation, 2) information communication, 3) information processing and management, and 4) service provisioning. Due to the holistic character of IoT-services, security must be vertically integrated in all layers, and is therefore a fifth building block. Functionalities and roles within each layer are provided by many IoT-players.

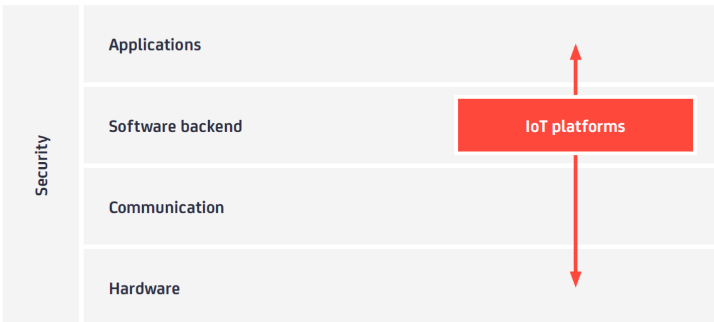

Figure 1-1: Building blocks of IoT – Software back ends provide back end connectivity between Things and applications (also known as IoT-platform) [2]

1.2.1.a Information generation

At the basis of smart services there is the information generating source. This translates into the physical IoT-objects that allow identification and have sensing and or actuating capabilities. The key building blocks of IoT-devices include sensors to sense context parameters, embedded intelligence in the form of a processor or micro controlling unit (MCU), power circuitry or a power supply unit (PSU) and at least one communication node to communicate directly or indirectly with the internet via gateways or base stations. Depending on the application, actuators such as motors, audio speakers, relays, etc. could also be part of the IoT-device. Figure 1-2 provides a schematic overview of an IoT-device.

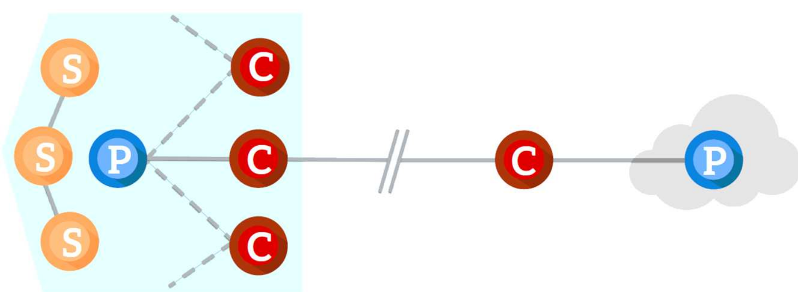

Figure 1-2: Basic building blocks of IoT-devices (in blue area): Sensors (S), microprocessor (P), communication module (C)

Sensors, being components that can detect changes or events in the context environment and provide a corresponding output, come in all sizes and variations. A set of the non-exhaustive list of parameters that can be measured or detected comprises; acceleration, barometric pressure, CO_2-level, location, light intensity, movement, temperature, vibration, electrical conductivity, etc. Communication between the sensor and the MCU is either a digital or a continuous analog signal of which the magnitude corresponds with the magnitude of the parameter being measured.

The MCU provides a limited amount of intelligence embedded in the device. The core of such micro processing units is able to execute pre-programmed task. Data can be stored in their often built-in memory such as ROM or EEPROM. Via input/output peripherals, input signals from sensors can be read out or outputs can be set. Microprocessors have also communication interfaces to communicate with other sensors or microprocessors via various protocols such as I^2C or SPI.

A power supply provides electrical power for the IoT device. IoT devices can be wired to the electrical net, battery fed or can be provided with energy wirelessly via magnetic induction. Electrical energy can also be harvested via kinetic, light or thermal energy sources. Often some type of energy regulator intelligence is required for proper battery charging or other types of energy storing components.

At last, IoT devices must have at least one communication transceiver to receive or send data to a base station or gateway. A various set of communication technologies for IoT is available. The choice for a specific technology or protocol depends on technical and functional requirements such as energy consumption and range (See Chapter 4). IoT-devices can contain more than one communication technology, leaving the option open to choose the most stable or economical communication protocol when used in different circumstances. Communication networks and technologies will be elaborated upon in more detail in Section 1.2.1.b.

1.2.1.b Information communication

To be able to communicate data between the IoT-device and the internet via gateways or base stations, at least one of the available communication technologies must be present. Although in some application settings IoT-device can rely on the wired Ethernet or IEEE 802.3 for communication purposes, most IoT-devices require wireless connections.

Over the last decade significant improvements in traditional cellar networks could be noticed. Whereas before second generation technologies (2G), such as GSM, formed the basis for mobile telephony, current 4G-LTE networks have paved the path for reliable data transfer at high data rates for more users. These cellular networks excel in connecting multiple devices simultaneously and do not suffer from signal interference. Some technical and strategical characteristics of cellular technologies do match well with the requirements of various IoT-systems. However, two main drawbacks of this technology are its power consumption and the fact that they operate in the licensed spectrum, with results in non-free usage. One can imagine these characteristics not fit well for a network of numerous energy resource constrained IoT-devices.

In response to these drawbacks a new set of networks have been arising. The so-called Low-Power Wide-Area Networks (LPWANs) focus on power consumption at the cost of high data-rates and makes them therefore very suitable as IoT-connectivity networks. Recently Lora and Sigfox, two LPWAN-providers, have started deploying their network on an international scale. Other LPWAN-providers are currently developing or starting to deploy their solutions as well (e.g. DASH7, Weightless-P). All current LPWANs are operating in the ISM (industrial, scientific, medical radio) bands, which are free to use. Therefore these technologies are expected to be cheaper than cellular network technologies. The downside of using ISM-bands is that controlling radio traffic is harder since multiple providers are active in the same bands. This could lead to suboptimal performance of the technologies due to interference. Therefore several mobile network providers are investigating to free up licensed spectrum in order to offer LPWAN connectivity networks combined with the quality level assurance similar of cellular networks. An example of this is the Narrow Band –IoT (NB-IoT) initiative.

For many smart service applications, it can be an overkill to equip every IoT-device with cellular or LPWAN-connectivity. Often use cases do not require the long range that comes with these technologies. IoT-based security and comfort applications in home environments such as smart thermostats or smoke detectors could connect via LAN-networks (Local Area Network) such as WiFi or Zigbee to an access point which is connected or integrated in the router to communicate to the internet. But even these connectivity technologies can be an overkill for some applications. Personal- or Body-Area Networks, respectively PANs or BANs, such as smart toothbrushes that communicate with a mobile application on brushing time and pressure, only require wireless connectivity of a couple of meters. Bluetooth, BLE (Bluetooth-Low-Energy) or other short range technologies such as ANT can be suited for similar use cases. Figure 1-3 provides a set of the available technologies in function of their geographical application domain.

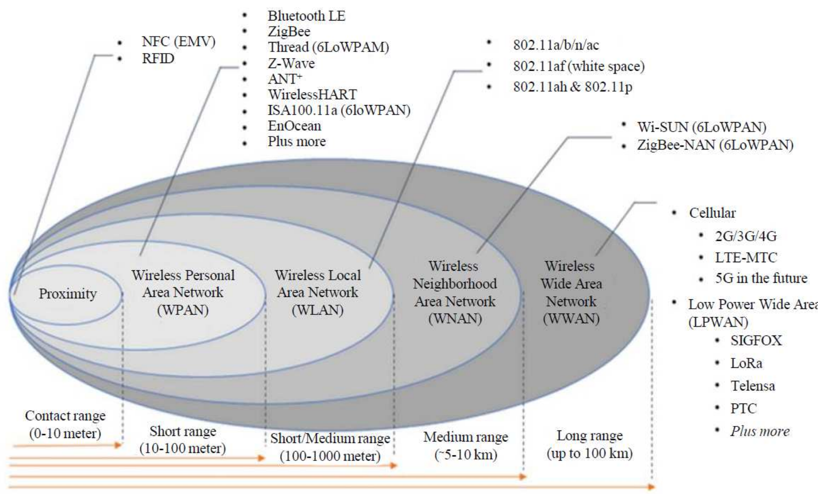

Figure 1-3: IoT-connectivity network technologies grouped in function of their geographical range [3]

Choosing appropriate connectivity depends not only on the technical characteristics of a connectivity network, but also on its functional and strategical characteristics. This in investigated in more detail in Chapter 4.

1.2.1.c Information processing and management via an IoT-platform

IoT-enabled smart services provide added value towards their end users based on information, insights and knowledge that is derived from the real-time or near real-time data coming from many various IoT-devices. But in order to transform this raw data into valuable knowledge, many intermediate data processing and management steps are required. This transformation process, which takes place in the software back end, is the value adding building block of the IoT-architecture, often referred to as IoT-platform.

An IoT-platform aggregates following key building blocks [2] (Figure 1-4):

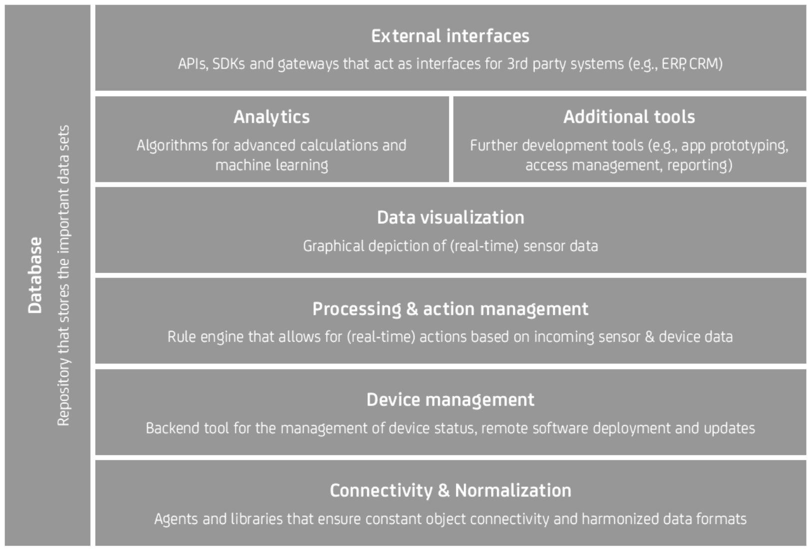

Figure 1-4: The eight key building blocks of an IoT-platform [2]

A. Connectivity and normalization

IoT-devices communicate via a wide set of protocols with the IoT-platform. Although currently many efforts are put into standardization, each IoT-device can have own data structuring schemes. To be able to process and handle all these various sources of data such as sensor readings and device states, the first thing to do is to normalize all these inputs. Normalization is about storing the data into formats manageable by upstream processes or adding an additional identifier to the data that instructs future processes on how to process the data.

The same is true for the abundant set of IoT-devices. The numerous interfaces to communicate from the platform with the IoT-devices makes it complex for overarching applications. Therefore the connectivity layer provides a generic interface towards overarching processes and translates or connects with the IoT-devices via their specific interfaces or APIs (application programming interface).

B. Device management

Setting up, maintaining and managing multiple IoT-devices, gateways and base stations requires a device management platform to assure proper functioning. Such a platform allows: remote configuration of the IoT and network devices, performing firmware updates, alerts for device failures or critical states (e.g. low battery level), and reset, restore and other troubleshooting actions. Because it affects the amount of manual labor required to manage and maintain the IoT-devices, the level of automating device management tasks has a direct impact on operational performance of the IoT-service provider, which is the actor who offers IoT-services to end users.

C. Processing & action management

This is the building block where data is analyzed and translated into actionable results (e.g. when daily energy prices are spiking due to high concentrated demand, the energy supplier could remotely shut off thousands of freezing installations of its customers in order to temporarily free up some energy capacity). This building block often comprises a rule-based decision process that leads to event-triggered actions.

D. Data visualization

Proper visualization of data and information is important for actors involved in the IoT-service provisioning or end users. Good data presentations allows the stakeholders to understand patterns and maybe discover new trends in data streams that have not been noticed by the rule-based analytics.

E. Analytics

Several IoT-services go beyond straightforward event-triggered actions by combining several sources of structured and unstructured data and analyzing trends and patterns in data streams. In order to achieve truly smart IoT-enabled services that can make autonomous decisions, complex techniques such as machine learning, neural networks, evolutionary algorithms and other artificial intelligence techniques are being developed [4]. An example of such a more complex self-learning IoT-service is a smart home care platform that learns the lifestyle patterns of elderly such as sleeping habits and social activities. When sudden changes in these patterns are detected, the smart services then notifies informal or formal care providers.

F. Additional tools

Next to the core functionalities of an IoT-platform, being information processing and action management, also additional tools can be offered to support the management of the core functionalities. Think of application for rapid service prototyping, user management, reporting, QoS (Quality of Service) and workload based scheduling, and billing services.

G. External interfaces

When IoT-services communicate and share data with other third party IT-systems and services (e.g. Enterprise Resource Planning (ERP) systems, call center systems, health information systems, etc.), external interfaces to assure proper data sharing are required. External interfaces come under various formats such as APIs or SDKs (software development kits).

H. Database

Massive IoT-deployment will result in an unprecedented amount of data and information. Sensor readings, device settings and identifiers, information and intermediate analytic results are only a glimpse of all data that need to be managed. This variety of data, structured or unstructured, must be stored intelligently for future processing whilst assuring its security, reliability and the velocity of the system.

Many of these building blocks can be provided by cloud services, see Section 1.2.2. That makes them scalable and adaptive to the real-time need for it. Elastic availability of computer resources for data analytics, data storage and network resources allows flexible response and growth of the IoT-service whilst eliminating the need for significant investments in own infrastructure. Therefore it can be expected that IoT will be a major driver for cloud services.

1.2.1.d Service provisioning – Application layer

Service provisioning is the building block, also often referred to as application layer, in which data and all information that was generated from it is transformed into value for the end users that can be monetized. End users can be individual consumers, enterprises or even cities and local governments. Mobile applications, SCADA-systems (Supervisory Control And Data Acquisition) or control architecture to control complex industrial processes, or web services are examples of how an IoT-application could look like. IoT-systems will thrive in all sectors and domains such as agriculture, healthcare, transport, industry, etc. How smart IoT-enabled services will impact these sectors will be discussed in more detail in Section 1.5.2.c.

1.2.2 Cloud computing

The term cloud computing rests on the virtualization of computing processes and resources, accessible by the internet. Although the concept of cloud computing, which is in fact an umbrella term for a various set of internet enabled resources, is already there for years, cloud computing certainly has been impacting the traditional economy in the recent years. Not only online data storage has become almost the new standard, now complete online end users services are hosted in the cloud. The so-called SAAS providers (Software-as-a-service) eliminate the requirement for individuals and enterprises to invest and maintain own IT-systems and hardware. Famous examples are the Office 365 applications, Salesforce, and various healthcare-related applications such as LindaCare that run completely in the cloud. The only thing users must take care of is a connection with the internet and an end user terminal such as tablet or laptop.

Additional models for cloud service that have been arising are PAAS and IAAS, respectively Platform-as-a-service and Infrastructure-as-a-service [5]. PAAS providers offer a platform to its customers to build develop and run own cloud service on top of it whist eliminating the need for developers to set up all necessary resources for it (e.g. servers, storage, virtualization, networking, IoT-device management, data-mining resources, etc.). Windows Azure is an example of PAAS.

IAAS providers on the other hand focus on offering the infrastructure in terms of virtualized computing power, data storage, networking services (e.g., Firewalls), load balancers and other computing resources towards their clients. The IAAS users are responsible for the maintenance and management of their rented infrastructure. Netflix for example migrated their service completely to the Amazon Web Services (AWS). The latter act as IAAS provider. Figure 1-5 provides some examples of cloud service providers active in the three layers of cloud service stack.

The increasing availability of cloud services and resources is a significant driver for smart services. First, it leads to radical cost reductions for service providers since capital intense investments in information and communication technology are not required any longer. Second, cloud resources are flexible, meaning that the required computing resources can be allocated towards the services in need in real time. Providing flexible and scalable resources according to real-time need allows smart services to grow according the user base and react on temporarily computing resource-intense tasks (e.g. the online ticket sale of the Tomorrowland concert, which spikes in a matter of seconds only once a year).
Last, cloud service models as PAAS and SAAS allow faster development of a service since much of the complicated networking and management tasks are taking out of the hands of the developers.

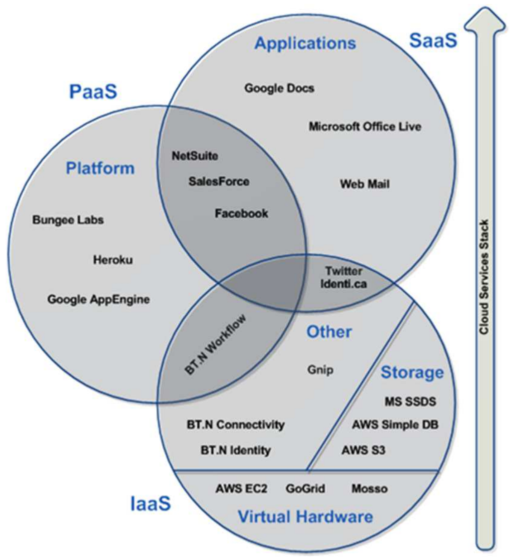

Figure 1-5: Different cloud services grouped according to different market models (SAAS, PAAS and IAAS) [6]

1.3 Multi-level impact of smart services

The overall goal of this dissertation is to provide a methodology for evaluating the impact of smart services. Thus after describing the concept of smart services and the technologies that enable these services, it's time to define the holistic term "impact".

When used in the context of smart services, impact, also referred to as effect, is a multi-dimensional phenomenon. On the one hand, smart services affect the network of interlinked actors whilst on the other hand they can change several layers and characteristics of how individual enterprises do and organize their business. For enterprises, smart services can for instance impact the cost of operations, extend the customer offerings, or open up completely new markets [7], [8]. For societies, deploying smart services could contribute to a safer environment (e.g. new bicycle lanes and routes based traffic density and road condition), a healthier environment (e.g. air quality control), reduced healthcare expenditures, etc. For end users, smart services can result in more added value, more customized service delivery or other more qualitative effects such as social empowerment and higher state of peace of mind (e.g. smart home services for elderly). On the other hand, smart services can also impact or be affected by the broader aspects of the context they are used in. For instance the lack of a regulatory framework can lead to a reticent attitude for adopting the service. Therefore to cover this general notion of impact of smart services, some conceptualization and clarification are in place.

From a business perspective, Glazer [9] identified five different strategies that can be used to create economic impact when offering smart services towards their customers: 1) “Mass customization” or offering more customized services at lower costs, 2) “Yield management” or maximizing the revenue by anticipating on consumer behavior (e.g. the volatile price electricity which reacts to the real-time demand, utilization and other factors), 3) “Manage by wire” or automating customer interactions, 4) “Virtual company” or co-operation with other companies to add value for the customer, and 5) “Capture the customer” or one-on-one marketing to maximize the total purchases of customers. Via case descriptions, Allmendinger and Lombreglia describe impact on company performance in terms of process-cost reductions, service extension or even new business opportunities, waste elimination and increased service margins [10]. In addition they formulate four strategies to realize these impacts: 1) the embedded innovator, which refers to companies which add “smartness” in terms of IoT to their product lines in order to extend the service offering (e.g. smart vending machines that alert operators when to refill), 2) the solutionists which are product-centric companies that build a complete service offer based on the product life cycle (e.g. leasing the equipment, providing preventive maintenance and repairs, offer consumables, and manage the product end-of-life phase), 3) the aggregator, which aggregates and analyses low-level data in order to create valuable input for other interested parties, and 4) the synergist, which refers to an actor that provides products that can communicate with other systems in order to create a community of data generating and data sharing products (e.g. Philips contribution to the ZigBee Alliance). Thus from a business perspective, impact will manifest depending on the way business choose to co-operate with other firms to implement and offer smart services to their customers.

In contrast with the business perspective, [11] states that impact for end users includes: enabling social interactions, improving user-experience, and providing clear transparency in security aspects. These findings are in line with the work of Cronin [12] that states that the impact of smart services from a company’s perspective can in some cases be the complete opposite of what end users experience as benefits. For example completely automated after-sale services can result in operational cost reductions for companies, but at the same time can feel very anonymous for end users.

In summary, the impact of smart services is an umbrella concept which includes all the changes, threats and opportunities these services introduce for all actors involved and the way they interact with each other. For actors introducing smart services in their offerings, this could mean that new forms of co-operation with other actors could arise. We define this as ‘impact on the value network’. A value network is defined as: *“A web of relationships that generates economic value and other benefits through complex dynamic exchanges between two or more individuals, groups or organizations”* [13].

On individual firm-level, smart services can affect or ‘impact the business model’. Osterwalder [14] defined a business model as: *“A Business Model describes the rationale of how an organization creates, delivers and captures value”*. Via nine business model ‘building blocks’ (Value proposition, Customer Segment, Revenue streams, Customer relationships, Channels, Key partners, Key activities, Key resources, and Cost structure), it describes the structure or way companies operate in order to generate revenue and make profit (e.g. operational process efficiency, increased revenue, larger market share, increased customer loyalty). Impact of a smart service depends on the perspective of the involved actor, and will not necessarily be experienced in the same (beneficial) way by all actors.

In Section 1.4 three application categories will be discussed. Via concrete cases the impact will be described these smart services have on 1) the value network and new sorts of co-operations between actors, 2) the business model and value offer of smart service providers, and 3) value perception and creation for end users.

1.4 Application domains of smart services

Smart services will, or have already been affecting the business and service structure of several application domains. Gubbi et al. [4] propose four main groups of application domains for IoT-enabled services:

1. Personal and home
2. Enterprise
3. Utilities
4. Mobile

Within these four groups, Asín and Gascón [15] define twelve different application categories of IoT-enabled smart services: smart cities, smart environment, smart water, smart metering, security and emergencies, retail, logistics, industrial control, smart agriculture, smart animal farming, domestic and home automation, and eHealth. Next to these IoT-enabled application domains, the four groups of application domains can be extended with non-IoT-enabled smart services such as data-sharing platforms. This allows the inclusion of non IoT-enabled application domains such as eGovernment services and smart education. The different groups of smart services application domains and their subsequent categories are depicted in Figure 1-6.

These groups cannot be seen as isolated domains due to the potential value of cross-sharing data and infrastructure. For instance, personal oriented smart services such as personal informatics, which enable people to track their lifestyle patterns such as personal expenditures, food intakes and level of happiness can serve as data sources for healthcare related smart services.

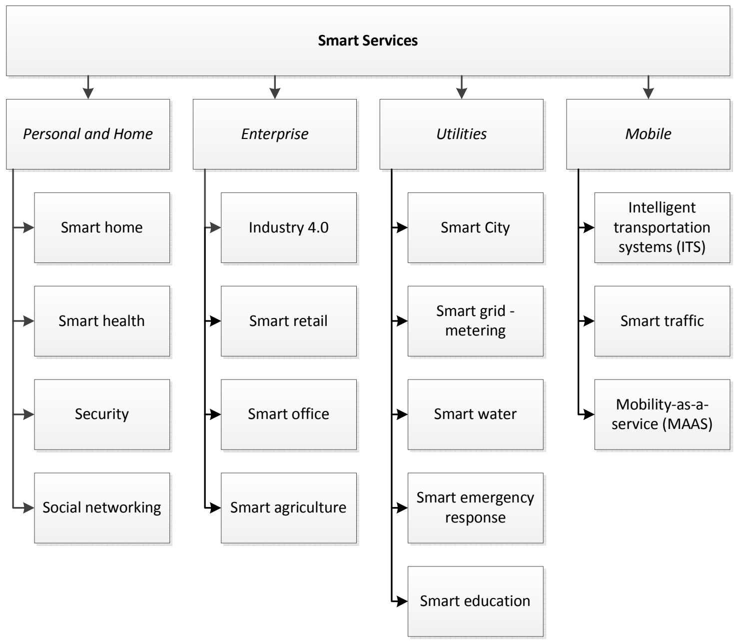

Figure 1-6: The four generic groups of application domains impacted by smart services and a non-exhaustive set of their subsequent categories

1.4.1 **Smart service application domain: Smart home**

Although the concept of smart homes exists already a couple of years, technological progression has allowed many of the visions of connected homes to become reality [16]. Smart home is an umbrella term for all smart services that allow and support home control in its broadest sense. But in order to be called ‘smart’, services must be responsive to its inhabitants, by supporting their comfort and enabling new functionalities which were not possible before.

Typical examples include connected lights and sound systems, which can be controlled by mobile applications, smart thermostats such as Nest, which learn about our lifestyle patterns and incorporate environmental data in order to fine tune and regulate the room temperatures, smart energy plugs that measure and allow controlling certain electrical circuits or devices whilst minimizing the energy bill based on data on actual energy prices. In general smart home services can be grouped in following categories [17]: Entertainment, Home comfort, Wellness, Home safety, Access control, Daily tasks management, Connectivity, Energy efficiency, and Home intelligence.

Integrating these services in our homes should deliver added value for the end users, otherwise there is no incentive to adopt smart home technologies. At the same time, for smart home service providers these smart services allow data acquisition and insights into the service usage and lifestyles of its users. This data could not only be valuable for the service providers themselves but could enable co-operations with other enterprises. Ultimately this overarching value network or ecosystem can increase the overall value or impact for the end users while being profitable for the involved actors.

1.4.1.a Smart home: case of Nest

Nest [18] for instance is a digitized thermostat that learns and adapts towards the lifestyles of the inhabitants. The thermostat not only measures temperature, but also ambient light, air humidity, and activity. Since Nest connects to the internet via Wifi and has BLE-connectivity inside, it can be controlled and managed via a mobile application. Smart algorithms determine the time to start heating or cooling in order to reach the desired temperature at a given time, which increases the comfort. Also via integrated energy saving features such as an auto-away mode that automatically sets back the temperature when nobody is at home energy consumption can be reduced up to 29% [19].

A: Impact on value network

Whereas the value chain of traditional thermostat producers was fairly product-centric and straightforward (Figure 1-7), Nest has been partnering with many other market players which results in a new value network that leads to more value for all involved actors (Figure 1-8). For instance, the data collected by Nest Labs provide insights into real-time energy usage of HVAC-systems (heating, ventilation and Air conditioning). Because of this potential, many energy providers are collaborating with Nest and offer it at reduced prices, sometimes for free, to their customers (e.g. in Belgium both Essent and Lampiris collaborate with Nest). This allows them not only to accurately predict the real-time energy consumption of the HVAC-systems of their users. They can also remotely control the HVAC-systems of their clients (e.g. temporarily switching off the systems during moments of peak-consumption).

In addition, Nest is also a source for off-line behavioral data of users. Probably this potential value is the reason why Google bought Nest for 3.2 Billion dollars back in 2014. Although it is speculative, but having a Google connected device in your home that is aware of your physical presence allows data aggregators such as Google to tie dynamic residential IP-addresses of other internet-connected devices (e.g. Smart TVs, tablets etc.) to specific individuals, which on their turn open new possibilities for personalized advertisement services.

Nest sells not only devices, but generates revenue via selling the data. By providing the ‘Works with Nest API’ to third party service developers, the ecosystem extends automatically and without costs. Although Nest should be easy to install by end users, Nest also trains HVAC-installers to become certified Nest installers. For the latter, this can attract additional customers. HVAC-producers can offer ‘Nest-ready” products and thereby expanding their value proposition towards their clients.

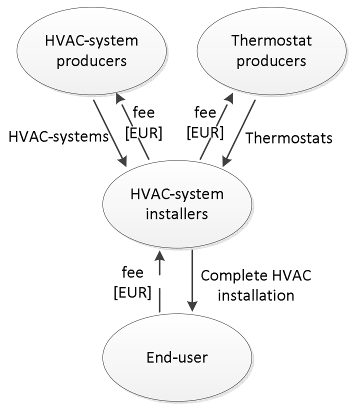

Figure 1-7: Traditional value chain for HVAC-installations

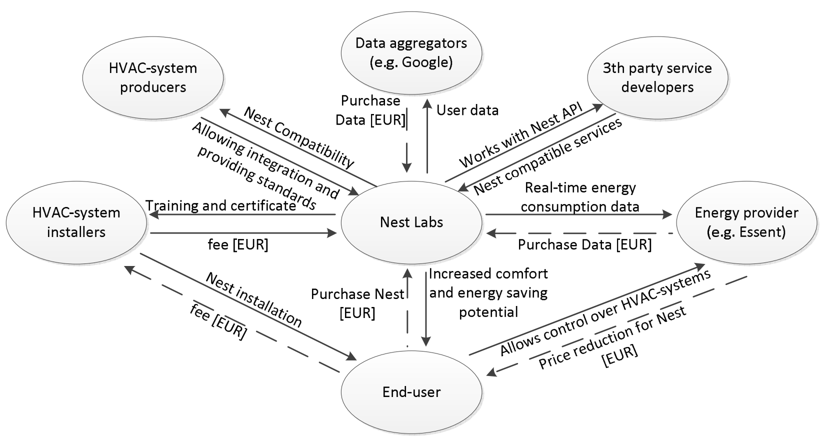

Figure 1-8: Value network of Smart Home services: case of Nest

B: Impact on the business model of the service provider

To determine what the impact is of offering a smart thermostat service on a business level, business models of traditional thermostats vendors need to be compared with the approach of Nest. Whilst traditional thermostats vendor have a product-centric offer, which focusses on selling devices, product-selling is only one of the revenue generating sources for Nest. They monetize also the valuable data that is captured by the devices. This model is often referred to as a multi-sided market in which consumer pay to have access to the services (in this case, end users using Nest) and providers pay to offer their services (in this case, HVAC-system installers and maybe in the future, also third party service developers) [20]. In addition, insights based on this data allow Nest for further customization and personalization of their services. This could lead to increasing market shares.

C: Impact from an end user perspective

For end users the impact of a smart thermostat lays not specifically in the fact that they can control it remotely via a mobile application. The true added value of it results from the automatic adaptability of the thermostat based on the lifestyle of the inhabitants and on the energy saving possibilities whilst not affecting comfort. Though concerns can arise on the level of privacy intrusion of smart home care services like Nest. This aspect should be carefully taken into account by all smart service providers.

1.4.2 Smart service application domain: Smart health

1.4.2.a Challenges for healthcare systems

Currently many industrialized countries experience pressure on their healthcare system. The total healthcare expenditures have been growing over the past decades, which is not abnormal. Many researchers indicate that a growing economy, which results in higher level of wealth, will lead to a higher demand for care as well [21]. But in many developed countries, latest grow rates of the total health care expenditures have been higher than the grow rate of the GDP (gross domestic product) which is an indicator for the growth of the national economy. This means that health care expenditures are and will continue to cannibalize on other sectors such as education, cultural sector, mobility infrastructure and so on. Many sources predict that the total health care expenditures will continue to grow in the future, making this an important agenda topic for many governments. The most important drivers of the increasing health care expenditures are:

1. *New care technologies*
   The introduction of new care technologies which are often more complex and costly. These new health technologies often address specific patient groups for which there were no dedicated services before. In addition, these new technologies can make care more accessible. Therefore these technologies can reach a larger population.
2. *Increased expectations of care users*
   Expectations on for instance financing of specific health care interventions or therapies (e.g. esthetic interventions and cures for orphan diseases), procedure performances (e.g. robot surgeries) or reduced chance on complications have been fueling healthcare investments of which the cost-effectiveness is not always known or even is doubted.
3. *Increased shift to long-term care*
   Due to medical progress now many adverse effects of diseases can be contained and postponed (e.g. HIV treatments have significantly slowed down the progression of the disease.). The effect of this is that many

people now live longer but become long-term chronic patients who rely on long-term care and healthcare.

4. *Ageing population*
   Many developed countries are characterized by an aging society. It is said that ageing on its own will not heavily impact the health care expenditures, but the indirect effect of ageing will. Many elderly people suffer from one or more chronic conditions. An ageing society will therefore further increase and speed up the shift to long-term care.

1.4.2.b Overview of ICT-supported health services

These societal, technological and demographic evolutions challenge current healthcare systems. ICT-supported health services have a considerable potential to improve the delivery and quality of care while reducing the costs. But over the years various definitions and terms have been introduced to name this type of services. Although they largely describe the same concept; the use of information and communication technologies (ICT) to support well-being, health delivery and health-related services; distinctions between several types of ICT-supported service can be found. To provide some clarity, the most important types are discussed:

- **eHealth**
  eHealth, is often used as an umbrella term that refers to the use of information and communication technologies (ICT) to support well-being, health delivery and health-related services. Eysenbach defines eHealth as follows:
  "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." [22]

  Examples include the use of wearable sensors to monitor biometric data of the patient (often called Telemonitoring), improved care scheduling and billing processes via the use of ICT, tracking assets in a hospital environment via RFID (Radio-Frequency Identification) and IoT, and enhancing communication between formal and informal care providers and patients via new services.

- **Telemedicine**
  When ICT is used to send medical data from one place to another in order to realize remote health delivery such as remote consultations and remote diagnostics, it is often referred to as Telemedicine. Examples are remote

tele-monitoring of heart-failure patients, and teleconsultations with physicians in rural areas.

- **mHealth**
  Mobile health or mHealth is a subset of eHealth focusing on the use of mobile communication networks for improving health care delivery and care support. These services often focus on disease prevention and diagnosis, rehabilitation, and monitoring the treatment and state of the patient. Examples include: tele-rehabilitation after a cardiac event, tele-monitoring of high risk patients, medical device certified mobile apps for melanoma detection, and mobile applications supporting home care delivery and integration of wireless sensors for lifestyle monitoring (such as connected step counters integrated in smart watches and connected blood pressure meters).

- **eCare**
  At last there are eCare services. Just like eHealth, eCare is defined 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 ageing, activities of daily living (ADL) and ambient assisted living (AAL). The latter is defined as concepts, products and services that combine new technologies with the social environment in order to improve quality of life in all periods of life [23]. Existing solutions include home monitoring systems to support independent living and systems to enhance social contact of elderly.

  Cases included in this work mainly focus on context data collection, lifestyle monitoring and eCare services.

All these types of services can contribute to the shift form health care to “care for the health continuum”. Current health care services focus mainly on cure, whilst prevention and non-medical care are less highlighted. In contrast, focusing on the health continuum includes disease prevention, curing disease, and providing non-medical care to prevent deterioration of the health state of the patient and surpasses the boundaries of the often fragmented pure medical and intra-mural care and cure provided by formal care givers and hospitals. In addition, smart health services can empower patients to be more involved in their own health and the data these services generate could, if designed well, be a perfect starting point for continuously measuring health outcomes. It are these potential opportunities that makes smart health services of important value for value-based healthcare [24].

Due the different types of ICT-supported health service several sorts of regulations and reimbursement schemes are in place, making the landscape for eHealth and eCare providers complex. Ignoring the impact and consequences of the both the regulatory and financial framework within this domain is therefore in most cases a recipe for failure.

1.4.2.c Potential value of ICT-supported health services

eHealth and mHealth services have the potential to tackle at least some of the challenges many healthcare systems encounter by increasing both the quality and the efficiency. In general, these services will contribute and impact following aspects of healthcare systems [25]:

1. *Increased prevention*
   Early detection of chronic diseases via self-test and assessment tools could lead to an improved quality of life and life expectancy whilst lowering the often stigmatizing barriers for seeking help. mHealth services can unlock multiple possibilities for population wide screening, (e.g. Fibricheck, a medical approved mobile application that can detect cardiac arrhythmia and communicates the results directly to the care providers). They can also play an important role in improving life style and therefore contribute to disease prevention. (E.g. The wide offer of apps that coach you during a healthy diet, smoking cessation, and adopting a more physical active life style.)

2. *Efficient healthcare provisioning*
   Smart care services that enable better data sharing, care communication, better management of chronic diseases, care scheduling and automated decision support systems based on data analysis can improve quality of the provided care at reduced costs. Also new services to monitor patients' conditions remotely will lead to more patients being monitored with the same amount of human resources.

3. *Empowering patients*
   eHealth and mHealth will contribute to the transformation of a care – centric organized healthcare system towards a patient-centric care system in which the patient has a more active role in their own care-organization. Self-manageable eHealth and mHealth services could provide the patients with more insights in the progression of their disease and can provide them with tools to gain control over their health or care (e.g. medication reminders). Additionally these service can contribute to a better health literacy and inform the patient on their medical condition.

Although there has been a vast amount of research on these topics, including many small scale deployments and resulting in many new eHealth and mHealth services available on the market, large scale deployments remain scarce and depending on the type of service, many barriers for adoption still exist [26]. For instance often there is a lack of clear financing structures for care actors which use these services to monitor patients, also patients have sometimes serious concerns on the privacy aspects and data ownership. These and other important barriers for adoption of ICT-supported care services are described in detail in Chapter 2. In order to develop, design and offer a sustainable smart care service, pre-evaluating the impact of it on the value network of involved care actors, their individual business models and the economic sustainability of the value network, will become a necessity.

1.4.2.d Smart health: case of monitoring chronic heart failure patients

Several systematic reviews indicate that remote patient monitoring (RPM) for people who suffer from chronic heart failure (CHF) could lead to an improved quality of life (QoL) whilst reducing health care utilization such as heart failure re-hospitalization [27]. Via daily telemonitoring of physiological parameters such as weight, blood-pressure and eventually electrocardiograms of CHF patients, deterioration of health can be anticipated by timely adjustments of the medications and life style changes, coordinated by physicians and specialized nurses. Although many research results have been indicating the positive impact of RPM on both the clinical outcomes and costs, wide scale adoption is still lacking.

A: Impact on value network

In the current situation the general practitioner and cardiologist are the main care actors which are paid by the care insurers (Figure 1-9). The integration of RPM services for CHF-patients does not make the value network of involved care providers more complex. In contrast, the value network of care actors monitoring heart failure patients is harmonized via the shared insights in the progress of the disease (Figure 1-10). This could allow care actors, other than the cardiologist, but in dialog with, to follow up, monitor and adjust the treatment. The service paves the way for better multi-disciplinary care.

But at this moment the value network is not perfect, nor sustainable. Currently there is no reimbursement for RPM-care for the involved care actors, and therefore it is not financially attractive to put effort in it for care actors. Additionally the RPM-data is often analyzed by a dedicated nursing team for CHF-patients. But without proper financing schemes, the sustainability of this set up is not guaranteed. In Belgium, pilot projects are currently testing bundled payments for these types of services. In such a financing scheme the care provider receives a budget per patient to cover all the health care related costs for treating that patient, including nurses, other care actors and costs for the RPM-providers. But it is not clear how this will affect the revenue stream of hospitals. In contrast, the shift from in-hospital care to care in the home environment could lead to significant amount of cost-savings for the society but would also lead to a loss of revenue for the hospitals as well. This could potentially further increase the high financial pressure they already encounter.

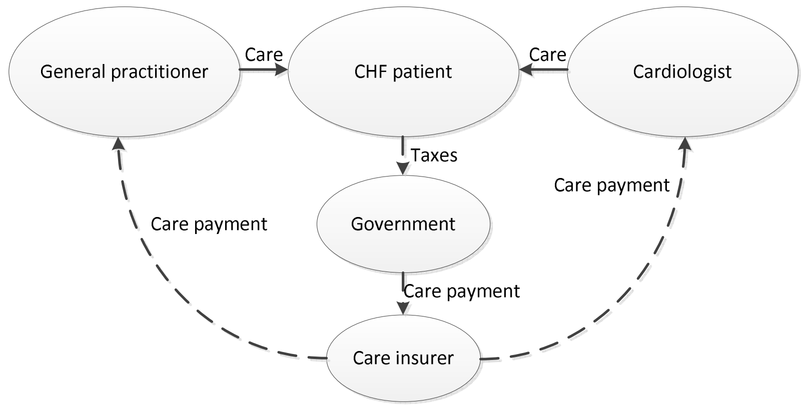

Figure 1-9: Simplified value network of traditional, often isolated, care provision for CHF-patients

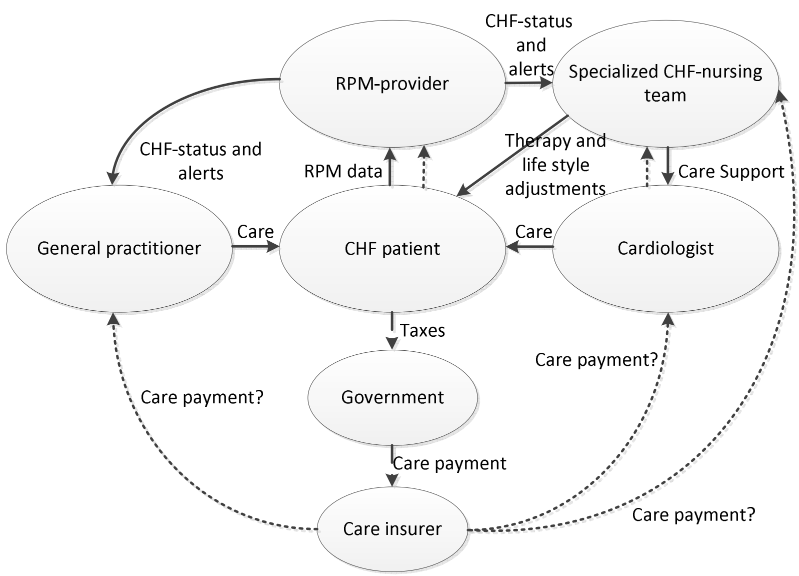

Figure 1-10: Value network for RPM service provisioning for CHF-patients. Via the RPM-service, cardiologists, general practitioners and CHF-nurses can share insights and adjustments to the therapy. Dotted arrows indicate currently non-existing value streams, solid lines represent existing value streams.

B: Impact on the business model of the care provider

Additionally, from the business perspective of health care providers, both the cardiologist and general practitioners who currently operate in a fee-for-service system, offering smart services to monitor the condition of their patients is cannibalization of their own revenue structure. In a fee-for-service system the care actors are typically paid per service provided during their contact moments. Thus investing time in analyzing the RPM-data of many CHF-patients, for which no financial compensation is installed yet, results in less time available to actually see patients and earn money. In summary, the currently installed payment schemes for care providers inhibit a sustainable adoption of RPM-services for CHF-patients.

C: Impact from an end user perspective

CHF-patients could experience more peace of mind, end up less in the (costly) intensive care unit due to acute hospitalization, and overall have a higher quality of life (QoL). Thus from the end user perspective, in this case the patient, RPM-services have a beneficial impact [27].

D: Impact on society

In this example, the care insurer is paid by the society via the installed tax system. Therefore cost savings in health care provisioning are in fact savings for the society as a whole. Continuous monitoring and dedicated follow-up of chronic heart failure, could lead to less consultations and re-hospitalizations of patients [28]. Thus in the long term remote monitoring of CHF-patients would reduce the costs for the healthcare system. But in order to achieve that goal initial short term investments should be made.

E: Impact on RPM-providers

The current financial framework is unclear for RPM-providers. Although there are pilot projects experimenting with bundled payment schemes, there is often no real reimbursement strategy in place yet. The moment any type of sustainable reimbursement will be installed, it can be expected that the market of RPM-providers will grow.

1.4.3 **Smart service application domain: Mobility-as-a-service**

Urbanization which reduces the need for a car, traffic congestions, environmental impact, high costs of car ownership, hassle to find parking spots and many others reason are slowly shifting the societal perspective towards shared mobility services. Boosted by new developments in ICT, the concept of ‘Mobility-as-a-service’ (MAAS), is currently being tested at various locations around the world MAAS refers to buying mobility based on a person’s needs, offered in a service package instead of buying the means of transports [29]. The services packages include various transportation modes such as having short or long-term access to vehicles, using public transport and/or taxis whenever more appropriate and even having access to bicycles when congestions in dense urbanized areas result in standstills. Offering a wide set of transport modalities can decrease the need for individual owned vehicles. Often MAAS offers also a single billing service, freight transport and a multimodal journey planner. The latter combines different transportation modes (e.g. bike, taxi and train transport) in order to get the user to his final destination.

A: Impact on value network

Up to now, transport service providing actors have been working quite isolated without much collaboration with each other (Figure 1-11). Mobility-as-a-service on the other hand, requires one actor, often referred to as the MAAS operator, which bundles and sales transport services of various transport service providers. Examples of transport service providers include: public transport services, car-sharing, bike-sharing, taxi providers and parking providers (municipalities and private owners).

But next to this role of broker, MAAS operators also provide processes for billing, registration, routing and managing mobility services. Therefore collaboration is required with transport data providing companies (e.g. traffic routing based on real-time traffic) or other digital service providers such as ticketing and billing [30] (Figure 1-12).

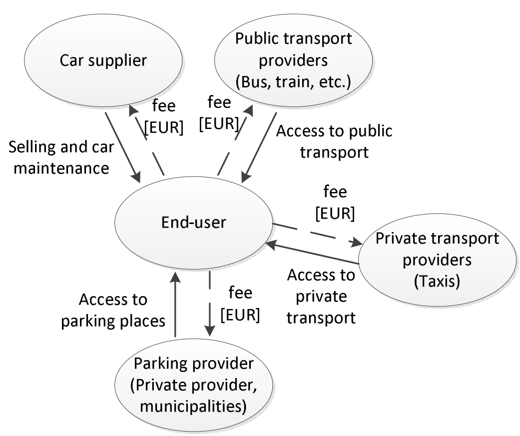

Figure 1-11: Traditional B2C value chain for personal mobility services

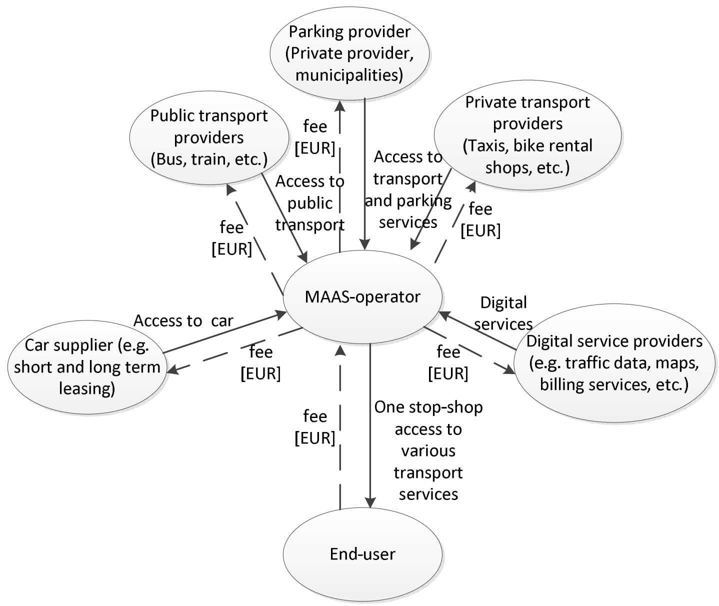

Figure 1-12: Value network of MAAS operator which offers mobility towards its customers

B: Emerging business model of the MAAS operator

To realize the concept of 'Mobility-as-a-service', traditional market actors have to rethink their position in the new value network. This transition can pose challenges or open opportunities since it could impact their current revenue streams, and other elements of the business model such as the cost structure (e.g. simplified billing processes) and target market. Having a good understanding of the new roles and activities actors are responsible for, is therefore key to comprehend how current business models of the involved actors are affected by smart services such as MAAS.

The role of MAAS operator can be fulfilled by different actors such as private transport providers, public transport providers, new digital service providers, or municipalities and governments. Also car producers are testing the concept of car sharing and mobility-as-a-service (e.g. the DriveNow program of BMW). A MAAS operator can also be a result of a public private partnership between public transport providers, municipalities and private actors [30].

Irrespective which actor takes up the role of MAAS operator, the value proposition towards end users will show similarities. Elements included in the value propositions are: one-stop-shop for transport services, transport billing and scheduling service, and integrated (multi-modal) routing [31]. Often all these aspects are offered via an online platform. The target group or customer segment

MAAS operators focus on depends on the actor which takes up the role of MAAS operator. For example a private car leasing company which extends its current B2B service offer; leasing cars to companies, with MAAS will probably have initially less attention for persons using public transport each day. The revenue model can look like a pay per usage model, monthly subscriptions, all-in-one, international packages and variants of these. Other sources of revenue can come from data selling and advertising activities.

C: Impact from an end user perspective

Since MAAS services could eliminate the need for owning a car, they have the potential to reduce end user costs for transport [32]. In addition they also provide a personalized service that can anticipate choices on travel preferences. Next, [27] suggest that the ease of transactions via a wide range of devices (chip card, smartphone, smartwatch, etc.) and the ease of payment (payment schemes according to the end users need) provide additional benefit of MAAS compared to the traditional systems. Features as dynamic multimodal journey planners which incorporate real-time data and user preferences in order to provide the best suited routes for end users also can be included in the benefits for the end users. At last, MAAS could indirectly contribute to a safer and healthier environment when it aligns with a broader set of government departments such as healthcare. For instance MAAS could improve patient transport systems via data insights and the multimodal ways to transport patient, users could be stimulated to change their transportation habits for healthier alternatives, and smart MAAS algorithms could direct bicyclist via safer routes and where air quality is better.
Although it seems that MAAS really could change the overall perspective on transportation, there exist risks and barriers which currently block large scale adoption of MAAS. Previous large scale pilots such as Kutsuplus, which was an on demand bus trip system, proved to be economic unsustainable. In his work, Hensher [33] presents some interesting and critical perspectives on the potential impact of MAAS services. Up to now it is unclear how MAAS will reduce traffic congestions, how MAAS can be scalable while eliminating the need for car ownership and if MAAS services will truly be able to provide more personalized transport in all users segments of public transport.

1.5 Research challenges

The introduction of smart services is an irreversible trend that just has started. A lot of the potential is still there to be harvested. But at the same time the uncertainty that comes with not knowing or understanding the impact these services will have on the involved actors, the users and the society as a whole, leads in some cases to a reticent attitude. For example, this can be witnessed by the raising concerns on privacy, the various discussions on data ownership and slow adoption rates of some smart services. Although the overall benefits and opportunities are expected to be larger than the concerns, these uncertainties and economic impact of smart services need to be evaluated very well in order to create or offer a viable and economic sustainable smart service.

However evaluation of the overall impact of smart services is not straight forward. First, smart services enable actors to collaborate with each other in other ways than traditionally known. To understand how smart services will affect or lead to new value networks, what the opportunities and challenges are, we need insights in the roles of the involved actors and collaborations between them.

Second, the impact smart services have on the business models of actors can be strategic or operational, is not always quantifiable in direct terms and is very case dependent. Smart services can affect current business models of the involved actors both positively (e.g. increased revenue, reduced costs, larger market share) and negatively (e.g. time intensive tasks, reduced income). In case of the latter, it is doubtable the smart service will be sustainable. Therefore analysis of individual business models is needed to comprehend the full impact of smart services.

At last, the feasibility of a smart service cannot be evaluated by looking at the impact of the individual actors alone. An overall evaluation of the complete value network and from an actor independent perspective on the actor dependent impacts, allows identification of potential overall barriers for the smart service, and possible go-to-market strategies.

1.5.1 **New opportunities and challenges due to new value networks**

Vertical value chains describe direct seller (upstream) and buyer (downstream) relationships between the involved actors without real collaboration between these actors when it comes down to provide value to the end customer. Value networks on the other hand, indicate some level of collaboration in order to provide a common added value towards the end consumer or create and strategic advantage for the actors involved (e.g. reduced time-to-market, enlarged technological know-how, increased market potential, reduced barriers for market-entry). Better information sharing, real-time feedback, customer insights, and other characteristics of smart services can enable new forms of collaboration in the form of cooperation and coopetition. Cooperative strategies between various actors result from a shared desire to achieve a common goal [34]. To realize that common goal, actors can share their tangible and intangible resources such as human capital, knowledge, and infrastructure. Coopetition on the other hand refers to the collaboration between competitors [34]. Collaboration in some activities could result in overall better achievement of the individual goals. Typical examples are the joined lobbying forces of competing big pharma industries or medical device manufacturers, aiming for reimbursement.

Smart services have led to a disruption in the way firms and other actors interact which each other. To create future proof service experiences for their customers, reduce transaction costs, or decrease resource dependency, actors are exploring the potential of value co-creation via more complex cross-industry relationships [35]. Actors involved in smart service provisioning are shifting focus to the formation of new horizontal alliances. These new value networks or ecosystems comprise a set of interlinked roles in order to co-create value towards the end users [36].

Although these new value networks should create a win-win solution for all actors involved, the disruptive character and fast introduction of new smart services can sometimes lead to incomplete or unsustainable value networks. Examples exist in which the added value created via the value network cannibalizes on the revenue models of involved actors. Therefore a first research question is: ***How can we analyze and evaluate the impact smart services have on the value network of the involved actors?***

1.5.2 Evaluating the strategic, operational and tactical impact of smart services on the business model of an individual actor

As stated in the Section 1.3, introducing smart services drives and enables firms to form more complex ecosystems to deliver value for their customers. All actors need to (re)define their roles within the value network. This can impact the business models of the actors. Sustainable value networks can only be formulated if the underlying business models of the involved actors are viable (e.g. the current gap in revenue schemes of physicians for providing eCare and mHealth services, see Section 1.4.2). This results in a second research challenge: ***How to evaluate the overall impact of smart services on the business model of individual actors?***

Since ‘impact on business model’ is rather general, further narrowing down this concept to impact on the strategic, operational and tactical level, allows a more specific definition and identification.

1.5.2.a Strategic level

Smart services can impact the main building blocks of the original business model of an actor or can even lead to completely new business models. This not only includes the value proposition but also the customer relationship and channels, partnerships and even the revenue streams (see Section 1.3 for the definition of a business model and its building blocks). These are all aspects of the business strategy of an actor. Since it is not always clear how smart services will impact the business strategy of individual actors, detailed analysis is required in order to define sustainable business models. For example: the transition of many traditional retailers towards ecommerce expanded their global reach but at the same time have been making traditional retail processes more complex. Due to high competiveness and additional process costs for ecommerce, there is often no guarantee on economic sustainability of this trend.

1.5.2.b Operational level

Evaluation of the operational level refers to the detailed analysis and breakdown of the current operations and processes, often referred to as 'as-is' scenario, into smaller process tasks. This allows identification of the impacted process tasks after introducing smart services (to-be scenario). Altered usage of relevant process resources such as labor time, changes in stock levels and equipment indicate the impact of the smart service on the operational processes of the individual actors. A smart home-care platform for instance allows better elderly monitoring and can be beneficial for their quality of life, at the same time this platform can simplify the current administrative processes of home care organizations, such as care scheduling.

1.5.2.c Tactical level

Integrating smart services in an actor's current processes requires at least some level of integration into current ICT-systems. This does not only include potential investments in IoT- devices, or installing a complete IoT-network (e.g. a smart container service that monitors the location and context parameters such as temperature and acceleration requires equipping and maintaining all shipping containers with IoT-devices). Also middleware and software development, setup and maintenance can come into play, as well as additional costs for access to communication networks. At the tactical level, which describes the required adjustments to current systems in order to realize the business strategy, the complete costs for the smart service provisioning for a specific actor must be analyzed. This lays the foundations for an economic analysis. In case multiple technological alternatives are available, the economic impact of all alternatives should be investigated.

1.5.3 Evaluating the overall viability of smart services

Whether or not a smart service is viable and sustainable depends not solely on the benefits one of the involved actors' experiences individually. In order to have a viable smart service all involved actors should at least have a cost/effect neutral impact on their business model and preferably add value for them, otherwise it's unlikely that they will participate in the value network of the smart service (see Appendix of Chapter 6). Also concerns can arise on fairness of cost or risk allocation in respect to the benefits.

At last, characteristics of the broader societal context in which the smart services are introduced can have a major impact on the both the sustainability of the service, the speed of adoption and overall viability of the service. Aspects such as privacy and security concerns, legal issues, low willingness to pay, market readiness, priority on political agendas, and even ethical considerations could results in opportunities or barriers which stimulate or inhibit a wide scale adoption of the smart service.

Therefore, a third research challenge is: ***How to detect and provide guidelines for potential barriers in both a multi-actor setting or value network, and business models of the involved actors?***

1.6 Approach

To tackle the research challenges, a six-step evaluation methodology has been formulated during this research (see Figure 1- 13). The approach is derived from the techno-economic methodology presented in [37] but is more focused on impact and potential barriers for adoption of smart services. The six steps of the methodology combine both qualitative and quantitative research and are clustered according to three levels of analysis:

1. *Macro level analysis: Impact on the way actors co-operate*
   Step 1: Value network analysis

2. *Micro level analysis: Impact for a single actor*
   Step 2: Business model analysis
   Step 3: Process analysis
   Step 4: Cost benefit modelling
   Step 5: Techno-economic evaluation

3. *Analysis of overall viability of the smart service*
   Step 6: Smart service viability evaluation

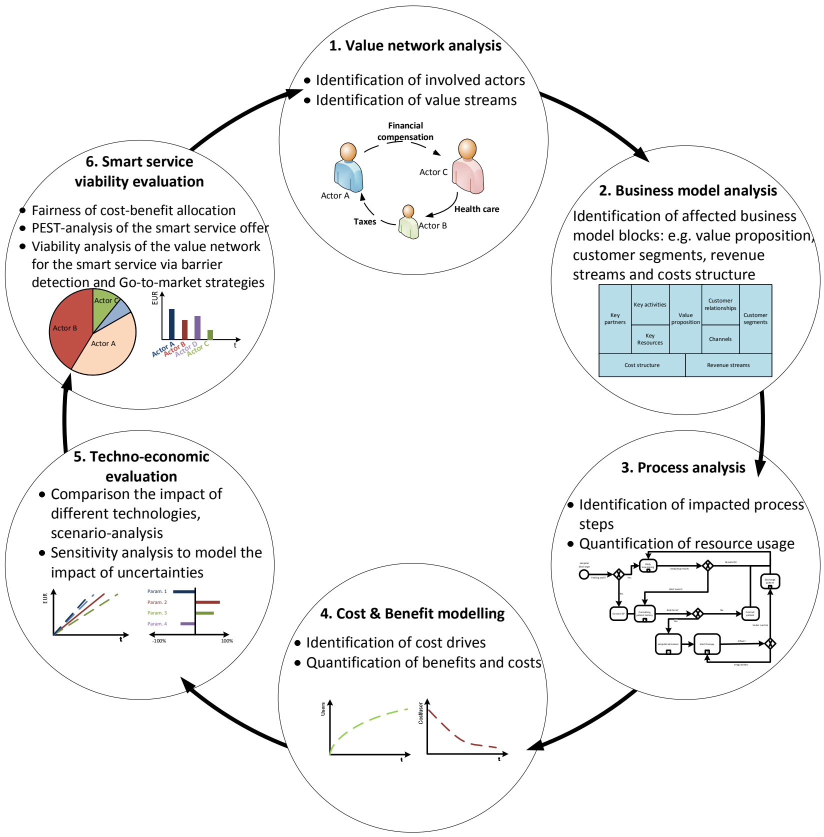

Figure 1-13: Six-step evaluation methodology to evaluate the impact of smart services

1.6.1 **Macro level analysis: Impact on the way actors co-operate**

The first step of the methodology is analysis of the value network which starts with the identification of all involved actors and their value streams in the smart service offering. An actor is responsible for at least one role, which is part of the value conversion process (e.g. hardware development, hardware installation, system maintenance). All the involved actors and their roles are interlinked with one another via value streams. Value streams indicate the exchange of tangible (e.g. goods, financial resources, human resources) or intangible (e.g. know-how and policy development) values in order to create the added value [13].

Value network analyses provide insights in how added value is created and allows identification of potential threats or gaps for a sustainable value network. If all the involved actors receive value in such a way they all benefit individually, the value network is sustainable and therefore will be supported by the involved actors. If this is not the case (e.g. example case of chronic heart failure, section 1.4.2.c), the value network will become unsustainable and non-viable in the current setting. Value network analysis is a macro-level since it is performed from an actor independent helicopter view over the smart service.

1.6.2 **Micro level analysis: Impact for a single actor**

After identification of all actors and their value streams, focus is on the impact of smart services on the individual business models of the involved actors. As stated in the research challenges (section 1.5), smart services have the potential to affect the business strategy, the business processes or operations and the business tactics. The latter describes the required investments and other resources to realize the strategy.

To understand how smart services affect a business actor, the second step of the methodology is a business model analysis. Osterwalder and Pigneur developed the 'business model canvas' which is a visual and comprehensive framework to describe the structure of a business [14]. See Section 1.3 for their definition of a business model. This tool can be used to describe the impact of smart services on business strategy by qualitatively identifying the changes and their effects on the relevant building blocks.

In a third step the goal is to quantify the impact of smart services on the operational level of the enterprise. Process analysis via detailed process breakdowns and comparison of 'as-is' or traditional scenarios and 'to-be' or scenarios in which smart services are deployed allows identification of operational benefits or costs due to smart service integration (e.g. reduced administration, faster client response, reduced process failure, increased revenue streams). BPMN (Business Process Model and Notation) is an often used representation for business processes and the specific resource usage per process tasks.

In a fourth step, all costs both capital expenditures (CapEx) and operational expenditures (OpEx) which result from the smart service integration are identified and quantified along with their cost drivers. The benefits from smart service integration are both quantitative and qualitative. The quantitative benefits include the operational impact, identified in previous step, but can also result from impact on business strategy. For instance, smart services could result in completely new revenue streams such as data sales, new customer segments, and multi-sided markets (see case of Nest in Section 1.4.1). Not all benefits are quantitative. For example for business deploying smart services, it can contribute to an innovative or green company image. For end users, many smart health services could result in increased peace of mind, increased QoL and less anxiety. Certain qualitative benefits of smart health can be quantified via utilization methodologies such as EQ-5D [38]. These utilities describe numerically the quality of life of a person at a given time. Combing this QoL with the societal willingness-to-pay for a year in perfect health [39] allows putting a monetary value on the qualitative impact of smart health services.

Next, in a fifth step, the costs and benefits are evaluated. Often the net present value (NPV) is used to carry out this economic evaluation per actor. In both the modelling of costs and benefits, various time effects can be included such as adoption of the service, economies of scale effects and learning effects [37]. When multiple technical alternatives for integrating the smart services are available (e.g. different network types or different deployment strategies) this will lead to different cost and benefit outcomes. Therefore different technical scenarios should be evaluated and compared. This often extends the pure economic evaluation towards a techno-economic scenario-analysis. Sensitivity analysis allows determining the impact of uncertainties in input factors (e.g. adoption rates, cost-evolution of hardware) on the results. An often used method is Monte Carlo simulations, in which the uncertain input parameters are modelled via probability distributions. Sensitivity analysis can also be used to identify the most important parameters of the evaluation model and therefore could lead to model simplification.

After completing steps two to five the total impact of a smart service for one individual actor is defined. But since one individual actor is only a part of the complete value network, the micro level analyses (Step 2-5) should therefore be performed for each actor involved.

1.6.3 **Analysis of overall viability of the smart service**

The last step of the evaluation cycle is evaluating the overall viability of the smart service. Due to their innovative and disruptive characteristics, smart services often face many barriers for large scale deployment. These barriers can be identified via PEST-analysis. A PEST-analysis is the process of describing the political, economic, social and technological context and factors that could influence the adoption or performance of the smart service. These factors will be quantified to the extent possible in order to allow comparing different smart services and formulating guidelines to increase service uptake.

A sustainable smart service not only is a result of the positive impacts on some of the involved actors' business models, nor on the viability of the complete value network but also of the lack of broader PEST-barriers. For instance, political and legal issues can impede adoption of disruptive smart services like AirBnB. Many governments now introduced taxes for people renting their house via the smart platform. The same is true for Uber, which introduced an online managed transport service based on the sharing-economy principle. Car-owners can transport people and goods for which they get paid and hereby become direct competitors of the traditional taxi services. As stated before, whenever an actor does not experience enough benefits from adopting a smart service compared to the costs, it is unlikely the will adopt the service. In contrast, in some cases they could impede and slow down adoption (see the chronic heart failure case, Section 1.4.2). From a social perspective, concerns related to privacy have become a major issue for many smart services in general. At last the speed at which the smart service market is evolving resulted in a technological fragmented market due to lack of standards. A fragmented landscape is often not beneficial for large scale deployments because of uncertainties of future technological trends. Next to the PEST aspects that can have a significant impact on the smart service, also other factors such as ethics and even ecology can come into play. Examples of these aspects are for instance smart services that potentially harm the equity and solidarity of health care systems or the society as whole (e.g. reduced insurance premiums for people with a healthy life style) or the growing importance of urban sustainability smart services that drives many smart City projects [40].

To be able to evaluate overall viability and formulate go-to-market strategies for smart services, the results of the previous evaluations steps are combined with the outcomes of the PEST-analysis, which can be for instance gaps in the revenue stream or other barriers for adoption. In case the smart service is not viable, the value network should be reconfigured in order to bridge the gaps in the business models. Potential barriers should be taken into account and a new evaluation should be performed.

1.7 Outline & Research contributions

In what follows an overview is presented of the work performed within the scope of this PhD. The five selected publications included in this dissertation (indicated in Figure 1-14) represent the main contributions that respond to the research challenges as specified in Section 1.5, being: *1) How can we analyze and evaluate the impact smart services have on the value network of the involved actors?*, 2) *How to evaluate the overall impact of smart services on the business model of individual actors?*, and 3) *How to detect and provide guidelines for potential barriers in both a multi-actor setting or value network, and business models of the involved actors?*.

Except for minor changes in layout, the form of the publications does not differ from the original publications. The complete list of publications realized during this PhD is presented in Section 1.8. This section provides an outline of the remainder of this dissertation and explains how the different chapters are linked together.

1.7.1 Value network analysis of smart services

My personal motivation to start this PhD was on getting insights into the overall impact and potential go-to-market strategies for smart services and in particular smart health services. As noted in Section 1.2 technological evolutions have been fueling an enormous wave of innovative smart service. But deploying smart services sustainably requires changes in the traditional way business actors interact with each other. This shift towards more complex value networks can be very hard for actors. In particular for the health care sector, which is already characterized by a very complex, fragmented and regulated landscape, this transition can be very challenging and could impose even additional barriers for adoption.

To get insights in how a smart service could be realized within the multi-actor landscape of home care we focus in Chapter 2 on how to set up a value network for integrating eCare platforms into the homes of elderly. Thorough identification of the involved actors, their roles and responsibilities, and the value stream they exchange or contribute to, sets the basic foundations for the formulation of potential go-to-market strategies. This chapter also describes the methods used to collect the input and discusses on the proposed value network. During the formulation of this value network several potential barriers for adoption of the smart health service were identified. Since the barriers originate from political, economic, social and technological aspects which cannot all be tackled in the near future or without 'de-siloization' of current care systems, a stepwise migration path for deploying the eCare platform functionalities has been proposed.

1.7.2 **Techno-economic evaluation of the impact of smart services on operational processes and business models**

A value network for smart services can only be sustainable on the condition the business models of the involved actors are not negatively impacted. Would this be the case, it is likely the impacted actor will not adopt or even block the adoption of the smart services. Therefore detailed identification and analysis of the total impact the integration of smart services has on the individual business models of the involved actors is of vital importance to evaluate the potential and viability of these services. Chapters 3 - 5 present the findings of the application of the proposed methodology on different use cases. This includes identifying the impact of smart services on the operational processes, impact on business model and techno-economic comparisons of the different technological scenarios.

In Chapter 3, a discrete event simulation (DES) model is presented to evaluate the impact of an ontology-based nurse call system on the operational processes, the care staff and patients. Such an ontology-based nurse call system takes into account a set of context-variables such as trust relationships, type of call (e.g. alert, care request, request for hotel services) and current agenda of the nurse staff when assigning a call to a specific staff member. Up to eight different implementation scenarios of an ontology-based nurse call system have been compared with traditional nurse call systems. To quantify the operational impact of the new system and compare the different scenarios several key performance indicators (KPIs) have been defined.

While focus in Chapter 3 is on a model to evaluate the impact of smart services on the operational processes, in Chapter 4 we focus more on the cost aspects to implement smart services. More specifically we look at several IoT-connectivity networks, and the trade-offs between them. In Section 1.2 the role of IoT as driving force for smart services is explained. In order to connect these ‘Things’ with the internet, IoT-developers have to decide which network technology they want to use. This decision can have a large impact on the cost structure of the actor who offers IoT-enabled smart services (also known as IoT-provider). Monthly network subscription costs, network maintenance, battery replacement are just a glimpse of the cost parameters which directly affect the overall cost of the smart service. To guide IoT-developer and IoT-providers in the decision process for a connectivity network that suits the needs of the service, a decision questionnaire has been developed in order narrow down the choice set. The elimination process of network technologies is based on matching functional and technical requirements of the smart service and the characteristics of the networks. In a second step of the guiding methodology, the economics of each remaining connectivity alternative are compared. This comparison includes both the CapEx and OpEx that result from each network type and therefore allows to make a viable and economical decision.

In Chapter 2 the integration of a smart care platform is analyzed from a macro level: the value network is described, actors and their roles identified. Chapter 5 elaborates on this work by evaluating the impact of the smart service on a micro-level. Within Chapter 5, the added value for the involved actors is identified and the impact of the smart care platform for care organization is quantified. In order to do so, first a breakdown of current ‘as-is’ processes for care scheduling and care billing is performed and compared with the future ‘to-be’ processes after integration of smart care platforms. These process breakdowns allow identification and quantification of the changed process steps and resource usage (e.g. time and number. of telephone calls). Combining these cost reductions with the total costs, CapEx and OpEx, results in a cost-benefit analysis for smart care platform integration from the perspective of a home care organization. This study also includes sensitivity analysis due to the uncertainties on process impact and cost parameters of smart care platform integration.

1.7.3 **Multi-actor evaluation, barrier detection and go-to-market strategies**

As pointed out in Section 1.7.1, the overall goal of the research described in Chapter 2 is to define viable go-to-market scenarios. Therefore the value network is identified and later on in Chapter 5 the operational and economic impact for a home care organization is evaluated. In Chapter 2, also several barriers for adoption are identified (e.g. concern about privacy, unclear payment structures, lack of standards). So in order to be able to formulate viable go-to-market strategies for all actors involved, these barriers should be taken into account.

To do so, Chapter 6 presents a multi-actor methodology to evaluate the impact of the PEST-barriers (political, economic, social and technological) on the viability of the smart services. The methodology also presents guidelines based on the type and magnitude of these barriers for a specific actor in order to be able to formulate a viable smart service offer. The PEST-analysis is based on both qualitative and quantitative effects and the relative importance of them for the involved actors. Due to this methodology, the impact of different smart services on the involved actors can be compared one another. At last, overall conclusions of the work are presented in Chapter 7.

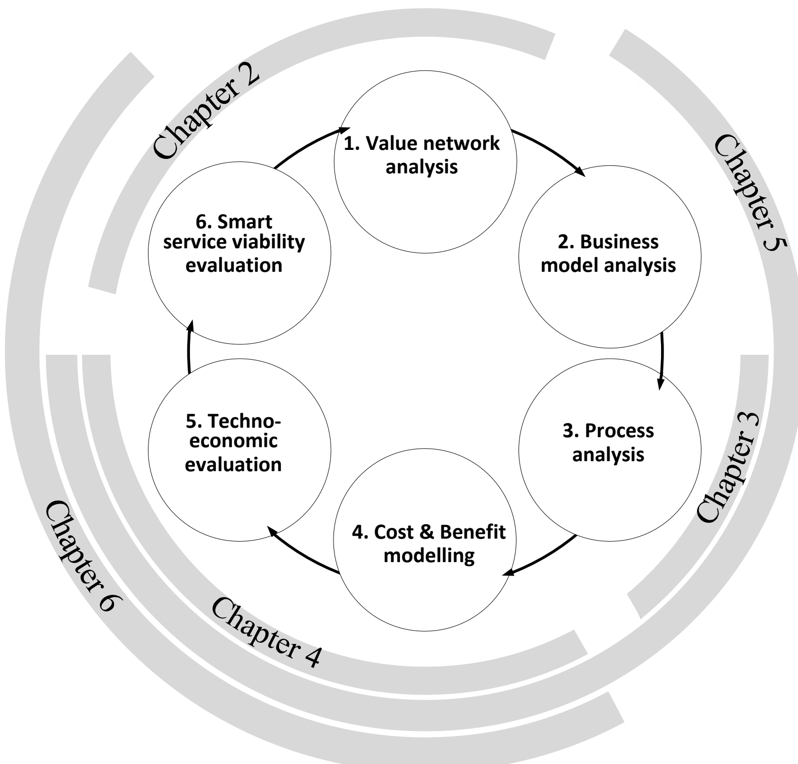

Figure 1-14: Schematic position of the different chapters in this dissertation. Chapter 2 covers Step 1 and Step 6, Chapter 3 covers Step 3, Chapter 4 covers Steps 4 and 5, Chapter 5 covers Steps 2-5, and Chapter 6 covers Steps 4-6.

The aim of the methodology is to offer a framework for evaluating smart services from a broader perspective than that of the pure economic aspects of one single actor. Although most papers included present an evaluation of a smart service from the perspective of the service provider, the research shows that the value network configuration, technological, political and social aspects can play an important role in the success and sustainability of the smart service. Although there is not a single paper in which all six steps of the methodology are explicitly mentioned, they are included implicitly. This can be in the background or introduction sections of the different papers.

The cases described are mainly in the domain of eHealth and eCare or focus on processes in the care sector, but in fact this methodology can and is already applied to many different domains. Examples of other research, not included in this work, are: the evaluations of the value of a smart monitoring system for dairy cows (smart agriculture), the evaluation of the potential benefits of a smart container system (smart transportation), and evaluating the impact of smart process optimization on current processes for hip replacements (smart health).

1.8 Publications

The research results obtained during this PhD have been published in scientific journals and presented at a series of international conferences. The following list provides an overview of the publications realized during this PhD.

1.8.1 Publications in international journals (listed in the Science Citation Index)

1. **Frederic Vannieuwenborg**, Mathieu Tahon, Sofie Verbrugge, Didier Colle, Mario Pickavet, and Piet Demeester. *Deploying charging infrastructure for electric vehicles; viability analyses for municipal and private car parking facility operators.* Published in the European Journal of Transport and Infrastructure Research 14, no. 4 (2014): 425-448.

2. Femke De Backere, Femke Ongenae, **Frederic Vannieuwenborg**, Jan Van Ooteghem, Pieter Duysburgh, Arne Jansen, Jeroen Hoebeke et al. *The OCareCloudS project: Toward organizing care through trusted cloud services.* Published in Informatics for Health and Social Care 41, no. 2 (2016): 159-176.

3. **Frederic Vannieuwenborg**, Thomas Van der Auwermeulen, Jan Van Ooteghem, An Jacobs, Sofie Verbugge, and Didier Colle. *Bringing eCare platforms to the market.* Published in Informatics for Health and Social Care (2016): 1-25.

4. **Frederic Vannieuwenborg**, Sofie Verbugge, and Didier Colle. *Choosing IoT – connectivity? A guiding methodology based on functional characteristics and economic considerations.* Submitted to Wireless Networks (2017).

5. **Frederic Vannieuwenborg**, Bart Sonck, Ludo Bols, Sofie Verbugge, and Didier Colle. *Potential economic benefits of a smart monitoring system for dairy cow health, parturition and heat.* Submitted to Agricultural Economics (2017).

6. **Frederic Vannieuwenborg**, David Plets, Bart Sonck, Ludo Bols, Sofie Verbugge, and Didier Colle. *Economic evaluation of a smart monitoring system for dairy cow health, parturition and heat. In preparation* (2017).

1.8.2 Publications in other international journals

1. **Frederic Vannieuwenborg**, Thomas Van der Auwermeulen, Jan Van Ooteghem, An Jacobs, Sofie Verbrugge, and Didier Colle. *Evaluating the Economic Impact of Smart Care Platforms: Qualitative and Quantitative Results of a Case Study*. Published in JMIR Medical Informatics 4, no. 4 (2016).

1.8.3 Publications in international conferences (listed in the Science Citation Index)

1. **Frederic Vannieuwenborg**, Femke Ongenae, Pieter Demyttenaere, Laurens Van Poucke, Jan Van Ooteghem, Stijn Verstichel, Sofie Verbrugge, Didier Colle, Filip De Turck, and Mario Pickavet. *Techno-economic evaluation of an ontology-based nurse call system via discrete event simulations.* Published in 16th International Conference on e-Health Networking, Applications and Services (Healthcom), 2014 IEEE, pp. 82-87.

2. **Frederic Vannieuwenborg**, Sofie Verbrugge, and Didier Colle. *Integrating digital Health services: The role of the government and the challenge of cost allocation*. Published in 17th International Conference on E-health Networking, Application & Services (HealthCom), 2015, IEEE, pp. 81-85.

1.8.4 Publications in other international conferences

1. **Frederic Vannieuwenborg**, Laurent Mainil, Sofie Verbrugge, Mario Pickavet, and Didier Colle. *Business models for the mobile application market from a developer's viewpoint.* Published in 16th International Conference on Intelligence in Next Generation Networks (ICIN), 2012, IEEE pp. 171-178.

2. **Frederic Vannieuwenborg**, Jan Van Ooteghem, Ann Ackaert, Sofie Verbrugge, Didier Colle, and Mario Pickavet. *Towards a national platform for personal medical data sharing.* Published in eChallenges, 2012, pp. 1-9.

3. **Frederic Vannieuwenborg**, Jan Van Ooteghem, Mathieu Vandenberghe, Sofie Verbrugge, Mario Pickavet, and Didier Colle. *A methodology for multi-actor evaluation of the impact of eCare services.* Published in 15th International Conference on e-Health Networking, Applications & Services (Healthcom), 2013 IEEE, pp. 76-80.

4. **Frederic Vannieuwenborg**, Jan Van Ooteghem, Femke Ongenae, Stijn Verstichel, and Sofie Verbrugge. *Integration of cloud based eCare services: a Multidisciplinary Challenge.* Published in Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare, pp. 239-243. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2014.

5. **Frederic Vannieuwenborg**, Thomas Van Auwermeulen, Jan Van Ooteghem, An Jacobs, Sofie Verbrugge, Didier Colle, and Mario Pickavet. *Smart home care platforms: where is the added value?.* Published in 25th European Regional Conference of the International Telecommunications Society (ITS Europe), 2014, pp. 1-27.

6. Sofie Verbrugge, Jonathan Spruytte, **Frederic Vannieuwenborg**, Bram Naudts, and Marlies Van der Wee. *A business game for offering IT solutions for elderly care homes.* Published in FITCE (Federation of Telecommunications Engineers of the European Union Forum for European ICT Professionals), 2016, pp. 1-7.

7. **Frederic Vannieuwenborg**, Bart Lannoo, Sofie Verbrugge, and Didier Colle. *Smart containers: quantifying the potential impact.* Published in ITS Biennial (International Telecommunications Society) World conference, 2016, pp. 1-20.

1.8.5 Other publications

1. **Frederic Vannieuwenborg**. *Research on a fundamental evaluation methodology, KPIs and guidelines for the integration of innovative eCare and eCure services.* 13th FEA PhD Symposium, 2012, Ghent, Belgium

2. **Frederic Vannieuwenborg**, Zviad Kirtava, Lambros Lambrinos, Jan Van Ooteghem, and Sofie Verbrugge. *Implications of mHealth service deployments: a comparison between dissimilar European countries.* Published in Telecommunication Economics, pp. 56-66. Springer Berlin Heidelberg, 2012.

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2

Bringing eCare platforms to the market

In this chapter, we focus on the formulation of a sustainable value network for integrating eCare platforms into the homes of elderly. Identification of the involved actors, their roles, and the tangible and intangible values they exchange, provides a good basis for formulating potential go-to-market strategies. In addition, several identified barriers for adoption are presented. We discuss how to tackle these and gradually move on to patient centered home care by proposing migration path for eCare platforms.

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ABSTRACT Due to changes in the demographic situation of most Western European countries, interest in Information and Communication Technologies (ICT) - supported care services is growing fast. eCare services that foster better care information exchange, social involvement, lifestyle monitoring services, etc., offered via ICT platforms, integrated in the homes of the elderly are

believed to be cost-effective. Additionally, they could lead to an increased quality of life of both care receiver and (in)formal caregiver.

Currently, adoption and integration of these eCare platforms (eCPs) is slowed down by several barriers such as unclear added value, a lack of regulations, or lack of sustainable financial models. In this work, the added value of eCPs is identified for the several involved key actors such as the care receiver, the (in)formal care providers, and the home care organizations. In a second step, several go-to-market strategies are formulated. Because the gap between the current way of providing home care and providing home care supported by a fully integrated eCP seems too big to bridge in one effort, a migration path is provided for stepwise integration and adoption of eCPs in the current way of home care provisioning.

2.1 Motivation for adopting eCare platforms

For years, researchers and politicians have been formulating the challenges that will arise due to the aging society of Western Europe. On top of that, these financial, cultural, and medical challenges have amplified due to the financial crisis that struck Western Europe during the last decade. For many Western European countries this has resulted or will result in a higher pressure on the care system while fewer resources are available.

Changes in health-care policies can be noticed in EU-member states in order to deal with these context challenges (e.g. formulation of new financing system for Belgian hospitals in 2016 [1]). Also, general interest in ICT-supported care applications, like remote fall detection applications [2, 3] and social contact enhancing applications [4], etc., grows exponentially. Although their impact is not always easy to prove [5], many researchers see these applications as tools to improve the quality of care while reducing or controlling the cost of care.

The growing interest in these ICT-supported care applications is confirmed by the numerous diversified research projects and existing applications in this field (mHealth, Tele-Health, eHealth, etc.) [6]. But because the care landscape is complex and consists of many actors and barriers, bringing these smart eCare applications and services to market is challenging. Also because of their individual, nonintegrated, and stand-alone characteristics, the current landscape is fragmented and fuzzy for users, both for care receivers and caregivers [7]. To tackle these issues of non-interoperability and non-integration for ICT-supported home care applications; eCare platforms (eCP) are being developed [8, 9]. These eCPs, subdomain of the broader Ambient Assisted Living (AAL) domain, allow integration, monitoring, and data exchange between a set of home care applications and services that run on the central platform.

Their goal is to provide added value for all involved actors or stakeholders by reducing or maintaining the current cost for care while improving the quality of life for the patient and the care providers. In general, eCPs allow information to be exchanged between the care receiver and his or her (in)formal caregivers, or between the caregivers reciprocally. Furthermore, the integration of various sensors in the homes of care receivers that monitor some specific context variables (e.g. room temperature, movement of the person, bed detection, sound level, etc.) [10] allow longitudinal analyses that can provide meaningful insights in evolution of the condition of the care receivers and their daily life patterns.

Although multiple international research projects in the area of AAL are ongoing or have been finished, to date eCPs have limited market presence. Despite the effort to formulate sustainable business models for AAL-projects [11, 12], only a few integrated examples are currently available [13], resulting in a limited number of economic and usability studies. Also the impact on the business cases of caregivers or organizations is not yet clear enough and depends heavily on the type of installed health-care system. The logical result of this is the difficult adoption of these high potential eCPs. This leads to critical questions: whether eCPs really have an added value for all actors, what the barriers are, and how to tackle them?

2.2 Objectives

The goal of this conceptual paper is threefold: In the first step the bottlenecks and the added values for all stakeholders are identified. Based on these identifications, in the second step, several potential go-to-market strategies are proposed for a sustainable adoption of this type of innovative ICT-supported care applications and platforms. At last, a migration path is proposed in order to prepare the market by stepwise integration of the eCPs services.

2.3 Challenges concerning the integration of eCare platforms

Integrating eCPs and services faces some key challenges for adoption [14]. The following challenging aspects are recognized: (1) A complex value network for eHealth and eCare services, (2) Added value is unclear, and still needs to be proven or is hard to quantify, (3) Technological barriers, and (4–6) Policy- and health system-related barriers.

2.3.1 The complexity of the eHealth and eCare value network

In most countries or regions there is a public health system installed ranging from completely publicly funded systems to almost exclusively private systems. Although many systems show similarities, there exist many differences in organization and reimbursements of care between all countries or regions. The differences result in different attitudes toward adoption of eCare services. For example, in places where health care is paid for by private insurers (e.g. the United States), the incentives and speed to deploy prevention stimulating eCare services or services that lead to reduced cost for care administration are often higher than countries with publicly funded systems (e.g. Belgium).

These dissimilarities make it difficult to formulate universally valid barriers or benefits resulting from integrating eCPs. Another consequence of the dissimilar

health-care systems is that the go-to market strategy will need fine-tuning for each country or region to fit in all local regulations and policy frameworks.
This work is situated within the context of the Belgian care system, a care system that is characterized by a compulsory care insurance for all citizens. Many citizens supplement their basic insurance with additional insurance.

Currently, care is offered in a very fragmented way in Belgium. Both informal and formal caregivers working privately or for different facilities/organizations are providing different levels of care to the care receiver (daily life assistance versus medical care).
All citizens have complete freedom in choosing their care providers. Sharing care data between all involved care providers and care organizations increasingly is being facilitated, sometimes compulsorily, using online platforms deployed by governmental bodies (e.g. online medication schemes [15], online assessment tools for the care need [16], e-prescriptions [17], etc.). The trend is positive, but currently one cannot speak of complete interorganizational collaborations.

This complex health-care landscape becomes even more confusing once technology and digital health are integrated. During the process it becomes clear that the value network of digital health care is so complex and fragmented that the creation/adoption/consumption of a digital eCP asks for extensive partnerships and collaborations (with non-care providing partners, e.g. service integrators, mobile telecommunication providers, hardware developers, etc.) to get accepted, promoted, and marketed within the healthcare sector.

The complex value network is often characterized with an unbalanced cost and benefit allocation. Often, the investing actor is not the one who will benefit the most [13]. These distorted cost/benefit allocations need to be solved in order to guarantee a sustainable business case, otherwise disadvantaged actors could slow down or even block the adoption of the service.

In Belgium and many other countries or regions the health- and home care market and value network is fragmented and fuzzy to operate in from the perspective of care technology providers [18]. Applying for reimbursement and formulating sustainable business models are especially challenging tasks. Also incentives for publicly funded care insurers are currently not strong enough.

2.3.2 Added value of such services still needs to be proven

Although health care is in need of new business models [1] and there is a big "buzz" around digital health-care innovation, there is not yet sufficient proof on the added value of new eCare services [13]. Also the fact that few examples exist of integrated eCPs, evidence on economic impact or sustainable business models is limited.

This is a reason why policymakers, health-care practitioners, patients, and other stakeholders are somewhat restrained in adoption and reimbursement [18, 19]. Typically reimbursement could be considered when significant scientific evidence is available (cf. evidence based medicine). This poses a chicken or egg duality for eCare services like smart care platforms since its adoption, and therefore also its expected impact would be slowed down by a lack of reimbursement [19].

Another characteristic of eCare services is that the added value for many actors is more qualitative. Care supporting services, such as meal delivery services, care agendas, and alerting services, often lead to an increased quality of care, increased peace of mind for the care receiver or care provider, increased social involvement, and an increased quality of life in general. These types of qualitative impacts are more challenging to quantify than pure quantitative effects such as process time reduction. There exist methodologies to quantify these qualitative benefits, [13] such as quality adjusted life years (QALY), [20] but often these methodologies do not cover all impacted aspects (quality of life of patients, formal caregivers, informal caregivers, societal impact, etc.).

Further research on cost-effectiveness, value calculations, and user experience research is needed to prove the added value of eCare services and platforms.

2.3.3 Technological barriers

Integrating eCPs also poses a significant technological barrier. On the one hand, the end users—care receiver or care provider—need to be at least somewhat educated to use and work with new ICT-supported care services. Also using the smartphone, tablet, or television as medium to interact with the eCP is a new given for many people [21]. Proper education and time will be needed in order to expect that the users are ready to work with an eCP.

On the other hand, there exist many standards and data formats to exchange care related information or to communicate with different sensors. Many hardware providers use their own "standard" to protect their technology or use a subset of international standards such as HL7 and DiCom [22]. Luckily, efforts on standardization are still ongoing and fostered by many initiatives such as Continua Health Alliance [23].

2.3.4 A lack of financial support

In international research of [19] and [24], up to 80% of primary health-care practitioners reported a lack of financial support for IT applications as a barrier for adaption. Integrating innovative ICT-supported care services (eCare services) not only requires upfront investments, but often results in changes or even completely new operational processes for care provisioning. Financial structures to compensate care providers for these new processes are often not in place. The incentive to integrate eCare services is thus rather low for most care providers.

On the other hand, together with the growing interest in eCare services, the number of requests for reimbursement grows as well. So the decision makers, who should have a societal perspective, should prioritize the allocation of reimbursement resources according to the simultaneous impact on the cost of care and effect or quality of life of the patient and his or her (in)formal caregivers.

Annemans [25] states that on a policy level, where decision makers decide on the reimbursements of treatments, there is often a short time vision in order to do quick savings and where there is too little attention to the long-term cost-efficiency of all treatments.

2.3.5 **Current willingness to pay**

In many Western European countries, policymakers have installed a health-care system that aims to be high quality, accessible, and affordable for their citizens. In many countries, public health insurance has been installed to make health care affordable. This implies that the costs for health care are borne by society, and therefore citizens themselves only have to pay a fraction of the total cost for their health-care provisioning directly. This results in two crucial impacts. First, health care is affordable and accessible for most citizens. Second, since we are used to paying only a marginal part of the total health-care cost, most citizens do not have an appreciation of the complete cost of health care.

Therefore, if eCare services are not (partially) reimbursed by the health insurers or other stakeholders, people face the real and complete costs of those services. This will form an adoption barrier in some cases [26, 27]. This is an important remark because it can be expected that only a minimum or none of all eCare services will be reimbursed because of the pressure on the financial resources and the current lack of impact/effect evidence.

2.3.6 **Privacy concerns and legal issues**

Privacy is another barrier hindering implementation of ICT in health care. Since electronic medical records and other digital health innovations are web-based, any physicians and patients fear that medical data may not be secure [19]. And this fear is even more the case when wireless Internet is used to transmit these data to various locations [28].

To counter these privacy concerns, governments impose strong regulations on ICT-supported eCare services in health care. Various laws related to fraud and abuse, malpractice and data security create a rough climate for health-care providers to implement new ICT services. This is the same case for new innovative health entrepreneurs entering the market.

2.4 Methodology

The proposed migration path for integrating eCPs into the current care landscape results from following a three-step research approach: (1) Added value identification, (2) Value network analysis and go-to-market strategy formulation, and (3) defining a migration path. Figure 2-1 gives a schematic overview. In what follows each of the research steps will be discussed. In this section, the methodology will be discussed. In Section 2.5, it will be applied to a specific case [29].

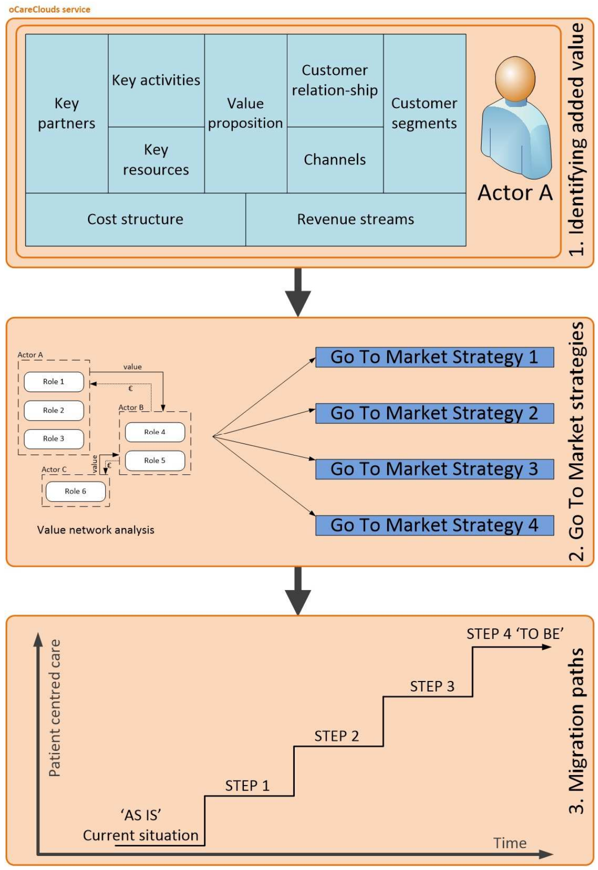

Figure 2-1: Schematic overview of research methodology.

Step 1: Data collection and added value identification

In order to collect data on added values, barriers, and potential impact on business processes, several types of data collection meetings were organized. Data collections techniques used during these meetings are as follows:

- Interviews with opinion experts: four managers and care professionals of care organizations and two managers of a service providing company
- Interactive focus group workshops with stakeholders who are member of the project consortium [29] (mobile service integrator, service providers, hardware provider, and care organizations). Topics treated during these workshops: business model canvas, value network configuration, value stream mapping, process decompositions, go-to market strategies, and migration path
- Data-input of a complementary project research [30] on user experience

- Iterative feedback meetings in which stakeholders could provide feedback on interim analyses

Finishing this step resulted in (a) a clear formulation of the needs of each actor and (b) the added value eCPs could offer to (partially) overcome these needs.

On the condition that all acquired information and data would remain confidential, participating care providers and patients approved the use of the data for scientific research by signing an informed consent. Also, this project is registered with the Commission for the Protection of Privacy as an iMinds ICON project. The study was exempt from formal ethical approval.

Step 2: Value network analysis and go-to-market strategy formulation
In this second step, we provide potential answers on questions as follows:

(1) Who will distribute and install these platforms?
(2) Which actor will educate the care receivers and care providers?

As stated earlier, via iterative focus group workshops, three realistic go-to-market strategies were developed and described in detail via value network and value stream analyses [31]. All necessary roles, being the tasks and responsibilities that are needed to be executed in order to deliver the product/service to the end consumer, were identified and allocated to one or more actors. An actor is the organization/person or firm that is responsible for one or more roles. Mapping all the actors on one or more roles clarified some important issues that will need to be tackled in the future.

Step 3: Formulation of a migration path
In the third and final step, the gap between the "AS IS" situation for home care delivery today and an improved and futuristic "TO BE" scenario is the topic of interest. The research findings indicate that the "AS IS" situation, characterized by a scattered landscape of care provisioning, offered by many different care actors, such as informal and formal caregivers and care organizations, is not ready for a complete integrated eCP in the homes of elderly.

The gap between the current situation and the desired scenario seems too big to bridge in one effort, therefore several intermediate targets are proposed that form together the migration path toward the "TO BE" scenario, which stands for the complete integration of eCPs in the organizational and operational processes of care provisioning. The migration path as such is proposed as a realistic integration strategy for eCPs.

2.5 Research outcome

In what follows, the proposed methodology will be applied to eCPs in order to determine the added value for several actors and to formulate several go-to-market strategies. Also one particular go-to-market strategy will be described in detail.

2.5.1 **Description of the functionalities of eCare platform**

Many examples of previous and ongoing projects on eCPs can be found in the literature. The AAL project: make it ReAAL [9], the eCare network of Bologna [5], the Telecare development program of Scotland [32], and the AAL Care4Balance project [33] are just a glimpse of national or international eCP projects. In essence, their functionalities can be categorized in four different themes:

1) Sharing care information, and according to the role-based rights of the involved actors, one can add, change, erase, or annotate particular information of the care receiver.
2) Providing care supporting services. Examples of these services are online meal delivery services, providing care journals and care agendas, alerting specific care actors, etc.
3) Social life supporting services. Making video calls with friends or relatives, or being able to share some memories with family are just some of the services that support the social life of the elderly.
4) Monitoring services. Examples are lifestyle monitoring services, which monitor daily life activities via a series of sensors such as movement, pressure sensors to detect bed or couch presence, accelerometers to detect falls, light, noise, temperature, humidity, smoke detectors, weighing scales. Via these sensors all kinds of biometric or context information can be captured. Sensor data allow the analyses and evaluations of the lifestyle trends.

Many eCPs provide some of the above services whilst others provide a basic set of services that can easily be extended by adding modular services [29]. The eCP called O'CareClouds and developed during the equally named project [29], which is the focus of this research, is a complete cloud based platform. O'CareClouds provides several services: (1) to foster better care information sharing (consulting and annotating the shared care record), (2) to support the care and care organization tasks (time and task registration of the caregivers, care agenda, and a smart task list), and (3) to enhance the social connectivity (smart messaging service, service catalogue for additional O'CareClouds services). Additionally, (4) modular lifestyle monitoring services can be added by installing the necessary sensors.

2.5.2 **Added value identification**

Addressing the needs of the involved actors is a first requirement in order to present a potential interesting offer for them. In what follows, the main users (being the care receiver, the informal care providers (such as family members, partners, or friends), the formal care providers and care organizations) together with the added value for them and a description of how of an integrated eCP fulfills their needs is provided.

To determine the added value for both the care receiver and the informal caregiver, results from user research within the O'CareClouds project are used, combined with the outcome of (in)formal interviews and workshops with various stakeholders (see “Step 1: Data collection and added value identification”)

Added value for the care receiver

The most important added values for the care receiver are identified:

- A direct result of an integrated eCP is that the care receiver immediately has more control of the organization of his or her care. Care receivers can consult and complete their own shared care record. This leads to a strengthened involvement and empowerment of the care receiver.
- The improved possibility to share care information between the involved care actors will lead to higher quality of care and could lead to a higher state of peace of mind because they know that someone is looking over their shoulders.
- Depending on the go-to-market strategy, integrating an eCP with lifestyle monitoring services after hospitalization could lead to a higher state of self-management. Being more self-manageable as a care receiver means that you are less dependent on care provided by other actors. Therefore, the possibility exists that a care receiver can live in, and stay in his or her own home, whilst now many care receivers need to go to an intramural or day care center because their care needs are too great to live qualitatively in their own non-adapted homes.
- A social calendar, which presents all social activities that are interesting and adapted to the situation of the care receiver, could lower the barriers for social contact and decrease the chances of social isolation.
- Many care supporting services and devices exist already. However, informing the end user of their existence is the real challenge. A digital catalogue service of compatible eCare services could lower this knowledge barrier. The smart catalogue could suggest care services, particularly interesting for the care receiver.

Added value for the informal caregiver

For family, friends, neighbors, and volunteers, the added value can be summarized as follows:

- A better care task coordination will lead to an improved quality of care/work atmosphere. Less stress, less unexpected tasks, increased state of peace of mind, etc. could all be results of better coordination and communication between all the caregivers.
- Being better (and real time) informed as caregiver about the care receiver and his or her actual situation will also lead to more appropriate care (e.g. when there was an abnormal incident earlier that day, etc.).

Added value for the formal caregivers (physiotherapist, general practitioner, cleaning help, etc.) and care organizations (day-care revalidation centers, home care organization, etc.)

To identify the added value an integrated eCare service could reveal for a care organization, several methods were used (see “Step 1: Data collection and added value identification”). First, based on user scenarios, a decomposition of the current care process is done (Figure 2-2). The process blocks with the dashed line indicate how the current process could be triggered by eCPs. The hatched blocks highlight the impacted steps of the current process. These steps will not only require some hardware and interaction with the platform, but also result in additional time investments.

In order to validate these findings and get data on the expected amount of additional time invested, expert opinion interviews took place with managers from care organizations. The goal of the interviews was to identify in which current process steps the most time was invested and where most efficiency increase could occur.

The complete process of care delivery by a care organization is currently divided on the one hand into patient driven process steps: (1) the patient intake phase, (2) the preparation of the care delivery, (3) the actual care delivery, and (4) the care delivery administration. On the other hand, there is also the overhead time investment needed to run the organization as well. Figure 2-3, which is a result of iterative feedback sessions of opinion experts, maps these process blocks and their cost drivers or parameters.

The major conclusion that can be drawn is that integration of eCPs will only marginally impact the first three patient driven phases. But all process blocks that require administration tasks can benefit a lot of such a system.

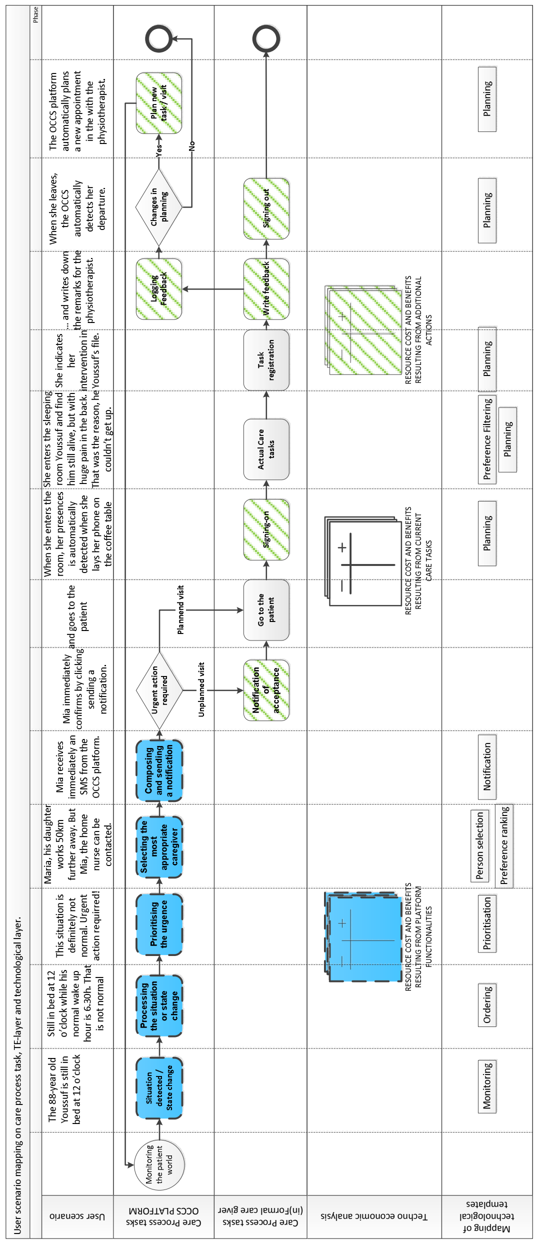

Figure 2-2: Decomposition of a home care process supported by an eCP. Note. Hatched blocks: impacted process steps; blocks with dashed line: process blocks triggered by the eCP

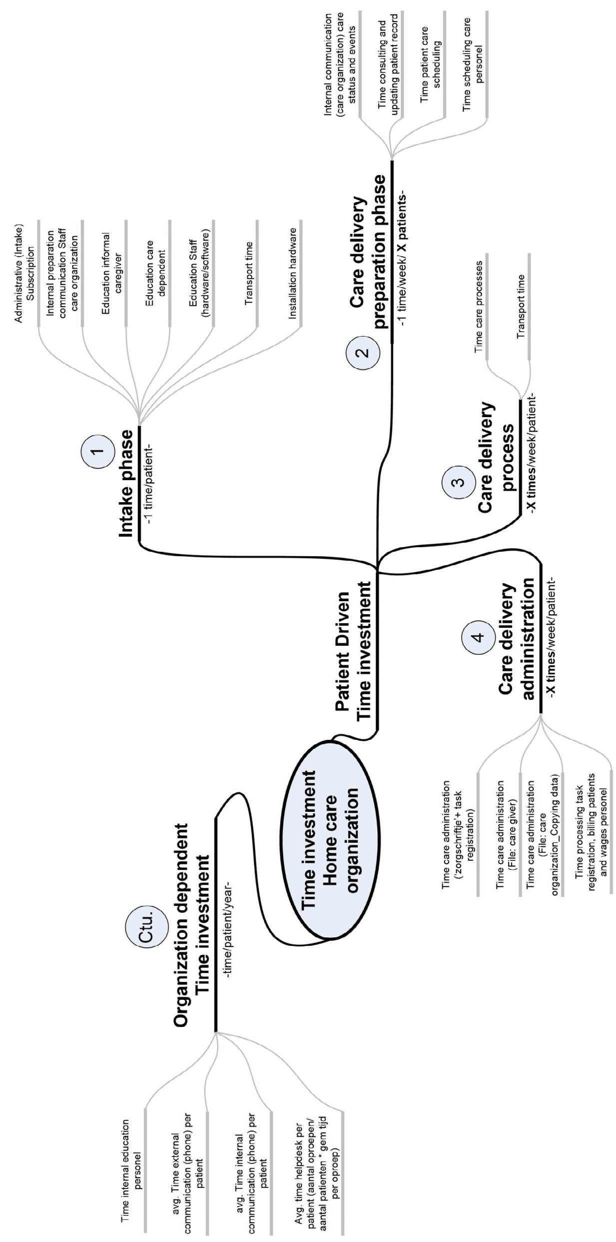

Figure 2-3: Parts of care organization process which are impacted by the integration of an eCP. Every block is expressed as average time investment per patient

In particular, the billing for care delivery and the (re)scheduling of it proved to be processes that are characterized by intensive manual labor in many care organizations. Apparently, due to the nonintegrated informatics systems, a lot of manual rework needs to be done.

These findings are crucial since they shift the focus of the quest to identify the added value from having the availability of a more complete care context to a focus on administrative time investment.

The following value-adding aspects of eCPs were identified from the perspectives of formal caregivers and care organizations:

- Using (and/or integrating) eCP functionalities in existing planning and billing software of the formal caregivers could lead to significant decrease in administration time. Administrative time gained at the home of the care receiver will result in more time for qualitative care (more added value for the care receiver).
- A better care task coordination will lead to an improved quality of care/work atmosphere. Less stress, less unexpected tasks, increased state of peace of mind, etc. could all be results of a better coordination and communication between all the caregivers. (Idem informal caregivers)
- Integrated eCPs allow a smoother switch between professional care colleagues from the same care organization (e.g. in case of sickness, etc.) because of the available care context the platform can provide. A more transparent data sharing between formal caregivers, who are not connected to care organizations (e.g. GPs, etc.), could also result from eCPs.

Added values: Summary

Table 2-1 summarizes the added value for the key users of an eCP and which type it is: qualitative versus quantitative added value.

Quantitative effects are those that can be translated to monetary value quite straightforwardly. Process time reduction and increase of throughput are examples of quantitative effects. In contrast with quantitative impact, there are the qualitative effects. Added values, such as “improved quality of care,” “less care stress,” and “better work atmosphere,” are all examples of qualitative impact factors not only for the care receiver but also for all his or her caregivers. Via socioeconomic and health-economic evaluations, qualitative effects can be quantified [34, 35].

For care receivers and informal care providers, eCPs will mainly result in qualitative effects. From their perspective, qualitative impacts, such as increased peace of mind and quality of care, are more important than the quantitative effects that could influence the cost for care provisioning, for example. For care organizations, the situation is different. Both types of impact factors (qualitative and quantitative) are important. Better insights in the home care situation through more detailed care information can lead to higher quality of work and work atmosphere.

On the other hand, an adjustment in the care planning process could lead to significant time savings in the overhead processes. This is an important given since a care organization is responsible for many caregivers, so potentially a significant amount of time can be saved but would also require a significant investment from the care organizations.

Care organizations are expected to have a crucial role in the integration, adoption, and scaling of eCP systems. The added value for this actor must be very clear. Therefore, not only a description of the qualitative impact is interesting, but also a cost-benefit analysis is needed in order to indicate whether or not investing in this kind of platforms is cost-effective.

Table 2-1: Added value for the key users of eCare platforms.

Actor	***Added value description***	***Type of added value: Qualitative/ Quantitative***
Care receiver	• control of the organization of care	Qualitative
	• strengthened involvement and empowerment	Qualitative
	• higher quality of care	Qualitative
	• higher state of peace of mind	Qualitative
	• higher state of self –management, less care dependent	Qualitative
	• lowered barriers for social contact and decrease of social isolation	Qualitative
	• better informed of existing and practical care support services	Qualitative
Informal Care giver	• better care task coordination	Qualitative
	• improved quality of care/work atmosphere	Qualitative
	• less stress, less unexpected tasks, increased state of peace of mind, etc.	Qualitative
	• being better (and real time) informed	Qualitative
Formal Care giver & Care organization	• better care task coordination	Qualitative
	• improved quality of care/work atmosphere	Qualitative
	• less stress, less unexpected tasks, increased state of peace of mind, etc.	Qualitative
	• significant decrease in administration time (scheduling, adapting schedules, billing, etc.)	Quantitative
	• reassuring care receivers when delay during care visits	Qualitative

2.5.3 **Value network analysis and go-to-market strategy formulation**

The goal of this section is to discuss possible approaches to get eCPs to the market. Three possible scenarios were found suitable for market entrance. A fourth reimbursement-based market scenario was formulated as well, but was considered non-desired. Reimbursement for eCare is under pressure or often not in place yet and cannot be sustained in the future. For one particular go-to-market strategy, first, the value network with all necessary actors together with their roles is formulated. And second, the value streams between all roles are indicated. To conclude, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is provided for that scenario. The following go-to-market strategies are identified:

(A) eCare platform provided by the care organization

The eCP gets sold by the integrator to the care organization, which offers this as a service to the final client. Apart from having a competitive advantage over other care organizations, interviews with home care organizations revealed no other forms of added value when offering eCPs in the current healthcare landscape. Willingness to pay from the customer's side is unclear for this scenario.

(B) eCare platform provided by service flats

The eCPs are offered by the service flat owners and their usage costs is included in the general service flat rent. Apart from having a competitive advantage over other service flats, there is little added value for them. That the real benefits of the system are also addressed to other actors, and that there is still a technology adoption gap for elderly, make the incentive to integrate the expensive eCP technology very small.

(C) eCare platform as billing and scheduling tool for care organizations

In a third scenario, this work tries to address the issue of a lack of added value for the care organizations. Taking into account the input from care organizations, we developed a scenario where we stepped away from the key focus of eCPs, but used a billing and scheduling tool as starting point. According to care organizations, these current processes demands major administrative and time-intensive efforts.

(D) eCare platform with government reimbursement

The last scenario was developed to show what the business model would look like if eCPs are offered by the care organization but supported by government reimbursements. There is no guarantee for a long-term sustainable business model for eCPs when based on reimbursement.

In this work, only the third go-to-market strategy, eCP as a billing and scheduling tool for care organizations (eCP as efficiency improvement tool), will be discussed in detail.

Value network and value stream analysis

The qualitative added values for key actors, such as care organizations and care providers, are not clear and strong enough in order to guarantee a sustainable adoption. Therefore, the focus shifts from an eCP as care supporting system to an eCP as tool for efficient time and task registration and care rescheduling. eCPs are expected to save a lot of administrative time. In this go-to-market scenario, the care organization subscribes to the eCP billing and rescheduling functionalities, provided by the eCP integrator. No other care actors are necessarily involved or have to invest in eCP services or hardware.

Task registration and gathering billing information could be easily added to the eCP functionalities. Also since these platforms foster better care information sharing amongst the care actors, rescheduling the care agenda would become easier.

Focusing on the billing and rescheduling processes appears to be an undervaluation of the potential of an integrated eCP but it has two main advantages:

- The billing and care rescheduling processes of many care organizations are often still very administrative and time intensive and therefore costly. Tackling these issues is of real added value for these actors.
- Care providers and members of a care organization are not always familiar with the latest ICT -technologies. Instead of releasing the full functionality of eCPs at once, which can be overwhelming, a controlled and stepwise introduction of functionalities that makes their job less administratively intense could lead to a better acceptance and adoption.

Figure 2-4 presents the value network for offering eCPs as billing and scheduling tools for care organizations. The legend indicates which actor (e.g. care receiver, platform provider, formal caregiver, government, etc.) is responsible for which role (hardware development, service integration, etc.). Actors are the persons of organizations that can deliver value, both tangible and intangible (service, support, craftsmanship, etc.). Actors take up one or more roles within the value network. A role indicates the responsibility about one or more activities that needs to be fulfilled by an actor in order to deliver the added value.

For a complete set of definitions and overview of the different actors, roles, streams (Care, Service, Big Mother central platform, Network and Financial stream), and phases (creation, delivery and consumption phase) see Appendix A.

In the value stream mapping (Figure 2-5), the value exchanges [financial, financial stream for care, value (tangible and intangibles) and care] between these actors are presented. The figure shows the value streams of an eCP as a billing and scheduling tool.

The integrator will use its own resources but also use external expertise and knowledge to create the final billing and scheduling tool. Financial flows will be directed from the integrator toward the suppliers to compensate for the value streams that flow toward the integrator. On top of its cost to produce this tool, the integrator will add a profit margin that will form the selling price of this tool for its clients, in this case the care organizations.

The care organization(s) will pay the integrator for the tool and for the installation and integration into their back-end systems. The integrator could charge additional (monthly) fees for service support, maintenance, yearly education, and other roles.

Feedback from the care organization shows that opening billing and scheduling records for review could provide additional value for care receivers and (in)formal caregivers. If the added value is of such a level that willingness to pay can be found, financial streams can flow from these actors to the care organization for the review of the care planning and billing. Further research could provide insights to the willingness to pay for these services.

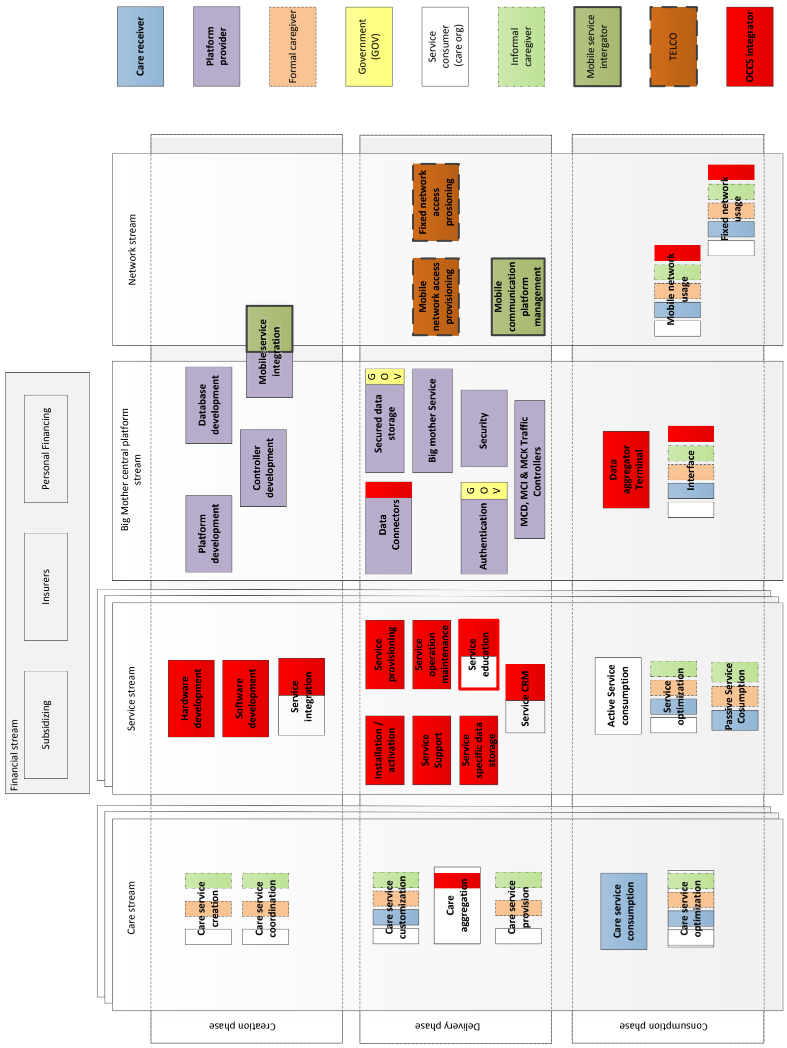

Figure 2-4: Value network configuration for go-to-market scenario: eCP as “efficiency improvement tool.”

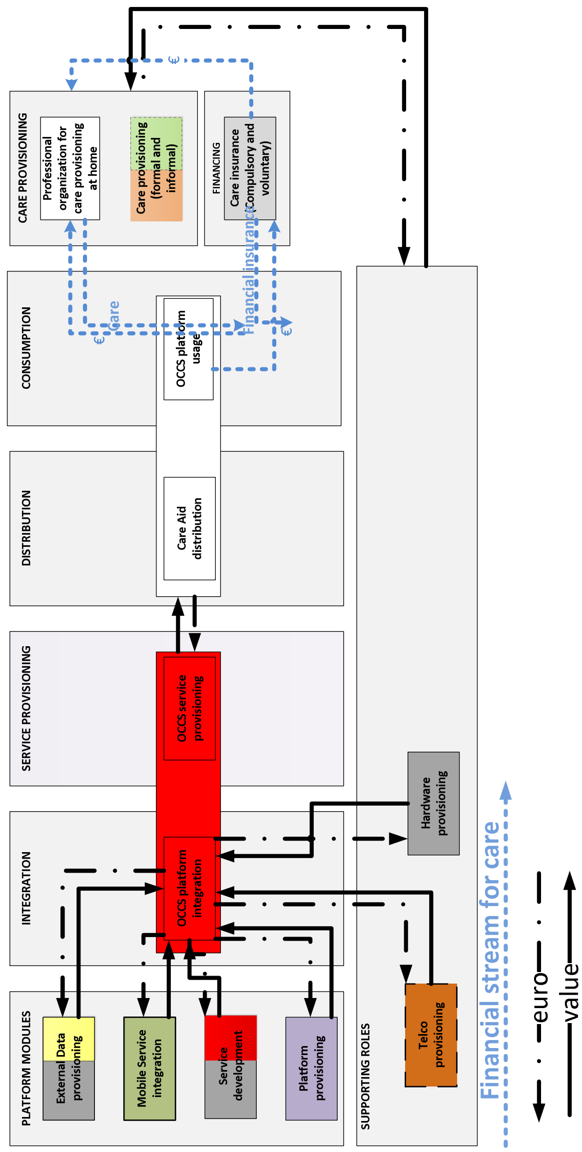

Figure 2-5: Value stream mapping for the go-to-market scenario: eCP as "efficiency improvement tool." This tool will be marketed in

Impacted care processes of care organizations

The care organizations themselves are convinced that a lot improvement is possible on the administration side of the billing and rescheduling processes. In order to detect which process steps would be impacted by eCPs, interviews with care organizations took place. The scope of the model is limited to East-Flemish work area of a care organization involved in the OCCS project [29].

First, a full decomposition of the current billing process and rescheduling process is done, as well as the process that takes place when something has to change to the actual care schedule. For instance, when a caregiver gets sick, all planned appointments need to be reallocated to other caregivers. Figure 2-6a shows schematically both process breakdowns.

In a second step, together with the care organization, we modeled how an eCP would impact the current billing and rescheduling processes. Some process steps would remain unchanged; others would even disappear or would be impacted. Figure 2-6b shows what process steps would be impacted and how.

In the third step, all impacted process steps will be quantified (e.g. time investments, decreased communication costs, etc.). This quantification is beyond the scope of this current work.

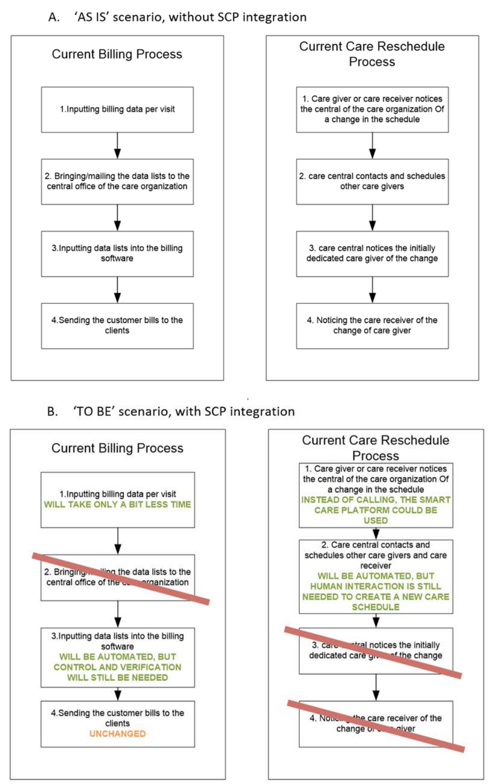

Figure 2-6: Process decomposition of (a) 'as is' and (b) 'to be' billing and care rescheduling processes, respectively without and with integration of an eCare platform.

2.5.4 SWOT analysis for the go-to-market scenario: eCP as efficiency improvement tool

Figure 2-7 shows a summarizing SWOT analysis for this go-to-market strategy. A SWOT analysis provides insights in both the internal (strengths and weaknesses) and external (opportunities and threats) factors that can influence the achievement of the goal. Based on the identified strengths and opportunities, one should conclude that integrating eCPs as tools for efficiency improvement does hold potential value.

On the other hand, the issues that can slow down the adoption are a lack of change management and overall willingness to adopt a new technology.

Strengths	*Weaknesses*
- Creates added value for the care organization - Could be a first step to digital integration of more digital services (e.g. OCCS) - Gives the care receiver and informal giver an overview on their expenses and care agenda - Show already potential income flows for the care organization - Increases cost-efficiency on the long run	- This model remains care organization centred and does not move to a patient centred system, which is the initial goal - Needs a strong change management
Opportunities	*Threats*
- Possibility to integrate this tool in a smart care platform	- Low willingness to adopt technology

Figure 2-7: SWOT analysis of GTM scenario: eCP as efficiency improvement tool.

2.6 Migration path

All actors in this study agreed that these technologies will be of value in the near future and will increase cost-efficiency.

But the business modeling and user experience research showed that the market is not ready yet for installing complete integrated eCPs into their homes. For the care receiver, there are some technical barriers to overcome and the added value of these technologies is still unclear. Currently, for the care organization, these technologies do not provide a unique selling proposition. Moreover, there is no clarity on who will pay for this. To implement eCPs, between care organizations, there needs to be strong cross-organizational cooperation and change management. These organizations do not seem ready yet for this sudden change.

To deal with these issues, a migration path was developed that, first, will fulfill the care organizations' needs, and second, will provide a gradual process to adopt eCPs within the organization and across the sector.

Figure 2-8 starts from the current care organization-centered model (as care coordinator). An integrated eCP, which is at the end of the spectrum, fosters a patient-centered system. To evolve from the current to the desired scenario, the research indicates that intermediate transitional steps are needed.

- *Step 1: an eCare platform as billing and scheduling tool*
  For the care organization to adopt an eCP, there needs to be proven additional value. Therefore, eCPs should also be able to be used as a scheduling and billing tool. As the current and future state process decompositions show, a billing and scheduling tool for care organizations can impact their administrative costs. If integrated within a patient-centered care system, it can deliver a competitive advantage toward the future.
  A remark from a care organization was that the patient should already be able to see their planning and scheduling (without an active participation in it). This will already create value for the patient. This step will probably pose the biggest hurdle for all actors: infrastructure installation, the education and change management within care organizations, drawing the baselines for future partnerships, etc.

- *Step 2: Internal use of the shared care record*
  During this second step, care organizations are encouraged to start using the eCP functionalities within their organizations. Note that the patient still does not get empowered to participate in his or her own health record and organization. This second step merely serves as a change management step, where the care organizations and its staff get immersed in the new eCP technology and are showed and convinced of its advantages and possibilities. Hereby, the eCP supplier/integrator of the system should educate all staff members.

- *Step 3: Cross-organizational use of shared care record*
  In a third step, when all possible technical issues are cleared and change management convinced future users of eCPs (formal/informal caregivers, staff members etc.), eCPs should become a tool for cross-organizational use. If sales operations in step 1 and 2 were performed extensively and network effects occur [36], rollout to step 3 could go smoothly. Cross-organizational use of the shared care record could serve as a catalyst for sales opportunities when network effects occur.

- *Step 4: eCare platforms as facilitating tools for patient-centered care*
  Once all previous steps are fulfilled, care organizations and actors could start thinking about opening the systems to the care receivers. At this future time, care receivers will get more and more receptive toward

(health care) technology innovations [37]. Care providers should foresee thorough education for care receivers to get accustomed to the health technology.

However, it will be important to develop key partnerships. A partnership could be the solution to develop a long-time business case to develop a market adoption plan and spread costs accordingly.

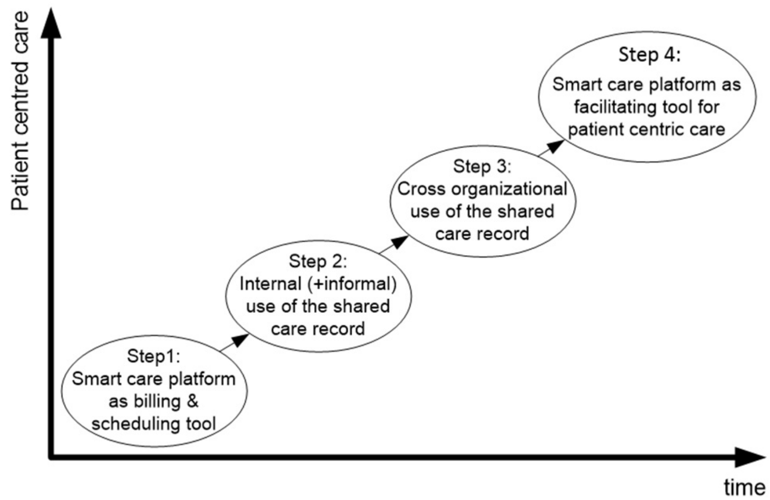

Figure 2-8: Proposed 4-step migration path to tackle the issues of adoption.

2.7 Conclusion

In this paper, we have looked into the marketing opportunities of new “Cloud-like” eCPs. The goal of these platforms is to offer trusted information and knowledge-based services related to the care organization and delivery to the client/patient. These services aim to support and foster communication on the daily care related needs, the social needs and daily life assistance.

This work started by detecting barriers and challenges for creating and developing products and services in the eCare landscape. Four groups of challenges are defined as follows: (1) the complexity of the eHealth value network, (2) unclear added value for several key actors, (3) technological barriers for both users and developers, and (4) policy issues concerning privacy, a lack of financial and regulatory framework and a deformed perspective on the reimbursement of health care.

The impact of these barriers is strongly amplified because of the dissimilarities in public health-care systems, installed in almost all countries (e.g. health-care systems based on private insurance versus completely publicly funded systems). The fact that most countries or regions have own structures for their care system and reimbursement make it more complex to export or copy eCare services to other places (e.g. different reimbursement schemes, different legal and privacy framework, standards, etc.). This work is situated in the context of a Belgian health-care system in which there is a compulsory insurance. The basic insurance is often supplemented with non-compulsory insurances. This context information is important because it can imply that the identified barriers have different weights of impact in other health-care systems.

To propose go-to-market strategies, this work started out by mapping the value network for creating and offering eCare services. The value network can be seen as the total overview of all possible roles that need to be fulfilled to create the services and get them into market. Each role is assigned to a generic actor. A key role within this story is the one of the integrator. The integrator is the actor responsible for turning eCPs into a tangible products and bringing it to the market. This actor will use its own expertise, but will also use input from external parties to install or integrate eCPs into existing or new systems of clients (e.g., the integrator can buy the hardware from a supplier, will use the services from a software developer etc.).

After mapping out the value network, four go-to-market strategies for eCPs are formulated. Also possible revenue streams are identified. In a first scenario, the eCP gets sold by the integrator to the care organization, which in its turn offers it to the final client. Apart from having a competitive advantage over other care organizations, interviews showed that the added value for the care organization is limited. Also, it is uncertain if the current level of willingness to pay from the customer's side will be enough to formulate a sustainable business model.

In a second scenario, the possibility is explored of service flats owners offering the eCPs and including the fee for the use of it in the general rent for the service flat. It was noticed that there is still a technology adoption gap for elderly, apart from having a competitive advantage over other service flats; there is little added value for the service flats to integrate this capital intensive technology.

The third scenario addresses the issue of a lack of added value for the care organizations. Taking into account the input from care organizations, we developed a scenario where we stepped away from the key focus of eCPs (supporting care via ICT-enabled services), but used the platform solely as a billing and scheduling tool.

The last scenario was developed to show what the business model would look like if eCPs are offered by the care organization but supported by government reimbursements. It is clear that this is a desired though less probable and a potentially unsustainable scenario from a societal perspective. Reimbursement strategies for eCare services are still unclear and not in place yet. Formulating the business model on reimbursement is no guarantee for a long-term sustainable business case.

A complete cross-organizational integration of eCPs requires efforts that are too big to handle at once, therefore we defined a stepwise migration path. Research on this migration path indicates that adopting a billing and scheduling tool (third go-to-market scenario) could bypass the problem of a lack of added value and technology adoption issues for the care receivers. If this tool is developed in such a way that it can be integrated into an eCP and the already existing back end systems of care organizations, this scenario would be most plausible at this moment in time.

A billing and scheduling tool has the potential to increase cost-efficiency. This is believed to be a first step to digital integration and collaboration of care organizations and a first step toward a patient-centered care system. Each following step on the migration path serves to open up certain functionalities and services toward different stakeholders. First a complete intra-organizational deployment and integration of eCP functionalities should be realized before starting inter or cross-organizational usage of eCPs. The fourth and final step of the path is about opening up all eCP functionalities toward the care receivers in order to support real patient-centered care.

2.8 Future work

In extension of this work, quantification of the impact of eCPs is needed to make up the business case for care organizations. This is currently work in progress.

Also research on the potential value of eCPs for society would be a great value. If a result of that research would be that integrating an eCP in the homes of elderly is a cost-effective investment for society, reimbursement structures could be pursued. Therefore, a health technology assessment study would be needed to determine the cost per QALY gained. The Model for ASsessment of Telemedicine (MAST) research framework [38] would be suitable for this kind of analysis.

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Appendix

In what follows, all value network elements (see Figure 2-4) are described. Elements are as follows:

- Roles
- Streams
- Phases
- Actors

Tables 2-2 to 2-6 provide an overview of all detected roles in the different streams of the value network.

Table 2-2: Description of all the roles in the care stream.

***The care stream** is the value creation stream that deals with the creation, delivery and consumption of care services (all services related with care, wellbeing, home help, etc.) in order to support people to live as long and as healthily as possible in optimal state of wellbeing in a safe living environment (home or neighbourhood).*		
Creation phase	Care service creation	The business role responsible for the creation of services related to care, wellbeing, home help, etc. to support people to live as long and as healthy as possible in optimal state of wellbeing in a safe living environment (home or neighbourhood) Example: the creation of a meal delivery service at home
	Care service coordination	The business role responsible for the creation of integrated care services in order to be able to deliver integrated and demand-driven care
Delivery phase	Care service customization	The business role responsible for customizing the care service to the needs and preferences of the end consumer (care receiver, informal caregiver, etc.) Example: personalization of the meal based on personal food preferences of the care receiver (soup without salt for example)
	Care service aggregation	The business role responsible for aggregating and integrating the care services (with existing and futuristic delivering channels) Example: the care receiver can order his/her preferred meal via a tablet at home
	Care service provision	The business role responsible for the actual delivery of care services to the end customer (care receiver) Example: provision of the ordered meal at home of the care receiver by the meal deliverer
Consumption phase	Care consumption	The business role responsible for the use of care services by the end consumer. Example: the care receiver eats the delivered meal
	Care service optimization	The business role responsible for improvements in the care service based on the feedback received during the care service consumption phase. Example: food delivered is not eaten, and nurse notice this. Other meal support service should be considered.

Table 2-3: Description of all the roles in the service stream.

***The service stream** is the value creation stream that is related with the creation, delivery and consumption of ICT services to support care*		
Creation phase	Hardware development	The business role concerned with the development, manufacturing and retailing of the hardware equipment. Example: development of gateways, sensors, displays, etc.
	Software development	The business role concerned with the development and integration of software components for care purposes. App development can be done by public users, private companies or group of app developers. Example: development of software so people can order via an online software program the meal of their choice
	Service integration	The business role responsible for integrating eCP services in existing back-end systems of the adopting actor (e.g. providing integrated software to care organizations that keep existing client files in account)
Delivery phase	Installation / activation	The business role responsible for the technical installation of the hardware within the care receiver environment. Example: technical installation of different sensors in home environment for a monitoring service (e.g. sensor in the fridge monitoring when/how often the fridge is opened)
	Service provision	The business role responsible for the provisioning/delivery of the ICT service(s). Example: the eCP and its services are continuously and with high quality of service delivered to the care receiver and his or her network of caregivers
	Service support	The business role responsible for supporting end customers (care receiver, caregiver, etc.) and resolving issues in case of problems (contact centre, help desk, etc.) Example: when there is a problem with the service, the end users can contact a contact centre for service support
	Service operation and maintenance	The business role responsible for the scheduled operations and maintenance of the ICT components. Example: yearly maintenance of the batteries in sensors, something is wrong and a technical person is send to the house to solve the problem if not possible from a distance (checking software updates already done)
	Service specific data-storage	The business role responsible for the storage and delivery of service specific data. Example: The storage of additional profile date of a friendship book
	Service education	Training of Caregivers and Care receivers: the business role responsible for educating and instructing these actors making them capable of using the service.
	Service CRM (customer relationship manager)	The business role responsible for dissemination and marketing of the service towards the stakeholders. Example: Keeping the end user up-to-date on new service improvements, care packages, price changes, reimbursement policy etc.

Consumption phase	Service consumption	Using the ICT-supported care service. Dependent on the user this could be: • data interpretation: Interpreting the data that result from the service and acting on that. • data creation: providing information as service input
	Service optimization	The business role responsible for improvements in the ICT service based on the feedback received during the service consumption phase. Example: In case of difficulties whilst using the interface of the service, the actor responsible for this role will be responsible for enhancing the ICT interface for a better user experience.

Table 2-4: Description of all the roles in the big mother central platform stream (smart care cloud server).

The central platform stream (also referred to as the "Big mother" stream, the omnipresent but subtle and responsible version of "Big Brother") *describes all the roles that form the central platform needed for the customer unique care and service provisioning. These roles are service independent and always available within the eCare system.*

Creation phase	Platform development	Developing the eCP with all its basic services
	Database development	Designing the database system that is dedicated to the eCP
	Platform Controllers Development	Developing all the needed controllers for the MCD (Meta Care Data), MCI (Meta Care Information) and MCK (Meta Care Knowledge) traffic between the actors.
Delivery phase	Secured data storage	Managing and operationalizing the databases that are needed to for the eCP
	Data connector	Providing the piece of software that translates the various data standards to others in order to allow easy data exchange in the form that fits the service the most.
	"Big mother" Central service / Semantic communication bus / data connector	Managing, guiding and operationalizing the eCP. All data, raw of reasoned passes is communicated via the semantic bus [2]
	Security	Providing the software to allow safe data access and data usage
	Authentication	Providing the software to allow safe authentication
	Access management	Operationalizing and managing the databases and service to provide user management
	MCD, MCI, MCK Traffic controllers	Managing and operationalizing the traffic controllers for the Meta Care Data, Information and Knowledge
Consumption phase	Data Aggregator Terminal	Providing the Terminal/box that captures all external hardware signals and translates the data in a chosen standard
	Interface	Providing the dedicated interface device (TV, Smartphone, Tablet, etc.) for interaction with the platform

Table 2-5: Description of all the roles in the network stream.

The network stream *aggregates all the roles needed for the provisioning of the interconnection between different users and devices connected directly or indirectly, wireless or wired with the eCP*		
Creation phase	Mobile service integration	The integration of mobile services in the creation phase of the central platform.
Delivery phase	Mobile network access provisioning	Providing access to the mobile Telco network
	Fixed network access provisioning	Providing access to the fixed Telco network
	Mobile communication platform provisioning/management	Managing the platform output according to the type of receiving device, user rights and network type
Consumption phase	Mobile network usage	Making use of the mobile network
	Fixed network usage	Making use of the wired network

Note. The involved actors in this go-to-market strategy are presented in Table 2-6.

Table 2-6: Description of the key actors involved in home care provisioning.

The care receiver	The actor who needs and consumes care services.
The informal caregiver	Is in most cases a person close to the care receiver and gets not paid for their care services. The informal caregiver has usually had no or little education in providing care. For example: family members, neighbours, friends, volunteers etc.
The formal caregiver	Is an actor who is paid for their care services and has had training and education in providing care. For example: nurses, doctors etc.
Care organizations	Are the organizations that organize formal care. They receive funding from health authorities to provide health services. Health care organizations include both non-profit and for-profit organizations.
The OCCS integrator	Is the developer that turns the eCP into a tangible product and brings it to the market. To create the final version of the product, the integrator will use its own expertise, but will also use input from external parties (for example: the integrator can buy the hardware from a supplier, will use the services from a software developer etc.)
OCCS Service provider	Is a care service provider or facilitator (e.g. Care organizations, Service flat owners, etc.)
The OCCS platform provider	Is responsible for the eCP back-end system, the maintenance and support for it. This forms the heart of the eCP.
Mobile services integrator	Is responsible for handling the mobile communication with the eCP, the maintenance and support for it.
Telco provider	Provides access to data communication network.
The government	Demands specific user identification before they provide access to some specific data platforms such as e-Health or Vitalink [15].

3

Techno- economic evaluation of an ontology-based nurse call system via discrete event simulations

Smart services are not necessarily synonym for disruptive innovations. Also more incremental innovations such as the ontology-based nurse call system, which is discussed in this chapter can lead to a smarter way working and have an impact on the current way of doing things. In Chapter 2, the perspective is on the value network, the actors, their roles and barriers for adoption. In contrast with this macro-level perspective, in Chapter 3 we focus on the impact of smart services on the operational processes of an individual actor. Via a discrete event simulation model the impact of an ontology-based nurse call system on the operational processes of several care departments, the care staff and patients is evaluated. Several key performance indicators are discussed to measure, compare and quantify the effects of the smart ontology-based nurse call system versus traditional systems. Several staffing scenarios are discussed.

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ABSTRACT Current nurse call systems hinder the efficiency of nurses as the systems are not aware of the type of requested help and the context in which their help is required. To tackle these issues, we have developed an ontology-based nurse call system that automatically takes the patients' and caregivers' profiles and context into account when assigning calls to nurses by modelling this information in an ontology, i.e., a formal domain model. For example, current tasks of the nurses and trust relationship with patients are considered while allocating calls to caregivers. Focus is not only on creating a higher quality patient care, but also on distributing the workload more evenly over all caregivers. However, not in all hospital departments such a smart nurse call system will have a significant impact, e.g., geriatric versus emergency care. To gain insights into the total impact of a smart nurse call system, a dedicated discrete event simulation (DES) model is presented that tests its performance. Based on realistic nurse call logs and information gathered at representative hospital departments through interviews and observations, the simulation model allows optimizing decisions, modelled as rules based on the information captured in the ontology, to allocate calls to the best suited nurse. Several scenarios with a varying number of calls, staff members, etc. are tested to be able to define the effectiveness and the (dis)advantages of the ontology-based system with respect to the current one. In conclusion, recommendations are made towards improving the currently employed nurse call systems in hospitals.

3.1 Introduction

Due to the persistent pressure on the financial resources of hospitals and the care sector in general, these parties seek to optimize budgets and cut costs where possible [1]. Consequently, they aim to increase the work efficiency of the nurses. However in reality this means doing more with the same staff, doing the same with a smaller staff or fragmenting the tasks for several care providing profiles. The latter means that new task and job profiles are identified and introduced next to the current tasks of nurses (e.g., logistic personnel that can take care for the hotel service requests and tasks that do not require medical competences, etc.). The workload on the staff and the required competences of nurses continue to rise. In order to preserve the time for, and quality of care, efficiency improvements need to be sought in their work methods and non-care related tasks in particular.

Current nurse call systems are not optimal for work efficiency since they do not provide context information on the particular nature of the call. This means that sometimes more than one nurse will go to a room and that there is no prioritization of the calls possible. Every call can be urgent and should be treated with the same effort. But in general there exist many different types of calls such as one for providing hotel services, e.g. getting a bottle of water, or pure care related tasks, e.g. giving medication. Also depending on person characteristics, a patient can call very often for non-urgent matters, while others may never call, even if it's very urgent.

The nurse call system, developed in the Accio Project [2], is an ontology-based nurse call system that reasons on available context information such as distance to the calling patient, type of call, personal and trust relationship with the patient, the current tasks of the nurses, etc. to alert the best suited staff member. The goal of this ontology-based nurse call system is to lower the workload by dividing it more evenly over all nurses, to lower the waiting times and prioritize urgent calls over less urgent ones [2]. The overall aim is not to interrupt the nursing staff while they perform difficult tasks.

3.2 Research objective

The goal of this research is to evaluate the impact and the effects for the nursing staff and the patients when implementing an ontology-based nurse call system that takes the context of the call and profiles of the staff and patients into account. The total impact of such a system depends heavily on the type of care department and setting. Consequently, it is expected that not all care departments will benefit equally from installing such a system.

To gain insights in the key-parameters that determine the impact of an ontology-based nurse call system a discrete event simulation model (DES) is built which allows comparing the potential impact of such a system with a traditional nurse call system that does not take into account context parameters.

3.3 Methodology

The DES model, developed to determine the impact of an ontology-based nurse call system and the adjustments to its rule set, is a result of a three step process: 1) Translating the ontology-based rule set to a format that can be handled by the DES model, 2) Setting up the simulation model based on the rule set and 3) analyzing the simulation results. Figure 3-1 shows a schematic overview of this methodology.

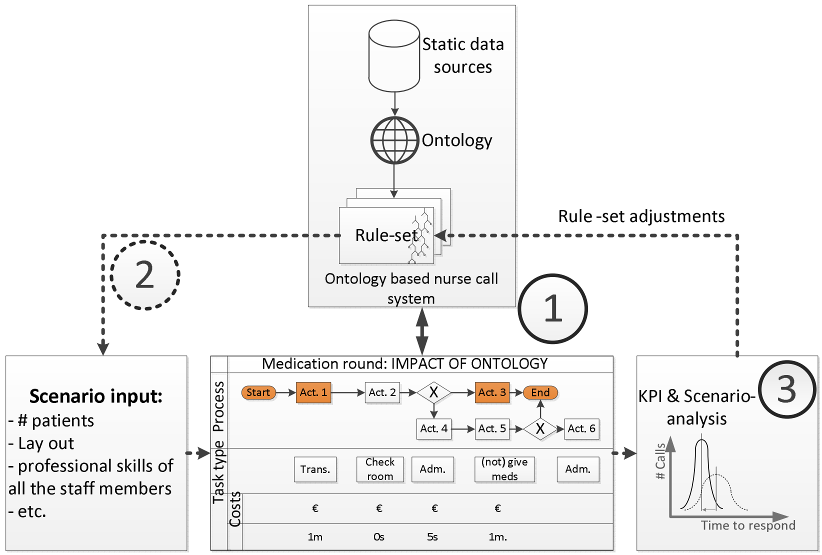

Figure 3-1: Schematic overview of the methodology

3.3.1 **Step 1: Translating the rule set**

A definition of an ontology is given by Gruber T. [5]: “An ontology is a specification of a conceptualization in the context of knowledge description”. This means that ontologies describe concepts, relations between those concepts and characteristics in a certain domain of interest. An example of a relationship in the ontology-based nurse call system is the degree of trust between patient and caregiver. For this research, the Ambient-Aware Continuous Care Ontology was used [13]. On top of the ontology a rule set is implemented that encodes the decisions that the system needs to make in a particular situation. Generic reasoning software, i.e., Pellet [14], is then used to process the ontology and accompanying rules in order to, e.g., determine the status of a caregiver or assign a call to a staff member. Excerpts of the decision process and accompanying rules can be found in [13].

Executives, such as the head nurse or the head of a department, should be able to make any adjustments to the rule set so that they are able to refine the nurse call assignment algorithm to their particular department. However, before introducing the new rules or definitions into the department, they need to evaluate whether these adjustments will have a positive impact. To ease the evaluation, rules should be interchanged automatically between the ontology and the simulation software.

Currently, the ontology in the nurse call system is implemented in the Web Ontology Language (OWL). [3] The rules, which use the information in the ontology, are implemented in Jena [11]. However, to make the translation process more generic and thus applicable to a wide range of (semantic) rule languages, it was opted to first translate the Jena Rules to the Rule Interchange Format (RIF) [12]. RIF is a recently developed format that is designed to exchange rules that are expressed in different rule languages. As such, most rule languages can easily be translated to RIF. This makes it an ideal starting point.

3.3.2 **Step 2: Developing the simulation model of the ontology based nurse call system**

For the simulations it is examined which software would be best for testing the nurse call system. Out of different discrete event simulation software packages such as TIBCO Business events [15], Arena [8], Flexism [7], etc. eventually FlexSim is chosen because of it graphical interface, well developed parameter dashboard and its ability to define the rule set in external files.

Input data is created in Microsoft Excel and consists of all calls and the different task rounds, with their respective labels, that will be launched during the simulation. Every aspect of the created data is based on anonymized real-life data from Televic [9], a Belgian nurse call system producer and integrator. The data was analysed for patterns in the arrival times of calls. As a result, each day was divided in several time periods in which calls have a predefined chance to occur. The distribution of the call types, e.g., calls for hotel or care services, urgent medical calls, etc., was based on a study by Meade, et al. [16].

3.3.3 **Step 3: Scenario analysis**

Eight different scenarios are investigated. First, a setting with the traditional nurse call system, 'Traditional', and one with the ontology-based nurse call system, 'Accio', are analysed. Second, three scenarios are used to test the effects of a certain decision on the effectiveness of the ontology. And at last, three new adjustments to the rule set are introduced to try to improve the performance of the nurse call system. The scenarios are described below in Table 3-1.

Table 3-1: Overview of the different scenarios

Scenario	***Description***
1. Traditional system: (3 nurses, 1 logistic assistant, 1 head nurse)	The traditional installed nurse call system calls all the nurses within the department that are linked to the room where the call is made and after a while reminds them again of the call after it is detected that nobody answered the first call. This is the reference scenario.

2. Accio system (2 nurses, 1carer, 1 logistic assistant, 1 head nurse)	The scenario in which the ontology- based nurse call system is installed. It takes into account the context parameters in which the call was made in order to inform the most suited caregiver and to be able to balance the workload better. In this scenario, the staffing differs from the staffing in the traditional scenario. One nurse was replaced by a caregiver without all the medical competences of a nurse.
3. Effect 1: Medical staff (3 nurses, 1 logistic assistant, 1 head nurse)	In this scenario, the impact is evaluated if the complete staff has medical competences. This means that every caregiver can respond to every type of a call. Since a traditional system does not know which type of call was meant, it cannot differentiate on competences like the Accio system can, e.g. medical tasks can be performed by medical personnel only and hotel task should be performed by logistic personnel but can also be done by medical personnel. For more information see [6].
4. Effect 2: Strict competences (Same staff as Accio scen.)	In this scenario, the impact is evaluated of the fact that not all caregivers have the required qualifications/competences to respond to certain calls, e.g. logistic personnel versus medical personnel.
5. Effect 3: Incorporation of trust relationship (Same staff as Accio scen.)	This scenario evaluates the impact of not respecting the trust relationship, in the sense of prioritizing staff members with a trust relation with the patient above other staff members, as there are doubts during the development to incorporate these trust relationships into the rule set and on the practical implementation of this constraint in reality.
6. Adjustment 1: Adding new respond statuses (Same staff as Accio scen.)	In this scenario, a first change to the existing Accio system is analyzed. If the Accio system detects that multiple nurses can respond to a call, the system will call all of them. Because the system will queue the call for the most appropriate nurse, the system should be aware of the fact if there are already calls waiting to be responded before adding new ones, otherwise waiting times would become unacceptable.
7. Adjustment 2: Workload balancing (Same staff as Accio)	In this scenario, a second adjustment to the existing rule set of the Accio system is analyzed. The system will direct the call to an appropriate person with the least amount previous answered calls. Doing so, the system tries to distribute the workload resulting from patient calls evenly over the complete care staff.

8. Adjustment 3: Prioritizing status above trust relationship (Same staff as Accio)	In a last scenario, two existing decision rules are interchanged in order to change their priority. The constraining rule on trust relationship is swapped places with the rule that respects the current task of the staff members. As such, the current task of the caregivers is taken more into account than the trust relationship with the patient when assigning calls. This adjustment is implemented because simulation results showed that the decision tree is too selective on the trust relationship and could not differentiate on the current task anymore.

Nine different Key Performance Indicators (KPIs) are considered during the analysis:

1. *Distance per shift:* As the Accio nurse call system considers the location of the caregivers and the patients, it could be expected that the caregivers have to walk less to perform the same work.

2. *Balancing the workload:* in the simulations it will be inspected whether the system succeeds in balancing the workload in a better way.

3. *Average waiting time*: Average time until a call is answered by a nurse or other caregiver.

4. *Maximum waiting time*: Maximum time until a call is answered by a nurse or other caregiver.

5. *Required competences*: Does the selected caregivers have the required competences to fulfil the intervention?

6. *Trust relationship with the patient*: Did the ontology respect the trust relationship between the patient and the caregiver?

7. *Number of simultaneous selected caregivers per call*

8. *Number of disturbing calls*: Can the ontology prevent disturbing the nurse while performing a hard task?

9. *Number of redirections per call*: being the amount of times a call cannot be responded by the addressed caregiver and therefore is redirected to another colleague.

3.4 Results

All eight scenarios are tested in two different departments. Department 1 represents a small department with a small number of caregivers and calls per week (normal staff: 3 nurses, 1 head nurse, and 1 logistic assistant; 18 patients; nbr. of calls: 40-280 calls per week). Department 2 is bigger in size and has a higher average number of calls (normal staff: 5 nurses, 1 head nurse, and 1 logistic assistant; 26 patients; nbr. of calls: 600-800 calls per week). More information on the particular departments can be found in [9]. First, a comparative analysis on the 'Accio' versus the 'Traditional' scenario is performed for both departments. Increasing the number of calls per week has a deteriorating effect on all KPIs. For example the average- and maximum waiting times rise for both departments as illustrated for the average waiting time in department 1 in Figure 3-2.

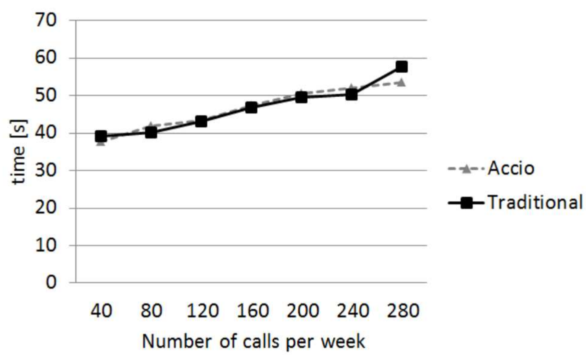

Figure 3-2: Average waiting time in function of the number of calls per week ('Accio' on department 1)

As can be seen, there is no impact of an ontology-based nurse call system on the average waiting time compared to the traditional system in this particular department. The variance on the average waiting time on the other hand is reduced compared to the traditional system. On top of that, in the Accio scenario, one nurse is replaced by a caregiver without the medical competences of a nurse. This could reduce the staffing costs of departments.

Next, the fraction of answered calls as a function of the waiting time is analyzed. On Figure 3-3 a significant difference can be seen between the Traditional and Accio scenario. For the Traditional scenario, two peaks arise. One at about 20 seconds – immediate answer – and one at 140 seconds –after ignoring a first call, e.g., because the nurse was busy with another patient, the system will send a reminder call to the nurses. This will prompt the nurses to answer the call then.

For the Accio scenario, these two peaks were scattered over a range of 20 and 120 seconds. These findings are a result of the possibility of redirecting a call to a colleague. Redirecting gives a caregiver the possibility to immediately forward a colleague when he/she is currently too busy to handle it. These findings indicate that if the nurse knows the context of a call, that person can better organize his responding actions to it instead of answering immediately.

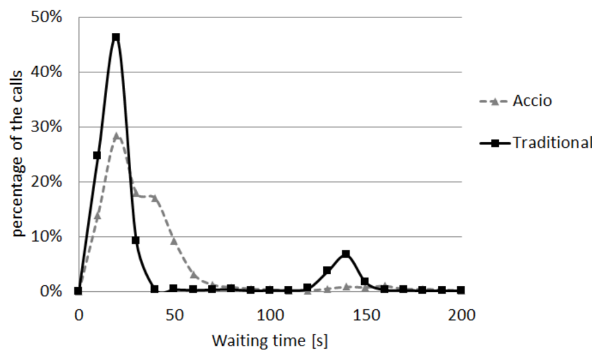

Figure 3-3: Percentage of calls in function of the waiting time (Accio vs Traditional on department 1)

Scenario 3: ‘Effect 1’ is analysed mainly to evaluate the difference in work load distribution between the Traditional and the Accio nurse call system (Effect1 and the Traditional scenario have the same staff members.). Fixed nursing rounds, e.g., check-up tours, are, together with answering patient calls, important factors that influence the work load of a nurse. Comparing ‘Effect 1’ to ‘Accio’, does not show many differences. This gives executives the opportunity to hire lower educated and thus less expensive employees without lowering the quality of care.

Another important KPI is the percentage of calls that disturbs a caregiver. Disturbing a nurse while performing a difficult task, e.g., medication preparation, significantly increases the risk on errors [10]. Both departments show different results for this KPI because of the different number of employees. In department 2, ‘Accio’ has a lower percentage of disturbing calls than ‘Traditional’. This percentage is higher in department 1 since the smaller number of employees prevented the system from selecting a nurse that is not occupied. This is mainly caused by the fact that the system acts too conservative on the trust relationship between caregivers and patients. This phenomenon is affirmed in ‘Effect 3’ (see Figure 3-4), where the system does not incorporate the trust relationship and therefore has a larger pool of employees to allocate calls to.

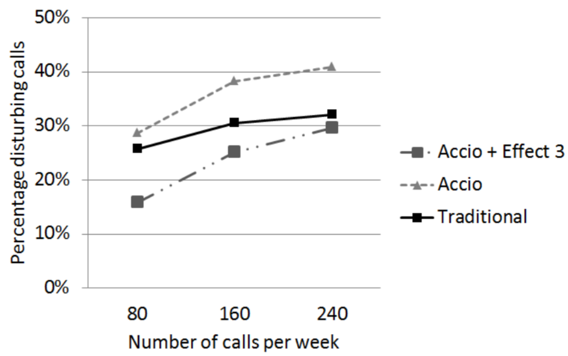

Figure 3-4: Percentage of disturbing calls ('Accio' vs 'Traditional' vs 'Effect 3' on department 1)

‘Effect 3’ has, next to the lower percentage of disturbing calls, also a drawback. As the system differentiates less on the trust relationship, more caregivers are selected per call resulting in a larger average covered distance per shift. This is illustrated in Figure 3-5 for the average distance for all caregivers during the evening shift on department 2. Thus relaxing this constraint means that more nurses start walking to the room of the patient. This effect can be remediated when the nurses get more and more acquainted with the system and know that they should acknowledge before starting walking to the patient. In this way all the other nurses see that the call is already assigned to a person, so no action is required from them.

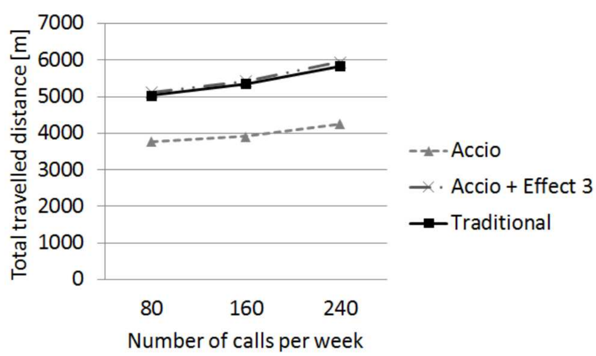

Figure 3-5: Total average covered distance of all caregivers in the evening shift ('Accio' vs 'Effect 3' on Department 2)

Scenario 6: ‘Adjustment 1’ is a first modification to the rule set to prevent a caregiver from having a large queue of calls waiting. Occasionally, it happens that a caregiver is on his way to a patient to answer his call and at that moment receives a new call from another patient because he is currently not busy with a task. With ‘Adjustment 1’ this situation can no longer occur. It is expected that maximum waiting times would drop. The model indeed indicates shorter waiting times as illustrated in Figure 3-6.

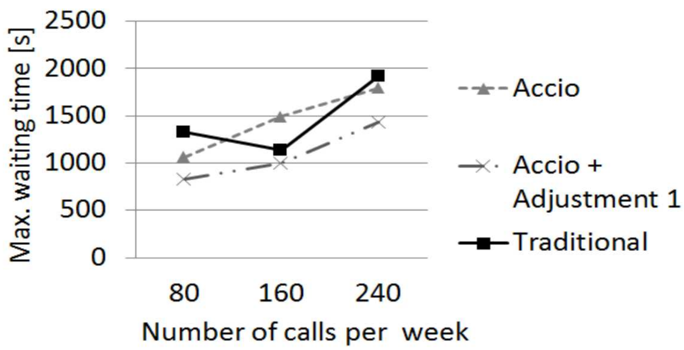

Figure 3-6: Maximum waiting time in function of the number of calls per week ('Accio' vs 'Adjustment 1' on department 1)

The modification to the existing rule set that gives the best results for both departments is ‘Adjustment 3’. This is the one in which the order of the decisive blocks in the rule set is changed. Now, the ontology first checks the status of the nurses before checking their trust relationship with the patient. The scenario strongly decreases the percentage disturbing calls, because the system will first direct the call to nurses who are not busy with hard tasks. This is illustrated in Figure 3-7.

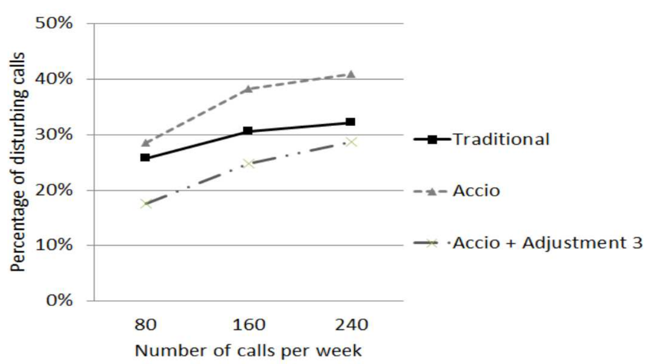

Figure 3-7: Percentage disturbing calls ('Accio' vs 'Adjustment 3' on department 1)

This has several positive effects such as lower average and maximum waiting times and a lower number of redirected calls. However, as the system cannot take into account the trust relationship as well for the Accio scenario does, this new rule set leads to a higher percentage of confidence breaks, i.e., the call is handled by a caregiver with whom the patient does not have a very good trust relationship. The difference in percentages is illustrated in Figure 3-8. It is up to the executives to choose what is most important for them, the trust relationships, or the disturbing calls.

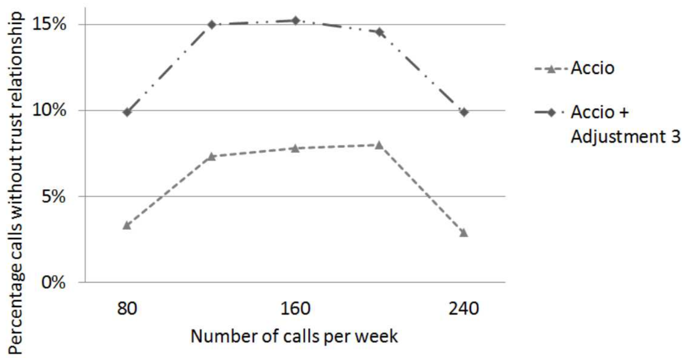

Figure 3-8: Percentage of calls for which there was no trust relationship between caregiver and patient ('Accio' vs 'Adjustment 3' on Department 1)

3.5 Conclusions

In this paper a methodology and results are presented of a discrete event simulation model of an ontology based nurse call system.

The results mainly shows that trade-offs will have to be made when executives choose the best rule set for their department. When one of the decisive rules becomes too discriminating, the system will not be able to properly use one of the next. One example has been given with the 'Trust Relationship' and the 'Current task' blocks. A lower percentage of breaks in the trust relationship will result in a higher percentage of disturbing calls and vice versa. Secondly, the results make clear that an ontology-based nurse call system can be beneficial for the work load, processes and atmosphere.

Lastly, it is recommended that, when the Accio nurse call system is introduced, it should be easy for executives to make adjustments to the rule set of the system (via a dashboard of KPI's). In this manner, they could impose their own accents on the system so that their department operates exactly the way they want it to. The developed discrete event simulation model and automatic translation tool could help in achieving this goal.

Acknowledgment

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4

Choosing IoT-connectivity? A guiding methodology based on functional characteristics and economic considerations

IoT is an important enabler for many smart services. But at the same time they require new investments and therefore can have a significant impact on the cost structures of an actor. In this chapter we look at several IoT-connectivity networks and present a methodology to guide IoT-developers and service providers in making the most economical and technically suited choice. The elimination methodology matches the functional characteristics of the IoT-connectivity networks with the functional requirements of the smart service. The remaining network alternatives are then compared via a techno-economic analysis. Finally, the methodology is applied to a case of deploying an IoT-connectivity network in a port. Although this is a case within the domains of Industry 4.0 and Smart Transportation, the methodology is generic and can be applied to a wider set of application domains (e.g. smart Cities and smart Health).

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ABSTRACT Along with the growing market of Internet of Things (IoT) also the set of IoT-connectivity networks is continuously expanding. Large scale deployments of the new Low Power Wide Area Networks (LPWAN) and announcements of new technologies are prove of this trend. Although these new technologies take care of some key IoT-challenges such as communication cost and power consumption, careful consideration of the IoT-connectivity is still required since there is no one-size-fits-all solution. Typical comparisons of IoT-connectivity networks are based on technical characteristics, but remain unpractical when it comes down to comparing functional characteristics. Questions on public network accessibility, ability for private network deployments and cost considerations related to IoT-connectivity networks often remain unanswered. In this work a two-step methodology is proposed to guide IoT-developers in choosing an appropriate connectivity network. Firstly, a questionnaire walkthrough eliminates IoT-connectivity networks based on mismatches between their functional characteristics and the functional requirements of the IoT-applications. In a second step an evaluation of the main cost components related to IoT-connectivity indicates the most economical solution. As an illustration, we present a case study on deploying smart shipping containers in the port of Antwerp.

4.1 Introduction

The Internet of Things (IoT), a fast emerging technological wave, already finding its way in the market under the form of various applications such as pet trackers, parking sensors and smart water meters, is about to flood our imagination. Various researchers report on market sizes of billions of devices within the next 5 years [1].

Addressing two important challenges being 1) power consumption and 2) range of the connectivity network, the deployment of Low Power Wide Area Networks (LPWANs) has been an accelerator for the development of IoT-applications. In recent years, numerous radio-based connectivity networks and protocols have been developed, all contributing to the reality of IoT.

Today, IoT-developers have a complete set of connectivity networks at their disposal, ranging from short range networks such as Bluetooth to global connectivity via satellite networks, all spread over the radio spectrum. Physical characteristics, such as frequency, regulations & technology used, result in an extensive set of connectivity networks, each with their own specific particularities.

These particularities translate in pros and cons when considering a specific connectivity network for an IoT-application. Since there is currently no 'one-size-fits-all' or best solution, choosing a well suited connectivity network that fits the needs of an IoT use case should be a careful trade-off between the ability of a technology to meet specific functional requirements and the connectivity related costs occurring during the lifetime of the application.
Research is available that compares a set of typical connectivity networks [2] [3]. Although these comparison charts sum up the core technical characteristics of these technologies, there remains a gap to their functional, strategical and economic related characteristics. Typical unaddressed and hard to answer questions in technological comparisons are:

- Is there a public network available?
- Can a private network be deployed?
- What about manufacturer dependence?
- What would be the difference in costs when choosing for a network A vs. network B over the lifetime of the application?

Therefore the goal of this research is to guide IoT-developers in choosing the right connectivity network based on functional requirements of the IoT-application and their economic aspect rather than pure technical characteristics of connectivity networks.

We start this work traditionally by comparing technical characteristics of a range of available connectivity networks. Next, an elimination questionnaire is presented which reduces the choice set in case of a mismatch between functional requirements of the IoT-application or service and the characteristics of a particular connectivity network. The remaining available options are subjected to a life cycle-cost modelling methodology. This second step allows comparing the costs associated with the various suitable connectivity networks. This two –step methodology is demonstrated via a specific IoT use case study.

4.1.1 **Radio based connectivity networks for IoT**

Different types of wireless or radio based networks are suitable for IoT. In this work focus is on following wireless network implementations:

1. Satellite (L-Band)
2. Cellular (GSM – LTE-A)
3. LoraWAN
4. Sigfox
5. Weightless-P
6. Wi-Fi a/n/ac – b/g/n
7. Z-Wave
8. 802.15 4 (Zigbee)
9. Bluetooth
10. Bluetooth Low Energy (BLE)

We refer to [2] [3] [4] and [5] for a technical overview of these network technologies suitable for IoT-connectivity. The provided list is certainly incomplete, but is a good mix of the available choice set. Although satellite is an often overlooked type of connectivity network when it comes down to IoT, it is included since certain applications (cfr. ultra-remote or global tracking) have no viable alternative yet. Figure 4-1 maps these technologies on typical comparison characteristics, being spatial range and data rate. Various different technologies are overlapping but have complete different functional characteristics, all serving very dissimilar sets of applications.

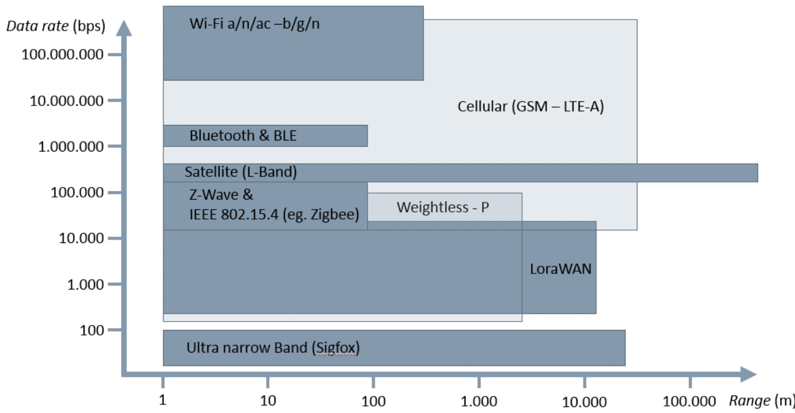

Figure 4-1: Wireless connectivity networks overview: Data rate vs. spatial range

Within this work, focus is only on a single radio link, meaning that only the link from end node to the nearest hub or internet access point is discussed. When making use of bridging technologies which accumulates and transmits data packets from one particular type of connectivity network to another (cfr. Zigbee end nodes communicating via Zigbee hubs, connected via Wi-Fi to the Internet) the proposed methodologies need to be applied to each different type of radio link.

4.1.1.a Technical characteristics relevant for IoT-developers

Various parameters describe the technical characteristics of connectivity networks or hardware related specifications [4]. Often used characteristics are for example: bandwidth, max nodes per gateway, modulation techniques, authentication and encryption technologies, collision detection techniques, and number of channels and orthogonal signals.

Because of their direct impact on IoT-application performance or business model, following relevant technical characteristics for IoT-developers are described:

- *Data rate*: The speed to transport data between transceivers.
- *Frequency band*: The interval or band within the radio frequency spectrum, used to carry the radio signals.
- Rule Interchange Format *band*: Specific frequency bands, reserved for Industrial, Scientific and Medical purposes. These parts of the radio

spectrum are unlicensed. Which means that anyone can use these bands for free when respecting a set of radio regulations to prevent interference and bandwidth monopoly. In contrast with ISM, there are also licensed frequency bands for which network operators have paid to manage. Using licensed bands often requires financial resources.

- *Mode of operation*: indicates whether the network is able to transmit data in both directions simultaneously (Full Duplex) or has to wait with transmitting until the message is received (Half Duplex)
- *Max. payload size*: maximum amount of bytes sent in one message
- *Power profile*: Often an indication of typical lifetimes of IoT-applications using a certain connectivity network. Hard numbers on energy consumption have a very limited value since this parameter is affected by various technical and design decisions such as data rate, sleeping modes, transmit power, etc.
- *Max. Range*: The max. spatial range a radio link can bridge. A very disputable parameter since various technical and environmental parameters affect the range.
- *Standard*: Whether the connectivity network is based upon wide available standards or not (cfr. LoraWAN, etc.)

Table 4-1 gives an overview of the technical characteristics of the selected connectivity networks. Although similar comparison tables [4] [6] are often an important decision aid, their value is limited in the sense that they don’t provide insights on functional characteristics of the connectivity networks. In the next section we translate technical parameters to functional characteristics of each connectivity network.

4.2 Two-step methodology leading to careful trade-off between the ability of a technology to meet specific functional requirements and the connectivity related costs

Comparing pure technical characteristics has limited value when it comes down to describing and comparing functional characteristics of IoT-connectivity networks and matching it with functional requirements of the IoT-application. In this section we propose a two-step methodology to guide the IoT-developer when considering multiple connectivity networks in a comprehensive and accessible manner. Firstly, the technological choice will be reduced if IoT-connectivity networks fail to address the IoT-application requirements. In a second step, we provide a methodology that allows modelling the relevant capital and operational expenditures (CapEx & OpEx) associated with the different network types.

Table 4-1: Comparing a set of technical characteristics of IoT-connectivity networks

	Satellite (L - Band)	*Cellular (GSM (lowest) to LTE-A (highest)*	*spread spectrum (LoraWAN)*	*UNB (Sigfox)*	*Weightless - P*	*Wi-Fi a/n/ac – b/g/n*	*z-Wave*	*802.15.4 (Zigbee)*	*Bluetooth*	*Bluetooth Low Energy (BLE)*
Data rate	200kbps	14.4 kbps (GSM); 1 Gbps (LTE)	300 bps - 50kbps	100 bps	200 bps - 100 kbps	54 Mbps - 1300 Mbps	40 -200 kbps	20/40/250 kbps	1-3 Mbps	1 Mbps
Frequency band	1-2 GHz	900/1800/1900/ 2100 MHz	868/915 MHz	868/915 MHz	169/433/470/780/868/915/923 MHz	2.4 / 5 GHz	868/915/ 2400 MHz	868/915/ 2400 MHz	2400 MHz	2400 MHz
ISM band	No	No	yes	yes	yes	yes	yes	yes	yes	yes
Mode of operation	Full Duplex	Full Duplex	Half Duplex	Half Duplex	Half Duplex	Half Duplex	Half Duplex	Full Duplex	Full Duplex	Full Duplex
max. Payload size			256Bytes	12B	min. 10B		64B	127B	358B	47B
Power profile	High (weeks)	Medium (months)	Low (+years)	Low (+years)	Low (+years)	High (weeks)	Low (+years)	Low (+years)	Medium (+months)	Low (+years)
Max. Range	global	35 km	5-15 km	10-25 km	2 km urban 5 km outdoor	150 m	100m	100m	30m	100m
Standard	Proprietary (e.g. Iridium)	GSM; GPRS; EDGE; HSPA; SPA+; LTE;LTE-A	LoraWAN	Sigfox (proprietary)	Weightless SIG	IEEE802.11 a/b/g/n/ac	z-Wave (proprietary)	Zigbee (based on IEEE 802.15.4)	IEEE 802.15.1	IEEE 802.15.1

4.2.1 Step 1: Reducing the technological choice set in case of a mismatch between functional requirements of the IoT-application and functional characteristics of IoT-connectivity networks, using an elimination questionnaire

By means of an elimination questionnaire, the technological choice set will be narrowed down based on mismatches between the functional requirements of the IoT-application and the functional characteristics of the different IoT-connectivity networks. Four categories of questions have been identified:

- *Application requirements*: requirements concerning application environment and setting such as required signal penetration, application mobility requirement, and its geographical span
- *Data or payload requirements*: requirements on data traffic streams, payload size and frequency of the messages.
- *Device or end node related questions*: specifications on power profiles and ability to address over-the-air updates
- *Requirements concerning the business model*: clarifications on vendor dependencies, public accessibility and ability for private network deployments

Next to decisive or eliminating questions also suggestive answers can be a result, which do not eliminate but suggest a certain network or idea (e.g. consider satellite based connection in extreme remote areas when no internet access point is available). The guiding process is a result of both technical and business related limitations concerning a network. Table 4-2 presents the questions directed towards IoT-developers or providers. The former develops the IoT-application and hardware. The latter offers or markets the IoT-application, not necessarily being the same party as the IoT-developer. Prioritizing the importance of the functional requirements is up to the IoT-providers since that depends heavily on the application. The formulation of the functional network characteristics is a result from recurring questions IoT-developers or providers are faced with. They are founded on technological and business related properties of the considered networks, acquired via data sheets and research literature [7] [8] [9] [10] [11].

The outcome of the elimination questionnaire is a set a feasible IoT-connectivity networks, which meet the functional requirements of the IoT-application.

4.2.2 Step 2: Life Cycle Cost comparison

In order to guide an IoT-developer to a well suited connectivity network technology for a particular IoT- application, not only functional characteristics of the networks should match the requirements of the service. Choosing a connectivity network is a trade-off between functionality and costs. Therefore in this second step a methodology is presented that compares life cycle costs of the network technologies, resulting from the previous step.

Table 4-2: Elimination questionnaire

Category	Questions		Answer	Action	Reason
App	1	Do you want connectivity with end nodes in extreme remote areas or overseas?	Yes	If there is no internet access point available, consider a satellite based uplink	Deployment of other types of IoT-connectivity networks may be impossible or very costly
			No	-	
	2	What geographic span is required	International	exclude Wi-Fi a/n/ac – b/g/n; z-Wave; 802.15 4 protocol; Bluetooth; BLE	Limited Range or uncertain access to public networks
			National	exclude Wi-Fi a/n/ac – b/g/n; z-Wave; 802.15 4 protocol; Bluetooth; BLE	Limited Range or uncertain access to public networks
			Local	-	
	3	What is the magnitude of the required range between Base station and end node?	+ 10 m	-	
			+ 100 m	exclude Bluetooth; BLE	Limited Range
			+ km	exclude Wi-Fi a/n/ac – b/g/n; z-Wave; 802.15 4 protocol; Bluetooth; BLE	Limited Range
			global	consider a satellite based connectivity network	Only satellite networks eliminate the need for on ground installed base stations
	4	What level of connectivity penetration is required?	outdoor	-	
			Indoor (moderate signal-strength-reduction)	exclude Satellite	Insufficient radio link budget
			deep indoor (strong signal-strength-reduction)	exclude Satellite; Cellular; Wi-Fi a/n/ac – b/g/n; z-Wave, 802.15 4 protocol; Bluetooth; BLE	Insufficient radio link budget
	5	End node mobility is a requirement?	Yes - high speed	exclude Lora, Sigfox	Currently too much packet loss
			Yes - Low speed (<20 km/h)	exclude Wi-Fi a/n/ac – b/g/n; z-Wave, 802.15 4 protocol; Bluetooth; BLE	Handoff performance insufficient

			No	-	
	6	Localisation of end nodes is needed?	Yes	Exclude Sigfox	Currently not able to localize an end node. But localisation via triangulation is on the roadmap of Sigfox.
			No	-	
Data	7	What kind of data traffic is required	Video streaming	Exclude Satellite L-band; LoraWAN; Sigfox; Weightless-P, z-Wave; 802.15 4(Zigbee); BLE	Insufficient data rate
			Audio streaming	Exclude Satellite L-band; LoraWAN; Sigfox; Weightless-P, z-Wave; 802.15 4(Zigbee)	Insufficient data rate
			no streaming	-	
	8	Messages from BS to end node required? (= downlink traffic)	Yes	Exclude Sigfox	Very limited downlink capability
			Yes - but very rare	-	
			No	-	
	9	What is the size of the message (= payload)?	> 12 bytes	Exclude Sigfox	Max. payload per message: 12 bytes
			< 12 bytes	-	
	10	Number of messages sent per day?	> 140	Exclude Sigfox	Regulated duty cycle (airtime) does not allow more messages per day
			< 140	-	
Device	11	What is the required order of magnitude for the battery lifetime of the end nodes? (assuming identical batteries and amount of messages sent)	#weeks	-	
			#months	Exclude Satellite; Wi-Fi a/n/ac – b/g/n	Power profiles of the technologies are too high

			#years	Exclude Satellite; Cellular; Wi-Fi a/n/ac – b/g/n; Bluetooth	Power profiles of the technologies are too high
	12	Over-the-Air firmware updates of the end nodes?	Yes	Exclude Sigfox	Downlink capability not sufficient for firmware updates
			No	-	
BM	13	Private network deployment or subscribing to a public network?	Public	Exclude z-Wave; Zigbee; Bluetooth; BLE	No public deployments available
			Private	Exclude Satellite; Cellular; Sigfox	Licensed spectrum or business strategies do not allow private deployments
			Both Public and Private	Exclude Satellite; Cellular; Sigfox, z-Wave; Zigbee; Bluetooth; BLE	No public deployments available or business strategies do not allow private deployments
			Neither of the 3	-	
Remarks	14	Be aware of some vendor or network operator dependencies	Lora	Currently there is a vendor lock-in, only Semtech can produce the Lora chips.	
			Sigfox	Currently only one network provider per country.	
	15	International access to public IoT-networks can lead to additional roaming fees.	Cellular	Additional roaming fees or international subscriptions required.	
			LoraWAN	Depending on the LoraWAN -network provider, international connectivity can require additional roaming fees.	

The model is a straightforward presentation of possible cost parameters likely to occur, depending on the setting. The magnitude of the costs is determined by cost drivers, variables scaling according to the specificities of the connectivity network. Capital expenditures are non-recurring investments in technologies (e.g. installation of base stations, which are the transceivers wirelessly connected with the end nodes and trafficking the data further to the internet). In controversy, operational expenditures are the recurring expenses that results from operations.

At last, economic effects such as price-erosion due to competition and maturing technology and market, and economies of scale can be taken into account if justified by the case. For example it can be expected that the costs for the relatively new LPWAN- based communication chips (e.g. Sigfox and LoraWAN) will decrease as the number of end nodes will increase over time and competitors will enter the market. Since cellular based chipset have been around for a while now, it is not realistic to say their price will decrease at the same rate of LPWAN –based chipsets. Also as the market and the competition in the IoT-connectivity landscape will grow, it is likely that today's subscription fee will no longer be competitive or realistic. As described in [12], learning curves are often used to model the effects of price erosion as the market matures.

In the presented methodology, figures of the listed cost parameters have not been provided since they depend on the use case, vary from country to country and are not always publically known.

Table 4-3 gives an overview of different CapEx and OpEx components and their related cost drivers. Having insights in each of these relevant cost categories and cost units associated with connectivity networks and their effect over the lifetime of the IoT-application, is key to make a profound decision on which technology to use.

CapEx components

- *Communication chip costs:*
  Depending on the technology, the newness of it, vendor lock-in or monopolies, etc., significant differences exist in the chip cost. This cost is a product of the unit cost of a chip and the amount of nodes needed.

- *Network installation: Base station cost:*
  The costs for base stations depends heavily on the network technology, IoT-application environment (e.g. outdoor vs. indoor) and the amount of base stations (BS) required. Main characteristics affecting the amount of BS are the covered range and the amount of connected devices. The latter one can be a constraint when deploying a private network in areas which are heavily populated with end nodes such as city environments or industrial sites. Starting from the total area to be covered and the range of a BS, one can map the theoretical covered area per BS. Which will

indicate the order of magnitude of the number of BS required. This is a simplification and could be an underestimation of the required amount because of path loss and interfering sources.

- *Network installation; Base station setup cost:*
  This cost parameter should not only consider the physical installation of each BS, which heavily depends on the IoT-application, but also on the development of required firmware for the BS (e.g. synchronization of base stations)

OpEx components

- *Network subscription fee:*
  Access to public networks is often granted under the form of a network subscription. Pricing schemes can be based on the amount of data sent per end node or a fixed monthly fee per end node connected. Subscribing to a public network is an important consideration since it leads to recurring expenses and scales with the number of end nodes connected.

- *Battery replacement; Handling cost:*
  Battery-only powered IoT-applications will eventually die if batteries aren’t charged or replaced periodically. Important parameters affecting the replacement frequency are: the power consumption of the end node and the energy capacity of the batteries. In addition the number of end nodes to take care for, and the handlings needed to change the batteries (e.g. parking sensors vs. sensors installed on power pylons) are important parameters in order to model the complete costs of the process and transport time.

- *Network operation; Network operation and maintenance:*
  Networks require periodic maintenance, both physical replacements and software updates. Often operational and maintenance costs are modelled as a percentage of the installation costs of the network [13]. The more base stations installed, the more maintenance required, hence the number of installed base stations as driver for this cost component. When subscribing to a public network, this cost is incorporated in the subscription fee.

- *Network operation; Base station site rental:*
  Lastly, often together with the installation of a base station also site rental comes into play.

Table 4-3: Overview of most important cost components and their drivers

Category	*Cost unit*	*Cost driver*
CapEx		
Communication chip		▪ Amount of end nodes
Network installation	Base station cost	▪ Amount of base stations (secondary cost drivers: range of the base station and area to cover)
	Base station setup cost	▪ Amount of base stations
OpEx		
Subscription fee		▪ amount of end nodes ▪ amount of data sent ▪ pricing model of network operator ▪ Lifetime of IoT-application
Battery replacement	Handling cost	▪ Amount of end nodes ▪ Energy consumption of the end node ▪ Installation difficulties ▪ Energy capacity of the batteries
	Battery costs	▪ Amount of end nodes
Network operation	Maintenance costs of base stations Base station location rental	▪ amount of base stations

Not all categories are relevant for all connectivity networks. For example, most local networks such as Wi-Fi or z-Wave, etc. do not require subscription costs, except as they are offered as a public service. Also network installation and network operation costs do not have to be addressed by IoT-providers when subscribed to a public available network such as Sigfox for example.

It should be stressed that the required lifetime of the IoT-application is a key driver for all above mentioned cost components. For instance: it might be not worth to install a private network at first glance, but eventually it could come the favorable option because of the recurring subscription fees resulting from the public network access.

Combining the elimination approach from step 1 with the cost considerations listed in step 2 will guide the IoT-developer not only to a connectivity network that meets the IoT-application requirements, but also to the most economical alternative.

In order to determine and quantify the total life cycle costs associated with IoT-connectivity networks, one must have access to relevant data on unit costs and cost drivers such as: amount of BSs, base station costs, subscription costs, installation costs, etc. Since these parameters are not always available or are uncertain, a sensitivity analysis could be performed [12]. This type of analysis determines how the outcome, in this case life cycle cost, is affected by the uncertain parameters. For instance, an applied example question could be: 'What is the total life cycle cost if 15 base stations are required instead of 10?'

4.3 Use case

In this section the suggested two-step methodology is applied to a case of the port of Antwerp which wants to improve the in-port operations by using smart containers. Not only the location (area-based) of the containers should be available, also door openings need to be monitored, humidity, indoor temperature (via air vents) and acceleration. In total, about 100 000 containers need to be temporary provided with IoT-end nodes whilst they are within the site. The total area of the site covers 120 km^2. A real time data connection is not required, but threshold alerts will trigger a send event. Although devices aren't installed permanently in the containers, so port-personnel could change or charge the batteries so now and then, the desired lifetime is at least 8 five years in order to reduce handling costs.

4.3.1 Step 1: Elimination questionnaire

Starting from the functional requirements of the IoT-application we learn that a LoraWAN- based connectivity network is suggested by the elimination questionnaire (see Table 4-4).

Table 4-4: Elimination questionnaire applied to use case

Category	Questions		Answer	Action
App	1	Do you want connectivity with end nodes in extreme remote areas or overseas?	No	-
	2	What geographic span is required	Local	-
	3	What is the magnitude of the required range between Base station and end node?	+ km	exclude Wi-Fi a/n/ac – b/g/n; z-Wave; 802.15 4 protocol; Bluetooth; BLE
	4	What level of connectivity penetration is required?	deep indoor (strong signal-strength-reduction)	exclude Satellite; Cellular; Wi-Fi a/n/ac – b/g/n; z-Wave, 802.15 4 protocol; Bluetooth; BLE
	5	End node mobility is a requirement?	Yes - Low speed (<20 km/h)	-
	6	Localization of end nodes is needed?	Yes	Exclude Sigfox

Data	7	What kind of data traffic is required	no streaming	-
	8	Messages from BS to end node required (= downlink traffic)?	Yes - but very rare	-
	9	What is the size of the message (= payload)?	< 12 bytes	-
	10	Number of messages sent per day?	< 140	-
Device	11	What is the required order of magnitude for the battery lifetime of the end nodes? (assuming identical batteries and amount of messages sent)	#years	Exclude Satellite; Cellular; Wi-Fi a/n/ac – b/g/n; Bluetooth
	12	Over-the-Air firmware updates of the end nodes?	No	-
BM	13	Private network deployment or subscribing to a public network?	Neither of the 3	-
Remarks	14	Be aware of some vendor or network operator dependencies	No problem	
	15	International access to public IoT-networks can lead to additional roaming fees.	No problem	

If it wasn't for the localization requirement and the required battery lifetime, Sigfox and Cellular would still be possible options. One could argue on that because the accuracy of the localization capability of the LoraWAN based networks is not clear yet and heavily depends on some unknown variables such as impact of metal containers on signal quality, amount of base stations or gateways installed etc. The alternative is to install an additional GPS receiver in each end node. But because of the power hungriness of this module, the needed connection time when awaking from sleep mode, the additional costs and the many signal blocking elements, this is a suboptimal solution.

In this case, challenge is to determine what the most economical solution is in the long run: 1) deploying a private LoraWan-based network or 2) subscribing to Lora, a public LoraWan-based network offered Proximus, a Belgian network provider [14]. Therefore these two variants are being analyzed in the next step.

4.3.2 Step 2: Life Cycle Cost comparison

In order to compare the life cycle cost of a privately installed and maintained network versus the costs resulting from a network access subscription within the same technology, we do not need to consider the difference in communication chip cost and the costs for battery replacement because they will be same in the two alternatives. This brings down the comparison to following three cost components: A) Network installation, B) Subscription costs, and C) Network operations.

Network installation

The CapEx has two components; the costs for the base stations and their installation and setup requirement. Mapping out the covered area per BS in a non-urbanized area indicates that three BS could theoretically suffice. But because of gateway limitations, being max. 8000 connected end nodes in this case, at least 13 gateways or base stations need to be installed. Current prices for industrial grade base stations and equipment vary between 600 and 1500 EUR.

Based on input from IoT-application developers, installing a BS will require 2 hours (50 EUR per hour) on average. Additionally and extra hour (50 EUR per hour) is foreseen for the network & activation setup component to join the gateways in one managed network. This leads to an investment of 19.5 kEUR, an installation cost of 1.3 kEUR and a network setup and management cost of 0.65 kEUR.

Subscription costs

In a privately owned network, no subscription fees are required. But to have access to a public IoT-connectivity network, typically a monthly subscription fee per end node must be paid. Typical prices for LPWAN network range from 0.3 - 1.5 euro per month per end node, depending on the number of messages sent per day, the number of end nodes and features such as downlink and OTA-update necessity. This adds up to total monthly fee between 30-150 kEUR. Because it can be expected that price erosion will occur due to growing competition and a maturing market, a price erosion has been modelled.

Network operations

Deploying a private network comes with the responsibility of network maintenance, both hardware and software related upgrades. To model this a yearly recurring cost of 10% of the total CapEx is taken into account. This results in a yearly fee of 0.975 – 2.145 kEUR, depending on the chosen BS.

Total cost overview

All costs are modelled over a ten year period. Communication chip costs are not taken into account in the cost comparison since both alternatives rely on the same IoT-connectivity network technology, which would result in the same cost components. However, at a cost of 2-10 EUR for a LoraWan communication chip, this cost component would contribute 200- 1000 kEUR to the overall CapEx of this use case. Since the LPWAN market is still in a nascent phase and current prices are likely to decrease [12], a price erosion is modelled via the extended learning curve with parameters Q0 = 10%, K = 0.9, Δt = 8 year, as described in [15]. Table 4-5, gives of summary of the cost components taken into account.

Table 4-5: Overview of relevant cost components of LoraWAN private deployment vs. public network subscription

kEUR	year	0	1	2	3	4	5	6	7	8	9	10
LoraWAN Private network deployment												
	BS & equipment cost	19.5	0	0	0	0	0	0	0	0	0	0
CapEx	BS installation cost	1.3	0	0	0	0	0	0	0	0	0	0
	Network setup & management	0.65	0	0	0	0	0	0	0	0	0	0
OpEx	Network operations	0	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145
	Total cost	21.45	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145	2.145
	Cumulative Cost	**21.45**	**23.595**	**25.74**	**27.885**	**30.03**	**32.175**	**34.32**	**36.465**	**38.61**	**40.755**	**42.9**
LoraWAN Public network access												
OpEx	subscription cost	0	360	360	360	360	360	360	360	360	360	360
	Price erosion (ext. learning curve)	0	100%	93%	87%	82%	78%	76%	74%	72%	72%	71%
	Cumulative Cost	**0**	**360**	**694.7**	**1007.9**	**1303.5**	**1585.4**	**1857.3**	**2122.3**	**2382.8**	**2640.6**	**2896.7**

One can see that deploying a private LoraWAN network is the most economical solution, given the current market prices. The subscription fee can't compete with a subscription free private network. The downside of a private network is its geographical limitations. If this use case should be deployed globally, currently a GPS based solution in combination with a globally deployed connectivity network (satellite or cellular) could be proposed. But such a solution comes with challenges concerning power consumption and economic feasibility due to the IoT-connectivity subscription costs.

4.4 Conclusions

Together with the continuous expansion of the IoT-market, also the number of IoT-connectivity networks grows. We believe many of them will serve the market in parallel since no technology offers a one-size-fits-all solution for the wide variety of IoT-applications. So the challenge for an IoT-developer or IoT-provider, if they are not the same actor, is to make a well-considered decision on the network technology. In response, we present a two-step methodology to guide IoT-developers or IoT-providers towards a feasible set of network technologies based on the match between the functional requirements of the IoT-application and functional characteristics of the IoT-connectivity networks and economic consideration associated with this set. Hereby complementing pure technical comparisons of connectivity networks with a more bottom-up approach. In a first step, the available set of IoT-connectivity networks is reduced via an elimination questionnaire on the IoT-application requirements. Four types of questions have been derived from technical capabilities, spectrum and market characteristics of the different technologies and their providers: 1) application related requirements such as geographic span and required signal penetration, 2) data or payload related requirements, for instance: transmission frequency and payload size , 3) end node or device related requirements such as desired battery lifetime and over-the-air update capability, and 4) questions concerning the business model (e.g. private deployment or public subscription) and provider dependencies such as vendor lock-ins. The questions, withholding functional descriptions of network characteristics allow comparing and eliminating different networks due to mismatches with the IoT-application requirements. In a second step all relevant cost components associated with IoT-connectivity are described along with their underlying cost drivers. Comparing both capital expenses (CapEx) and operational expenses (OpEx) associated with a certain connectivity network over the expected lifetime of the IoT-application guides IoT-developers to the most economical choice. Main components of CapEx are network installation costs and costs for the end node communication chips. Amongst the elements resulting in OpEx we find battery replacement, network subscription fees and network operation and maintenance. Methods to take market evolutions into account such as price erosion are described as well as how to deal with uncertainty when quantifying life cycle costs of IoT-connectivity networks. The proposed two-step methodology has been applied to a use case of a large scale IoT-deployment in the port of Antwerp, BE to track the location, movement, acceleration, temperature, humidity and gasses within shipping containers.

Finally, it should be noted that together with the enormous opportunities and potential of the IoT- market place, the set of connectivity network technologies and providers is continuously expanding. Traditional network providers are responding to the IoT-market with new LPWAN technologies such as NB-IOT and LTE cat. M1. It can be expected that competition will be driven by quality of service, costs, network availability and technical characteristics. Therefore we acknowledge that the set of connectivity networks treated in this paper is incomplete. Many technologies (such as NB-IOT, LTE-M1, DASH7, Wifi.ah (Halow), and ultra-wide band networks) currently in development or gaining interest should be added in the future. Additionally, as market evolves, data on specific network related costs will become available and could be added in order to further detail the cost comparison between the different networks.

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5

Evaluating the Economic Impact of Smart Care Platforms: Qualitative and Quantitative Results of a Case Study

In Chapter 2, sustainable value networks, go-to-market strategies and a migration path for smart care platforms are introduced. Now we zoom in on the impact these platforms can have for the different stakeholders and identify and quantify the effects for home care organizations. When breaking down the process of care delivery, it becomes clear that both care scheduling and billing processes could be simplified and be made more efficient. This is important because when home care organizations benefit from integrating these smart services, further adoption and integration could be driven by this actor.

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ABSTRACT

Background: In response to the increasing pressure of the societal challenge because of a graying society, a gulf of new Information and Communication Technology (ICT) supported care services (eCare) can now be noticed. Their common goal is to increase the quality of care while decreasing its costs. Smart Care Platforms (SCPs), installed in the homes of care-dependent people, foster the interoperability of these services and offer a set of eCare services that are complementary on one platform. These eCare services could not only result in more quality care for care receivers, but they also offer opportunities to care providers to optimize their processes.

Objective: The objective of the study was to identify and describe the expected added values and impacts of integrating SCPs in current home care delivery processes for all actors. In addition, the potential economic impact of SCP deployment is quantified from the perspective of home care organizations.

Methods: Semistructured and informal interviews and focus groups and cocreation workshops with service providers, managers of home care organizations, and formal and informal care providers led to the identification of added values of SCP integration. In a second step, process breakdown analyses of home care provisioning allowed defining the operational impact for home care organization. Impacts on 2 different process steps of providing home care were quantified. After modeling the investment, an economic evaluation compared the business as usual (BAU) scenario versus the integrated SCP scenario.

Results: The added value of SCP integration for all actors involved in home care was identified. Most impacts were qualitative such as increase in peace of mind, better quality of care, strengthened involvement in care provisioning, and more transparent care communication. For home care organizations, integrating SCPs could lead to a decrease of 38% of the current annual expenses for two administrative process steps namely, care rescheduling and the billing for care provisioning.

Conclusions: Although integrating SCP in home care processes could affect both the quality of life of the care receiver and informal care giver, only scarce and weak evidence was found that supports this assumption. In contrast, there exists evidence that indicates the lack of the impact on quality of life of the care receiver while it increases the cost of care provisioning. However, our cost-benefit quantification model shows that integrating SCPs in home care provisioning could lead to a considerable decrease of costs for care administrative tasks. Because of this cost decreasing impact, we believe that the integration of SCPs will be driven by home care organizations instead of the care receivers themselves.

5.1 Introduction

5.1.1 A Societal Challenge

Many parts of the world face the same social evolution: an aging society. It's a challenge because with an aging society the demand for care increases while resource availability (both human and monetary) is under pressure.

Information and Communication Technology (ICT)-enabled care services have the potential to reduce costs while maintaining or increasing the quality of care. Many examples in the primary (the general practitioners and health centers) and secondary care sectors (hospitals and specialist) already exist. Electronic health records and electronic drug prescriptions are only a couple of many examples. All these types of ICT-enabled services foster better care communication, organization, less medication or diagnostic errors, and more transparent data sharing [1].

5.1.2 eCare Services

In recent years, focus intensified on aging in place and how ICT-enabled services could support this. The number of ICT-supported care applications (eCare) such as remote fall detection [2], social contact enhancing applications, and telecare services to diagnose patients remotely [3] grew exponentially. This has resulted in a fragmented and scattered landscape of eCare applications. Most of the services have individual and standalone characteristics but interoperability often lacks [4].

5.1.3 Smart Care Platforms

In response to this barrier of noninteroperability and nonintegrated eCare services, the introduction of smart care platforms (SCPs) can be witnessed [5-9]. These SCPs allow integration, monitoring, and data exchange between a set of home care applications and services that run on a central cloud-like platform. Smart care platforms foster better care communication and information sharing among the professional, informal care providers, and care receivers [10]; therefore, SCPs are not the same as telecare services though they can support them. Furthermore, many SCPs allow the integration with various monitoring sensors that provide specific context information (e.g., room temperature, movement of the person, bed detection, sound level) [11]. Longitudinal analyses of these data give meaningful insights in evolution of the condition of the care receivers and their daily life patterns. In general, the functionalities of SCPs in terms of providing services can be categorized and summarized as follows [9]:

- *Support Care and Care Processes:* Examples of these services are: online meal delivery services, alerting specific care actors in case of certain events, care journals, and care agendas.

- *Sharing Care Information and Care Communication:* According to the role-based rights of the involved actors (e.g., GP vs informal caregiver vs care receivers), one can add, change, erase, or annotate particular information of the care receiver.

- *Support Social Life and Activities:* Making video calls with friends or relatives or being able to share some memories with family are just some of these services that support the social life of the home care receiver.

- *Monitoring Services:* Integration of various sensors into the homes of the care receivers allows monitoring of context data such as movement, pressure sensors to detect bed or couch presence, accelerometers to detect falls, light, noise, temperature, humidity, smoke detectors, weighing scales, and so on. Through these sensors all kinds of biometric or context information can be captured. Analysis of sensor data allows evaluations of lifestyle trends.
  Most SCPs exist with one or more of the above described functionalities. In other cases, SCPs provide the basic set of functionalities, which can easily be extended by adding modular services [12]. O'CareCloudS (OCCS) [12], the SCP developed in the identically named research project is a complete cloud-based platform. The basic service set of OCCS does provide several services to foster better care information sharing and social connectivity. The complete service set covers: (1) consulting and annotating the shared care record, (2) time and task registration of the care givers, (3) care agenda and a smart task list, (4) social calendar, (5) smart messaging service, and (6) a service catalogue for additional OCCS services. In addition, modular lifestyle monitoring services can be added by installing the necessary sensors. Although SCPs can support care provisioning for all types of home care receivers, in this work focus is on elderly, as it can be expected that more elderly will stay longer at home.

5.1.4 **Evaluating Smart Care Platforms**

SCPs are believed to have a positive impact on the quality and the cost efficiency of care. But at the same time the main characteristic of SCPs, the ability to connect multiple actors, poses challenges for its adoption. Multi-actor or multi-stakeholders systems require at least a neutral and preferably a positive perceived impact for every actor involved before a successful adoption is possible [13]. Also it's not clear which actor will initiate the adoption of SCPs.

Therefore, this paper focuses on determining and quantifying the impact of integrating SCPs into present home care processes for the elderly; in other words, evaluating the potential effect or added value of SCPs.

In the literature, previous work on several aspects of the evaluation of SCPs can be found. We distinguish (1) research on the evaluation methodology and (2) results of evaluation processes of eCare services.

The nature of SCPs and eCare services in general requires a multi-aspect evaluation method. Evaluating these services solely based on their medical impact would be insufficient; also focusing on economic impact would be too narrow. Evaluating eCare services in their totality requires looking at them from several angels such as the economic perspective, the medical impact, the social aspect, the impact on the involved actors, legal issues, and technical barriers [13, 14].

In this knowledge, different frameworks are developed especially for evaluating eCare services [13-16]. All of them present a model or framework that takes into account several perspectives of the impact of integrating eCare or SCP services. Salvi et al [17] presents an overall evaluation framework based on quality of eCare services in the context of ambient assisted living. This incorporates many quality characteristics such as functionality, reliability, efficiency, and usability. However, the framework does not take the economic perspective into account.

In addition to the literature on the methodologies used for evaluating eCare services or SCPs, previous work on the impact of the integration and adoption of SCPs is also available.

Bossen et al [9] conclude that integrating SCPs in the home environment of care receivers can facilitate and augment the current home care processes and enhance the cooperation between the several involved actors even more. Although larger pilot tests are needed to further evaluate the CareCoor system, initial tests revealed promising results and positive impacts for the care network.

In contrast with the results of Bossen et al, findings from the Whole Systems Demonstrator cluster randomized trials indicate that the effects of "second-generation" telecare are very limited and even without significant impact [18-20]. Except for a small benefit on psychological outcomes, the gain in quality of life is very small [18]. This also results in a very high cost-effectiveness ratio, meaning that the costs needed to obtain that small increase in quality of life are very high and far above the willingness to pay for it. According to Steventon et al [19] the telecare services as implemented in the Whole System Demonstrator do not lead to significant cost reductions in the use of care services.

Contradiction of the results of these researches indicates that more research is needed to clarify the impact of ICT-supported care service. This lack of evidence is seen as one of the barriers for adoption of eCare services [21]. The absence of the proof of positive effects also impacts the formulation of policies or new reimbursement systems [22]. This can affect the complete business model of the eCare service provider [10].

This paper identifies the expected impact of SCP integration for all actors involved. Via economic analyses, from the perspective of home care organizations, potential benefits and costs are compared with costs of current processes. Doing so, this research provides more clarity on viable economic business cases for SCPs.

5.2 Methods

5.2.1 **Overview**

The methodology consists of 2 phases (see Figure 5-1). In the first phase, all various forms of potential impact and benefits are identified. During a second phase a 4-step economic cost-benefit analysis was modeled from the perspective of home care organizations.

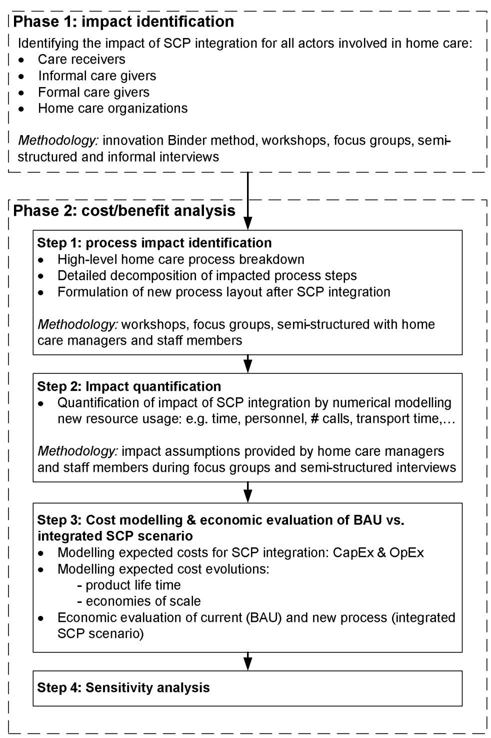

Figure 5-1: Schematic overview of the two-phase research method.

5.2.2 Phase 1: Impact Identification

First, expected fields of impact should be identified for each actor within the context of home care provisioning. The methodology known as the innovation Binder Approach [23] resulted after multiple iterations in input data from various perspectives such as technology, user or social, and business.

Additional input for this identification process resulted from workshops, focus groups, and semistructured and informal interviews with field experts such as managers and administrative staff members of home care organizations, home care providers, and technology providers. Both qualitative (e.g., less anxiety, increased peace of mind, decreased burden of care) and quantitative impacts (e.g., process excellence such as less administration or faster billing procedures) can be expected for the actors.

5.2.3 Phase 2: Cost-Benefit Analysis From the Perspective of Home Care Organizations

Step 1: Identifying the Affected Home Care Processes via Process Breakdown Analyses

Adopting SCPs will affect several processes needed to provide home care such as administration tasks, communication, and sharing information. Via a high-level home care process breakdown, home care organizations were able to locate the most resource-intensive processes that could be affected after integrating SCPs. After this step, the identified process steps, care scheduling and billing processes in this case, were further decomposed.

Step 2: Quantification of Costs of the Current Business as Usual and Integrated Smart Care Platform Scenario

Effects such as better scheduling and task coordination have direct quantitative impacts in terms of monetary or time savings. In this project, no qualitative or quantitative research has been carried out on the impact on health utility for care receivers such as surveying the quality of life. Therefore, this work focuses on the changes in the care scheduling and billing processes of a care organization (direct quantitative benefits).

To do so, first the annual expense of the BAU was quantified. After SCP integration, the BAU could be affected, resulting in new costs. This assumed impact, provided by home care managers and staff members during focus groups and semistructured interviews, is modeled in as well. The difference or delta between the 2 scenarios is defined as a direct benefit if the costs of the integrated SCP scenario are lower than the costs of the BAU scenario.

Step 3: Economic Evaluation: Comparing the Integrated Smart Care Platform Scenario with the Business as Usual Scenario

The goal is to research whereas the resulting benefits justify all the operational costs and investments that are needed for adopting SCPs. Thus, after quantifying the expected effects, the BAU is compared with the new "Integrated SCP scenario." Therefore, the costs of SCP integration are also modeled.

Step 4: Dealing With Uncertainty via Sensitivity Analyses

Although this cost-benefit model is developed with realistic data provided by service providers and experts from home care organizations, it is likely that variations of the values will occur. Therefore, we need to check whether the model still behaves normally with varying input values. Sensitivity analysis also provides us with a confidence interval for the result based on the input parameters modeled with known variations.

5.3 Results

5.3.1 Phase 1: Overview of Potential Impact Per Actor

In the first step of this research, the potential impacts or added values, resulting from the adoption of SCPs, are identified per actor involved. Methodologies used to identify the impacts are: the "Innovation Binder Approach," as described in [23], informal and semistructured interviews with managers of care organizations, informal and professional care providers and care receivers.

Table 5-1 presents the various expected added values identified per actor along with the nature of impact (qualitative or quantitative). Within the context of home care, the following actors are included: (1) care recipient or patient, (2) informal care giver, (3) formal or professional care giver and home care organization, (4) care insurers or payers and society, (5) primary care, and (6) secondary and tertiary care.

Table 5-1: Identification of added values that can be expected per actor.

Actor	Added value description	Impact type: qualitative or quantitative
Care receiver	Control of the organization of care	Qualitative
	Strengthened involvement and empowerment	Qualitative
	Higher quality of care	Qualitative
	Higher state of peace of mind	Qualitative
	Higher state of self-management, less care dependent	Qualitative
	Lowered barriers for social contact and	Qualitative

	decrease of social isolation	
	Better informed of existing and practical care support services	Qualitative
Informal care giver	Better care task coordination	Qualitative
	Improved quality of care or work atmosphere	Qualitative
	Less stress, less unexpected tasks, increased state of peace of mind	Qualitative
	Being better (and real time) informed	Qualitative
Formal care giver and care organization	Better care task coordination	Qualitative
	Improved quality of care or work atmosphere	Qualitative
	Less stress, less unexpected tasks, increased state of peace of mind	Qualitative
	Significant decrease in administration time (scheduling, adapting schedules, billing, etc.)	Quantitative
	Reassuring care receivers when delay during care visits	Qualitative
Primary care (GPs)	Access to more complete care and context data	Qualitative
	Improved quality of care, faster and more complete diagnoses	Qualitative
	Being better (and real time) informed	Qualitative
Secondary and tertiary care	Access to more complete care and context data	Qualitative
	Being better informed	Qualitative
	Improved quality of care, faster and more complete diagnose	Qualitative
Care insurer or payer and society	More opportunities for prevention	Qualitative
	Savings because of delayed transition to care home	Quantitative
	Increase in cost-efficiency	Quantitative
	Overall higher quality of care	Qualitative
	Transition from curative to preventive care	Qualitative

Although the potential impact for every care giver is considerable, in what follows only the impact for the care organization is quantified. This actor is considered as an SCP initiator for 2 reasons:

- Several home care organizations already provide monitoring services such as personal alarm system and work with call centers. Offering SCPs toward their clients would extend the current service offers.
- SCPs have the potential to simplify and decrease the costs for organizing home care. Therefore, home care organizations have a potential incentive to adopt SCPs.

5.3.2 Phase 2: Cost-Benefit Analysis From the Perspective of Home Care Organizations

The home care organizations themselves are convinced that a lot of improvement is possible in the process of home care provisioning. In order to detect which process steps would be affected by SCPs, semistructured interviews and focus groups with care organizations were carried out to collect data to be able to quantify the current costs for billing and rescheduling processes.

These data served as input for a numerical model to calculate the potential benefits and costs. In what follows, all results of the 4-step model (Figure 5-1) are discussed.

Step 1: Process Impact Identification

In the first step, the complete process of home care provision is broken down into several main and sub process blocks. This allowed the managers and staff members of the home care organization to locate process steps that potentially would be affected when integrating SCPs.

Figure 2-2 presents the high - level process spider chart for home care provisioning. The main process blocks for home care provisioning are patient intake phase, preparation of the care delivery, actual care delivery, and care delivery administration.

Two-process steps were identified by the expert team as potentially impacted by adopting SCP. First, the current process for billing for home care was identified and second, the process that takes place when something has to change to the actual care schedule. For instance, when a caregiver gets sick, all planned appointments need to be reallocated to other care givers. A second example provided by the expert group is: when a client visits the hospital, all planned care visits should be replaced with others, otherwise the care givers would have no work. A more detailed decomposition of both processes is shown in Figure 2-6a.

Step 2: Quantification of Costs of the Current Business as Usual and Integrated Smart Care Platform Scenario

The Process Break Down and Resource Usage of the Current Business as Usual Scenario

In the next step each process block of the current billing process is quantified in terms of cost per year. The same is done for the rescheduling process. Relevant data in order to calculate the cost of the current processes or business as usual are presented in Table 5-2.

Table 5-2: Cost parameters and drivers used to calculate the cost of the business as usual (BAU) process.

Numerical parameters for the current billing process	**Numerical parameters for the current rescheduling process**
Number of care visits per month	Frequency of care rescheduling in terms of percentage of the total amount of planned care visits
Total amount of care givers	Telecommunication costs for calling the central administration office
Full-time equivalents (FTEs) of care providers	Average time needed to make the rescheduling exercise (not every care provider can be reallocated to a changed care visit due to professional or personal reasons (e.g., care provider must speak Dutch, cannot be pregnant because of potential diseases of the cat of the care receiver)
Time needed to input the data into the back-end system	Time needed to inform the original dedicated care giver
Cost for mailing the monthly visit records of the care giver to the care organization	Scheduled visits per month
Time needed for inputting the data after each visit	Number of rescheduled visits per month
Average wages of the administration staff and the care providers	
Transport time	
Transport frequency	
Time needed for rework due to errors	

The model was initially designed for an East Flemish Care organization involved in the OCCS project, but is not limited to this organization. This region counts about 881 full-time equivalent home care givers who are members of the care organization. All data and results are valid within the scope of the OCCS project [12]. According to the managers of the care organizations, the input provided and process issues described are similar for all Flemish and even Belgian care organizations. For detailed data of current billing and rescheduling processes see Appendix 1.

Figure 5-2 presents the current cumulative cash outflows per quartile for both the billing and rescheduling processes. In total, these 2 processes cost about

€510,000 per year for this provincial division of the Flemish care organization involved in the OCCS project.

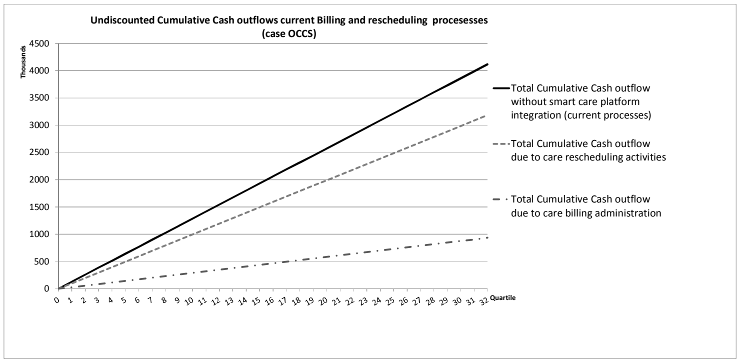

Figure 5-2: The costs for the current rescheduling activities are more than 3 times higher than the current costs for billing administration. This is mainly caused by the wages of central office staff members who do the actual rescheduling (see Appendix 1).

The Process Break Down and Resource Usage for the Integrated Smart Care Platform Scenario

Together with the care organization we modeled how an SCP would affect the current billing and rescheduling processes. Some process steps would remain unchanged; others would even disappear or would be affected. Figure 2-6b shows what process steps would be affected and how.

For detailed data on the affected process parameters, see Appendix. Figure 5-3 shows the expected cumulative cash outflows of the new processes.

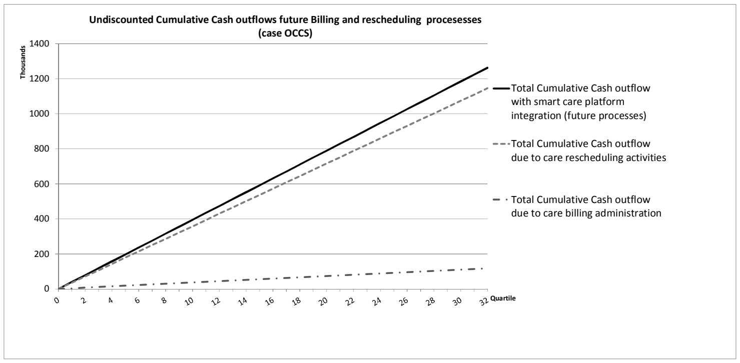

Figure 5-3: In the new integrated smart care platform scenario, the billing process is almost completely automated. That explains the low cumulative cash outflow due to the future billing processes (see Appendix 2)

Given the validated impact assumptions such as reduced time needed for putting in the billing information, fewer telephone calls, no correspondence needed anymore, and so on, the total annual expense of the new processes, investments in SCP excluded would decrease to €160,000 per year. This means a reduction of 69% of the total cost of the current billing and rescheduling processes can be obtained. Figure 5-4 presents the comparison between the cumulative expected costs of the current and future billing and rescheduling processes.

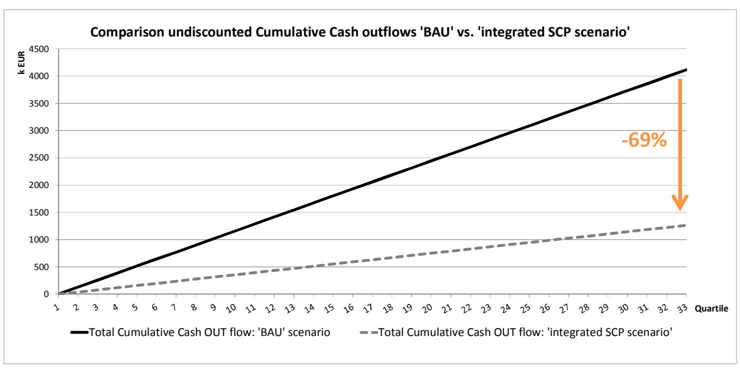

Figure 5-4: Automating the billing processes and rescheduling processes would lead to a process cost reduction of 69%.

A clear difference between the costs of the current and potential new billing and care rescheduling processes can be seen. But the latter requires a significant investment in order to reach these potential savings. Furthermore, it is expected that the data inputting process could be more time-efficient for the care provider by the use of the smart care app on the mobile phone. For the provincial home care organization involved in the OCCS project, this could free up nearly 11,000 h per year ([1488 min/year − 744 min/year] × 881 FTEs); see Appendices 1 and for data. This time could be spent with the care receiver, resulting in better quality of care (more quality time for the patient) without affecting the cost.

Step 3: Investment Modeling and Economic Evaluation

Smart Care Platform Investment Modeling

The expected savings can only be obtained if the home care organization invests in an SCP system like OCCS. These investments are modeled in Table 5-3.

Furthermore, economies of scale are modeled for the SCP subscription cost per care provider. This is modeled as a staircase function, driven by the number of care providers connected with the SCP.

The rollout of an SCP within the complete care organization is modeled as a staircase function as well. This was asked by the managers of the home care organization. Each quartile, 25% of all care givers are provided with the needed hardware and the education time. After 1 year, all care givers are connected with the SCP.

Table 5-3: Investments to integrate O'CareCloudS (OCCS), based on expert estimations within OCCS and sector averages.

Description of investment	Value	Unit
Every care provider needs a (basic) mobile phone, not only the people who work full-time, but also the people who work part time. (The lifetime of these devices is currently set at 3 years. Then they need to be replaced) [CapEx]	80	€/care provider
Every care provider needs a mobile telecommunication subscription. (There exist special group tariffs for care organization, that is why this annual expense is initially modeled rather low) [OpEx]	40	€/year per care provider
Each care provider needs to have access to OCCS. An annual subscription cost is modeled per care provider. [OpEx]	20	€/year per care provider
Each care provider needs to be educated to understand the functionalities of the SCP (2 h of education) [CapEx]	31	€/care provider
The SCP needs to be integrated into the back-end systems (1 FTE during 3 months) [CapEx]	14,700	€
An annual operational cost which is modeled as a percentage of the integration cost is needed to keep the SCP up and running [OpEx]	5%	

Economic Evaluation: Comparing the Integrated Smart Care Platform Scenario with the Business as Usual Scenario

Now that the impact and costs of SCP integration are known, we can investigate whether the impact is still positive after taking into account all the costs for SCP deployment.

The following graph (Figure 5-5) shows the expected evolution of the undiscounted cash outflow in a situation in which a smart care system would be deployed in 1 year compared with the costs of current billing and rescheduling processes.

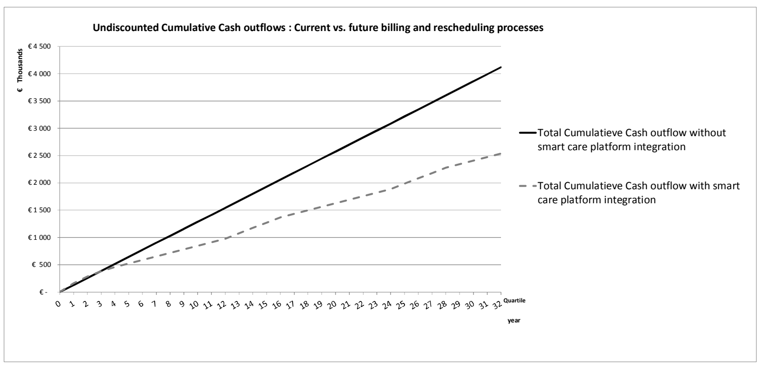

Figure 5-5: In the first year, the cash outflow of the integrated smart care platform (SCP) scenario is the same as for the current business as usual (BAU) scenario because of the initial investments. But after that, one can see clearly the potential savings of integrating an SCP.

Based on the provided data, integrating an SCP would have a payback time which is less than 1 year. Within a period of 8 years after the investment, a total cost reduction of 38% can be expected. From Figure 5-6 one can see that, according to this model, the total annual expense per care provider can maximum increase to about €150 per person per year. At that level, the expected costs of the SCP integration would be the same as the current costs, everything smaller than €150 would lead to savings.

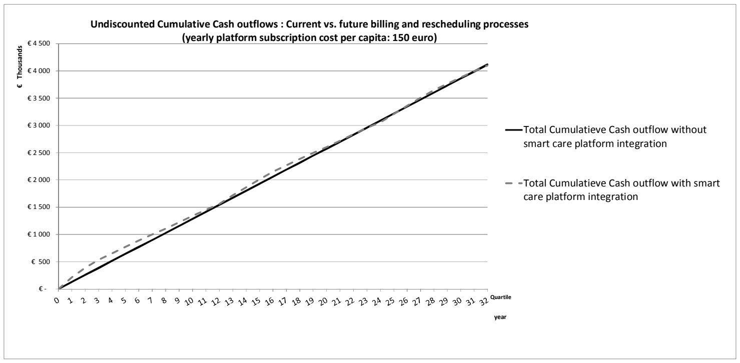

Figure 5-6: Expected evolution of the cumulative cash outflow in case the annual cost per care provider would be € 150. This is the upper boundary for the yearly costs per care provider

Step 4: Dealing With Uncertainty

To take uncertainties into account, such as the assumed impacts on both affected processes, a sensitivity analysis is performed. Table 5-4 depicts the variations on uncertain input parameters.

The result of the sensitivity analysis indicates a 90% chance that within a period of 8 years after the investment in an SCP, the cumulative undiscounted cash outflow will lie between k€2400 and k€3400 (see Figure 5-7). Testing the model robustness indicates that the SCP subscription cost is the driving parameter in this model (see Figure 5-8). This is acceptable as the variance on this parameter is rather high and because of the annual effect of it. The same is true for the Telco subscription cost. This means that it will be important to negotiate good subscription prices for both access to the SCP and for the telecommunication subscriptions.

Table 5-4: Modeled distributions for uncertain input parameters, based on expert estimations within O'CareCloudS (OCCS)

Parameter	**Modeled distribution**
Number of hours needed for education (h)	Normal distribution with parameters mean=2.00, SD=0.32
Annual SCP maintenance costs (% of integration cost)	Normal distribution with parameters mean=0.05, SD=0.01
SCP back-end integration cost (€)	Lognormal distribution with parameters location=104,000, mean=14,700, SD=3498.6
Cost for mobile phone (€)	Maximum extreme distribution with parameters likeliest=80, scale=1.94
Yearly Telco subscription for the care provider (€/year)	Normal distribution with parameters mean=40, SD=11.76

Yearly smart care platform subscription cost for the care providers (€/year)	Beta distribution with parameters minimum=15, maximum=100 alpha=1.2, beta=2.6

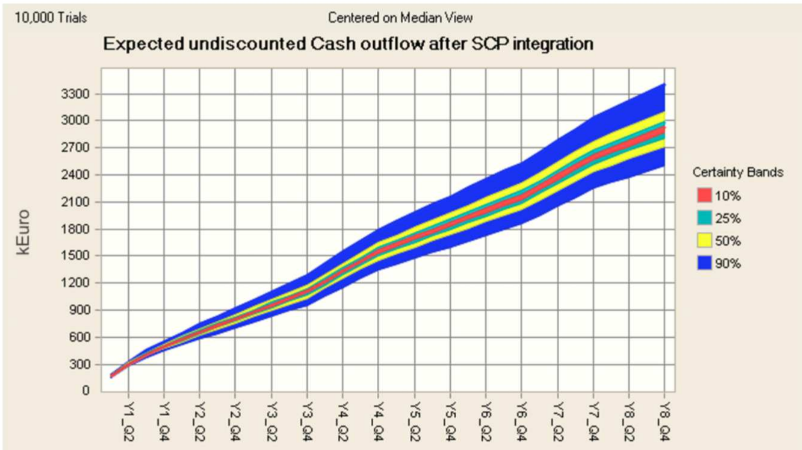

Figure 5-7: Expected undiscounted cumulative cash outflow with CIs 90%, 50%, 25%, and 10%. In the worst-case scenario, the cost of the billing and rescheduling process will still cost 18% less than in the current situation.

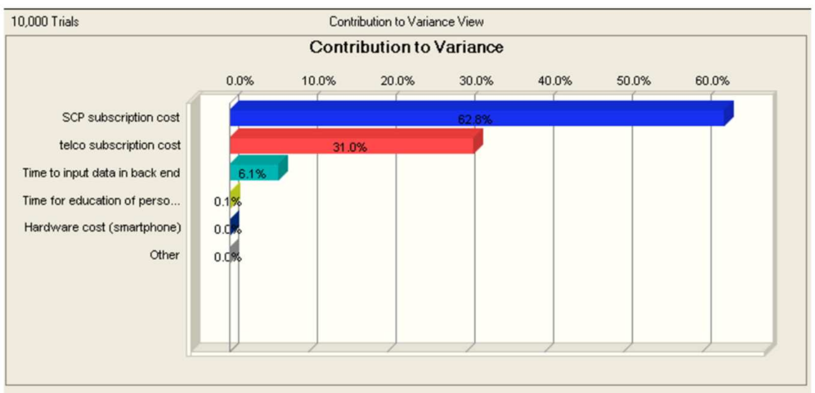

Figure 5-8: The annual subscription cost for smart care platforms is expected to have the biggest impact on the expected savings, followed by the annual expenses for telecommunication.

5.4 Discussion

Principal Findings

Integrating SCPs such as OCCS could affect the care administration process of care organizations. Based on the provided process data of BAU and "integrated SCP scenario," an annual cost reduction of 37-38% could be expected. This cost reduction does not result from the SCP's main purpose, being sharing care data or monitoring care receivers, but from the fact that digitizing one or more parts of an often time-intensive manual process can save expensive resources.

The results indicate that at least for care organizations, which are often important actors in the home care provisioning for elderly, the impact of integrating SCPs within their own scheduling and billing software is positive. This is important because literature indicates that the impact of SCPs on the quality of life of care receivers is rather limited and still not convincing enough to drive a viable adoption.

This SCP integration would not require involvement of the care receivers or their informal caregiver. Only professional care givers within the organizations could consult the care information. Initially, for the care receivers and informal care givers the added value of such a system would remain very limited.

Therefore, we believe that until the added value of SCPs for the care receiver increases to a critical level for which there exists a viable willingness to pay, the adoption of SCPs will be driven by a positive affected actor such as the care organizations. This could be a first step to digital integration and collaboration of care organizations and a first step toward a patient-centered care system.

Once all personnel of the care organization receive education and familiarize themselves with the functionalities, the home care organization can open the other functionalities of the SCPs also toward the care receivers, their informal care givers, and other care providers. In this way also other actors with a lower willingness to pay, because of the less direct quantitative benefits of SCPs, can experience the added values of SCPs.

As this research is a part of the Flemish OCCS project, the results are pertaining to the Flemish homecare organization involved in the project. As the field experts who provided data for this research stated that the situation is the same in the entire Belgium and is the same even in many Western European countries, therefore, the findings could be generalized.

Limitations

Although there are many beneficial impacts due to SCP integration, it should be noted that SCP adoption will result in some challenges and threats. Often there are concerns about privacy, data ownership, and replacing human care toward automated less personal care. It was not the focus of this research to describe all potential barriers. The results of the economic evaluation should not be affected by taking these challenges and threats into account.

Another point of remark is the single-sided perspective of the economic evaluation. Considering the case of the home care organizations alone is a well-considered choice because we strongly believe that these actors will drive adoption for SCPs. However, other actors such as society, care payer, and formal care providers could also experience economic impacts. From that point of view, the results of the analyses are probably an underestimation of the real effects. Future research on the evaluation from more perspectives complemented with a study on the impact on quality of life can bring more clarity.

Conclusions

This work envisions to identify, describe, quantify, and evaluate the impact of integrating new “Cloud-like” smart care platforms into the current home care processes. The goal of these platforms is to offer trusted information and knowledge-based services related to the care organization and delivery to the client or patient. These services aim to support and foster communication on the daily care-related needs, the social needs, and daily life assistance.

One of the goals of integrating SCPs is to foster open communication and data sharing among all the involved actors (eg, care organization, general practitioner, formal and informal care givers). Thus, in order to stimulate usage of SCPs, all actors involved should benefit from it or at least not be affected negatively.

The research indicates that all actors could benefit from the integration of SCPs. Care receivers can expect a higher quality of life, informal care givers could face a higher state of peace of mind, and formal care providers can provide the same quality of care while there could be more quality time available. Care organizations can optimize their care administration processes and push the level of digitization even further. Finally, care insurers and society in general could profit because of the possibility to provide personalized prevention and decrease or postpone the move to care homes and let the elderly stay at home instead. Although these expected effects sound acceptable, it is not clear yet whether these impacts will convince care receivers to adopt SCPs.

However, when we step away from the main goals of integrating SCPs and focus on the potential effects that result from digitizing and optimizing the current administration of home care processes (billing and care scheduling in particular), our quantification model indicates that a cost reduction for the home care organization of 37-38% could be expected and thousands of hours per year could be freed up for providing quality care by optimizing the current administrative tasks. Thus, if SCPs could be integrated within the already existing back-end systems of care organizations or vice versa, the savings potential could be a viable driver for the adoption of SCPs by home care organizations.

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Appendices

Appendix A: Current process breakdown

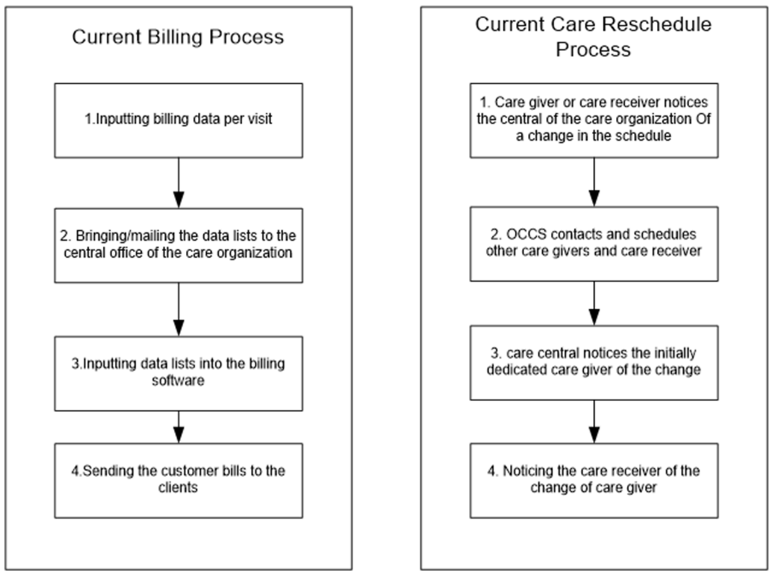

Figure 5-9: Process decomposition of 'as is' billing and care rescheduling processes

In following two tables a concise overview of the data is presented. All data was validated by experts involved in the OCCS project.

Table 5-5: Overview of the data for the current billing process

Description data parameter	***Value***	***Unit***
Time needed for inputting data per visit	2	min/visit
# visits per month per FTE	62	visits/month
Frequency of data list delivery by the care provider to the care organization administration	12	deliveries/year
Cost of envelopes to send the lists	12	euro/year
Time needed for inputting one line of the data list into the back end system	0.31	Min/data line
# care givers in 'Interregio Gent' (full time + part time)	1719	Persons
Full Time equivalent of the total amount of care givers	881	FTEs
Total amount of data lines inputted in the backend system by the central administration (March 2014)	88000	data lines/month
% rework due to mistakes in inputting	4%	of # data

Table 5-6: Overview of the data for the current rescheduling process

Description data parameter	***Value***	***Unit***
Time needed by the care receiver or care provider to inform the care central	1.5	min/call
Telco costs needed to inform the care central (in case the care provider calls with own mobile)	0.5	euro/call
chance that that a visit needs to be rescheduled	15%	Of planned monthly visits
# visits per month per FTE	62	visits/month
Chance that it the care receiver informs the care central him/herself	70%	
Time needed to inform other care provider	1	min/contacted care provider
Costs Telco for the care administration	0.01	euro/min
Average amount of care actors to contact (number of calls to make)	4	
time needed to make the new care schedule	4	Min

Based on these inputs, the model provides following results on current resource usages:

Table 5-7: Resource usages for the current billing process

Description data parameter	***Value***	***unit***
Total time needed per FTE when inputting billing data when he is with the care receiver (time is paid by care receiver)	1488	min/year
Total time needed for the care administration to put in all the billing data of the care givers into the back end system	339120	min/year
Costs for the care administration to put in all the billing data of the care givers into the back end system	96084	euro/year
Costs to provide each care provider with 12 envelopes to send the data lists once a month	20628	euro/year
Total cost for the care organization caused by the current billing process	116712	euro/year

Table 5-8: Resource usages for the current care rescheduling process

Description data parameter	***Value***	***unit***
Total time needed per care provider to contact and discuss the new care schedule with the permanency station (central office)	496	min/year
Total cost of wages for the care organization to pay for the time needed of each care provider to contact and discuss the new care schedule with the permanency station (central office)	119180	euro/year
Total costs for compensating the telecommunication cost of the care providers when they called with their own device to the care central	14748	euro/year
Total telecommunication costs for the permanency station due to calling to the care providers (central office)	6292	euro/year

Total cost for the wages of the people of the permanency station (central office)	264644	euro/year
Total cost for the care organization caused by the current care rescheduling process	397981	euro/year

Table 5-9: Total cost of current billing and care rescheduling processes

Total cost for the care organization caused by the current billing process	116712	euro/year
Total cost for the care organization caused by the current care rescheduling process	397981	euro/year
Total cost of the current billing and rescheduling processes	514693	euro/year

Next to high costs for the processes we notice from the table 5-9 that all the clients in total pay for about 22000 hours (1488 min/year per FTE x 881 FTEs) per year for filling in the billing data.

Appendix B: Future process breakdown

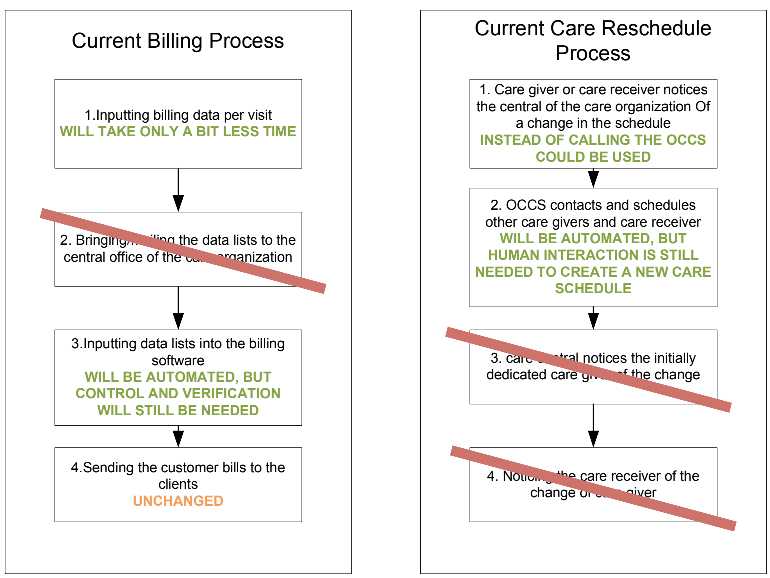

Figure 5-10: Process decomposition of 'to be' billing and care rescheduling processes

Following data of the new processes was validated by field experts involved in the research project.

Table 5-10: Input for the Billing process when a smart care platform is integrated

Description data parameter	***Value***	***Unit***
Time needed for inputting data per visit	1	min/visit
# visits per month per FTE	62	visits/month
Frequency of data list delivery by the care provider to the care organization administration	0	deliveries/year
Cost of envelopes to send the lists	0	euro/year
Time needed for inputting one line of the data list into the back end system	0.05	Min/data line
# care givers in 'Interregio Gent' (full time + part time)	1719	persons
Full Time equivalent of the total amount of care givers	881	FTEs
Total amount of data lines inputted in the backend system by the central administration (March 2014)	88000	data lines/month
% rework due to mistakes in inputting	4%	of # data lines/month

Table 5-11: Input for the Rescheduling process when a smart care platform is integrated

Description data parameter	***Value***	***unit***
Time needed by the care receiver to inform the care central	1.5	min/call
Time needed by the care provider to inform the care central	0.33	min
Telco costs needed to inform the care central (in case the care provider calls with own mobile)	0	euro/call
chance that that a visit needs to be rescheduled	15%	Of planned monthly visits
# visits per month per FTE	62	visits/month
Chance that it the care receiver informs the care central him/herself	70%	
Time needed to inform other care provider	0	min/contacted care provider
Costs Telco for the care administration	0.01	euro/min
Average amount of care actors to contact (number of calls to make)	4	
time needed to make the new care schedule	4	min

The new process would lead to following resource usages exclusive the investment in a smart care platform!

Table 5-12: Resource usages for the billing process when a smart care platform is integrated

Description data parameter	***Value***	***unit***
Total time needed per FTE when inputting billing data when he is with the care receiver (time is paid by care receiver)	744	min/year
Total time needed for the care administration to put in all the billing data of the care givers into the back end system	51859	min/year
Costs for the care administration to put in all the billing data of the care givers into the back end system	14693	euro/year
Costs to provide each care provider with 12 envelopes to send the data lists once a month	0	euro/year
Total cost for the care organization caused by the current billing process	14693	euro/year

Table 5-13: Resource usages for the rescheduling process when a smart care platform is integrated

Description data parameter	**Value**	**unit**
Total time needed per care provider to contact and discuss the new care schedule with the permanency station (central office)	11	min/year
Total cost of wages for the care organization to pay for the time needed of each care provider to contact and discuss the new care schedule with the permanency station (central office)	2498	euro/year
Total costs for compensating the telecommunication cost of the care providers when they called with their own device to the care central (now included in investment for mobile subscription)	0	euro/year
Total telecommunication costs for the permanency station due to calling to the care providers(central office) (now included in investment for mobile subscription)	0	euro/year
Total cost for the wages of the people of the permanency station (central office)	140679	euro/year
Total cost for the care organization caused by the current care rescheduling process	143177	euro/year

Table 5-14: Total cost of billing and care rescheduling processes when a smart care platform is integrated

Total cost for the care organization caused by the future billing process	14693	euro/year
Total cost for the care organization caused by the future care rescheduling process	143177	euro/year
Total cost of the future billing and rescheduling processes	157870	euro/year

6

A methodology for multi-actor evaluation of the impact of eCare services

The goal of the previous chapters is to identify, describe and quantify the impact of new smart services on both the value network and the individual business models of the actors. Also, it has become clear that there are several barriers slowing or even blocking adoption for some of the smart services. In this chapter we present a methodology to evaluate the impact of PEST barriers and to provide high-level guidelines for smart service providers on how to tackle some of these detected barriers. The aim of the paper is to indicate the importance of looking at the broader PEST context when evaluating smart services. The appendix provides additional insights in how the methodology takes these aspects into account.

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ABSTRACT The healthcare sector is an incredibly complex system with many public and private actors and a wide diversity of services. Because of the aging society and the growing evolution of health expenditures, pressure on available resources (time, people, budget, etc.) is increasing. Innovative ICT supported eCare and eCure services are expected to increase efficiency, coordination and organization of care. Currently many initiatives already introduced ICT-supported eCare services into the current healthcare ecosystem. However, it's quite a challenge to estimate the impact and expected uptake of these new eCare services. It's no surprise that only few services commercially succeeded. This paper presents a methodology that identifies and evaluates the PEST factors (political, economic, social and technological aspects) that impact the involved care actors when introducing eCare services. The model takes into account the overall socio-economic aspects of the service, but also the subjective importance that an individual actor can ascribe to a particular eCare service. Combining the impact of these PEST factors leads to an expected adoption rate. Both new services and existing initiatives can be compared to one another and the impact of economies of scale can be investigated. In case a negative impact on some actors is observed, the model proposes cost allocation or service offer alternatives to ameliorate the business case for a particular service. Finally, a sensitivity analysis helps to indicate the most significant parameters that drive the business case.

6.1 Introduction

Because of the further increasing pressure on the healthcare sector, mainly due to an aging population and growth in health technology investments, the need for service and process improvement as well as an overall increase of resource efficiency never was clearer before. Last decade, interest in innovative ICT supported care and cure services grew significantly [11] [12] [23]. On the one side there are the eCare services with a strong focus on the improvement of the care process and personal wellness e.g. telemonitoring of chronic heart failure patients, fall detection, etc. [2] [21]. On the other hand, there are the eCure services for supporting, automating and facilitating medical treatments and/or processes such as teledermatology [24], hospital information systems (HIS), etc. Both kinds of services already proved a positive impact on quality of life and resource efficiency.

When focusing on care dependents at home (thus outside the traditional care institutions), an evolution towards Integrated Personal Health and Care Services can be noticed [15]. These eCare services aim to fill the care gap between the patient (the care dependent), the informal care network (neighbors, friends), the primary (general practitioner) and secondary care network (physicians). Already a lot of eCare initiatives are being tested and deployed (e.g. The patient Briefcase, MyDoctor@Home, etc. [15]). Currently all these solutions are offered in a fragmented way. Offering these eCare services via a communal care platform could lead to less fragmentation and more integration of the service provisioning [13] [19].

Moreover, many of those eCare services fail or are being shut down after the pilot phase because they are unable to accurately predict their uptake [9] [20] [21], or because their offer leads to unexpected negative impacts on other relevant care actors. It is of crucial importance to make sure that the business case for each stakeholder for their service offering is viable, otherwise that service will not succeed.

Therefore, having a methodology and model for categorizing and assessing these various impacts for all the actors involved would be a great help when debating the best way of introducing eCare services.

6.2 Objectives

The goal of our research is to construct a model that is able to identify the impacts on the involved actors when offering eCare services (focus on eCare services only) in a qualitative (e.g. increase of patient self-actualisation level) and quantitative (e.g. decrease in administrative overhead for the formal caregivers) way.
It also wants to provide insights into why some eCare services work better or have a higher uptake than others. Next to an impact evaluation of a single eCare service, the model is able to evaluate complete service packages offered via an eCare service platform. Whenever an actor is impacted in a negative way, the model should be able to formulate service offer improvement guidelines based on the evaluations of the service.

6.3 Methodology

A four step methodology is developed for being capable of formulating service integration guidelines (see Figure 6-1 for a schematic overview). A first step is called target population modeling. By defining characteristics of the user target groups, the potential market size and its evolution can be modeled. In the following PEST analysis step, the qualitative and quantitative performance indicators (PI) of each actor involved are clustered according to their political, economic, social or technological level. The PEST analysis for each actor forms the basis of the service impact evaluation as third step. Whenever one or more services would lead to a negative impact on an actor, service improvement strategies and guidelines are formulated in a last step.

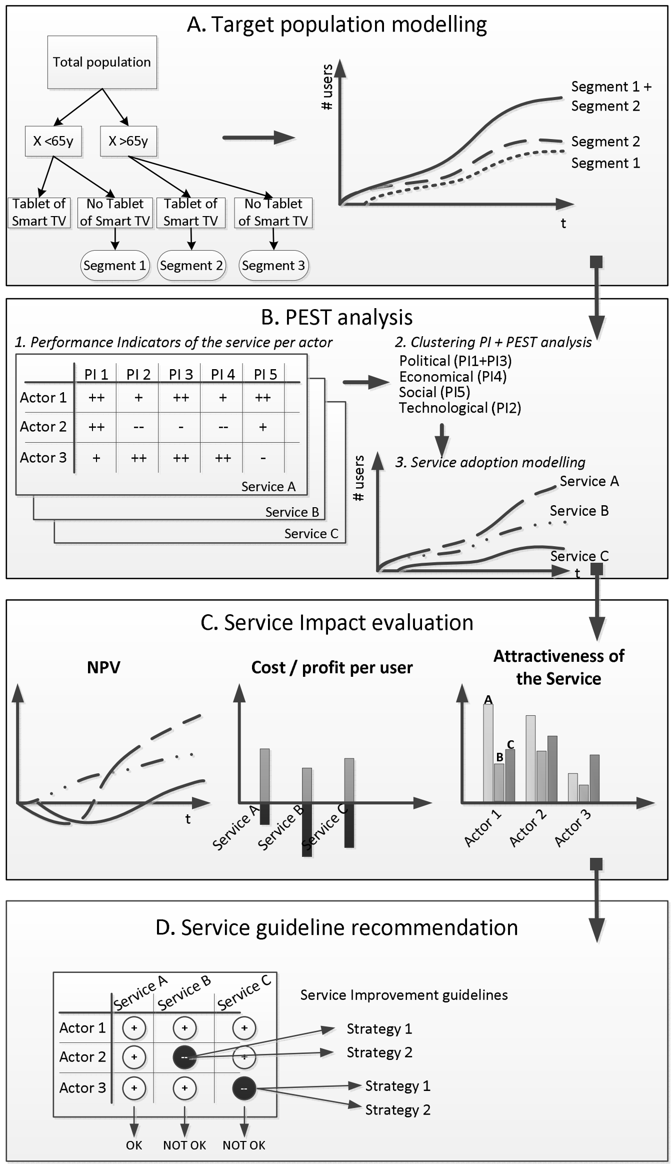

Figure 6-1: Schematic overview of the methodology

6.3.1 **A. Target population modelling**

Most eCare services address a particular group of users. Since it is a challenging task to estimate the size of this specific set of users, we started from the total projected demographic curve of Belgium [5]. Based on age, acceptance of technology, specific pathologies, service characteristics and other user requirements, potential user segments can be filtered from the entire population. For example: some services require a tablet or smart TV, other services require mental fitness or target users with hearing disorders, etc. Also time dependent variations of the user characteristics can be integrated (e.g. today 30% of the +65 population has internet access, within ten years this percentage could grow to >70%). To model this time evolution we rely on the adoption curve modeling theory of Bass or Gompertz [8] [22]. The results of these steps are time functions indicating the size and the evolution for each defined user segment. These segments can be allocated to one or more services. Figure 6-2 shows an example of a segmentation of the total starting population.

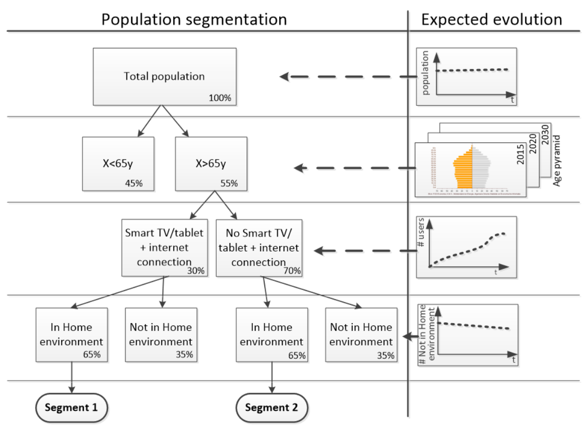

Figure 6-2: Population segmentation and customer segment definition

6.3.2 **B. PEST analysis**

Whether an eCare service will succeed depends on several PEST (political, economic, technological and social) factors [17]. Examples of these factors are: existence of an elaborated legal framework, protection of privacy (political); reimbursement of the service, needed investment (economic); social acceptance of personal monitoring services, privacy issues (social); technology gap and device uptake (technological), etc. The combination of those parameters will play a very important role in the market adoption of services [14].

To be able to formulate and quantify the PEST factors, the model needs both qualitative and quantitative performance indicators (PI) as input from each actor. Quantitative PIs are defined as the impacts on actors that can be described, quantified and translated into monetary results in a straightforward way (e.g. gains in time, decrease of costs, decrease of number of transports, change in operational processes, etc.) Qualitative PIs on the other hand are defined as subjective and personal experiences or psychological effects (e.g. the value of perceived mobility increase, peace of mind of a family member, decrease of anxiety of the care dependent, etc.) This type of PIs can be indicated on a measurement scale that is based on existing health utility indication systems as the visual analog scale (VAS), often used to determine quality of life (QALY) [4].

When all qualitative and quantitative PIs are formulated, the model clusters them according to the relevant predefined PEST parameters. PEST parameters on their turn influence the attractiveness, and therefore the adoption curve for a particular eCare service for a particular actor. If a service would lead to a positive impact for some actors, but to a worsening for just one particular actor, the overall uptake of the service will be highly impacted by this one actor. The latter could slow down or even block the adoption of the service. This approach allows modeling the overall adoption rate of a service based on 1) the time dependent evolution of the targeted user segment, 2) the attractiveness of the service and its expected impacts on all actors involved (See Figure 6-1 tab B).

6.3.3 C. Service impact evaluation

In this step, the model evaluates first the services individually and then makes a comparison with others when offered in a package. Several economic outcomes will be calculated e.g. the evolution of the net present value (NPV), the costs or profits per customer, the impact of the platform cost on the adoption of the services, etc. and will provide insights into the expected results of the service offers.

When providing an eCare platform that offers a complete service package consisting of various eCare services, one can expect that some costs can be shared and that economies of scale will lead to lower costs.

Therefore evaluating services packages is an important addition to a service individual approach. Some individual services could impact an actor in a negative way, but when offered in service package the overall impact of the total offer could be positive again through economies of scale, cost erosions, lower impact of platform cost and higher service adoption rate. The model allows calculating the impact of service packages and its service composition on its expected adoption.

6.3.4 D. Service guideline recommendations

Lastly, based on the evaluation results from the previous step, the model is able to offer viable strategies to improve a service. When the model detects that an offered service has a negative impact on a particular actor and therefore the adoption of the service is hindered (See Figure 6-1 tab D.), this sub model formulates some possible improvement strategies for making the service more attractive. The model indicates the value that needs to be compensated in order to obtain at least a neutral, non-negative impact. The model makes a suggestion for tweaking some parameters. For instance it could suggest that a higher subscription fee is required to compensate the actor for possible extra tasks; but also suggestions could be made for adding a certain service to the offered service package to improve the overall attractiveness of the service package.

6.4 Preliminary results

Since up to now focus of the research has been on the design of the methodology and model, fully validated results aren't there yet. Preliminary modeling results of the analyses of three different eCare services are already available. Due to the lack of validated data formulated by each modeled actor, the needed user input for the qualitative and quantitative performance indicators was formulated by field experts involved in the research project.

6.4.1 Modeled services and actors:

- PAS: Personal alarm system, a reimbursed alarm system that allows the user to alarm a local care center whenever the user is a danger situation. [7]
- Tele-Monitoring of the glucose level: Patients monitor their own glucose level and the results are sent to their care givers. Doing so, the care givers have always up to date data to diagnose on, without going to patient every day for obtaining the glucose level results. [10] [6]
- Fall Detection: A service that sends an alarm to the appropriate care giver (informal or formal) when a care dependent fell onto the ground. [16]

In the model following actors were distinct: patient/care dependent, informal caregiver (family, neighbors, friends, etc.), professional care providers (home nurses) and primary care actors such as general practitioners (GPs).

6.4.2 Result indications

Starting from the total Belgian 60 years+ population, eight different user segments were identified based on following criteria: age (>75y), technological requirement (Internet access), pathology or risk group (actual number of users of fall detection or PAS services). (See Figure 6-1 tab A for a segmentation tree). Using this methodology, each segment is mutually exclusive and therefore avoiding double counting of users.

This projected potential of users, combined with the impact of the qualitative and quantitative PIs, results in the total projected number of users per service (see Figure 6-3).

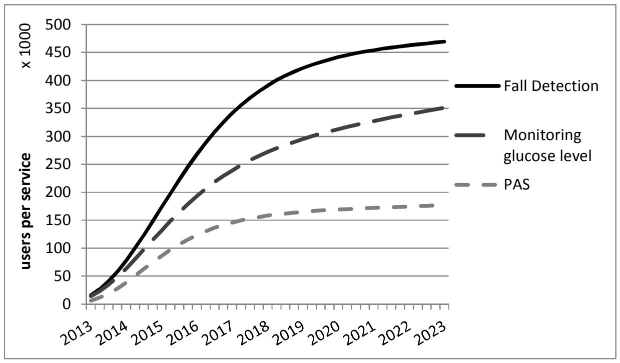

Figure 6-3: Expected evolution of users per service

Coupling and discounting the modelled costs (e.g. service upfront costs, platform cost, operational expenditures, etc.) and revenues (e.g. subscription fees, etc.) for each service to these adoption rates, leads to the projection of the Net Present Value (see Figure 6-4).

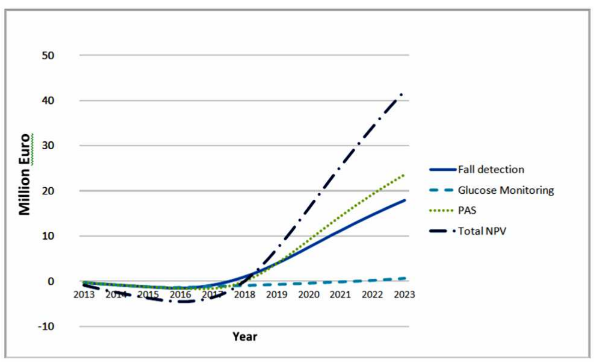

Figure 6-4: NPV analysis of the modelled service

Despite a significant market potential, one can see that from a service provider's perspective the service for monitoring the glucose level isn't interesting at all because of the long payback time and the low profits. But on the other hand, the PI analysis (combination of the qualitative and quantitative PIs) identified the glucose monitoring service as perceived the most valuable service by the informal caregiver and the care dependent (see Figure 6-5). Thus dropping the glucose level monitoring service would be a bad idea for an eCare service provider.

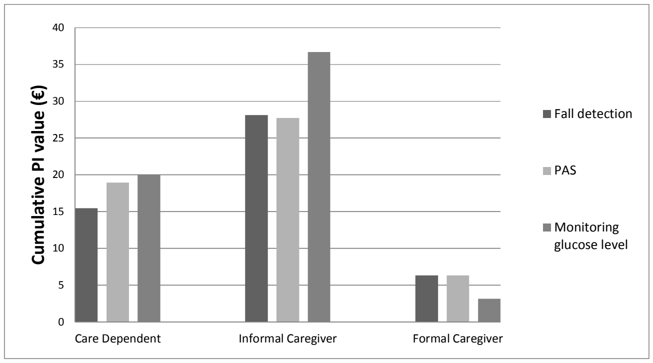

Figure 6-5: PI value per actor and per service

Looking to the cumulative PI impact of the glucose monitoring service on the different actors, the model indicates that formal primary care givers experience a much lower impact by using the service.

In a last step the model suggest decreasing the monthly service fee for the care dependent to compensate the extra burden that results from learning and using the service compared with a regular visit to the GP. Also previous research and literature [1] [21] showed that the lack of a legal and financial framework to compensate the GP seems to be a significant part of the problem. Today a GP isn't compensated to follow up the glucose monitoring results while investing time and losing direct contact hours and revenues. So without financial framework, this actor will only lose revenues by using this service. Today policymakers are looking to integrate these services into the existing care ecosystem [3]. This should make the service more attractive to use.

6.5 Conclusions

The methodology described in this paper allows to perform a multi-actor impact analysis on offering eCare services.

Through the categorization of actor individual quantitative and qualitative service performance indicators such as gains in time, decrease of costs and increase of peace of mind, etc. the model projects the expected adoption of the services.

Service and services package analyses (e.g. comparison of the economic profitability of the individual and combined service packages, the attractiveness of their added value and effects of economies of scale, etc.) provide meaningful insights in the overall impact of the service offer on the involved actors.

If a service isn't attractive for an actor and even could lead to a negative impact, the model formulates strategies for improving the service offer. Guidelines range from increasing the service subscription fee, other cost allocation strategies or increasing the overall added value of the service package by adding additional services to original package.

6.6 Future work

The methodological approach for evaluating eCare services may serve as a guideline to assess and justify the correctness and future perspectives for many systems which are now under development. An extensive validation of the methodology with direct input from the involved actors needs to be executed. Because the methodology derives the impact of quantitative PIs based on user input, it’s important to have clear defined translation multipliers such as QALY [18], otherwise the qualitative impact could be overestimated.

Acknowledgement

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Appendix

The goal of the paper presented in this chapter is to indicate the importance of obtaining a broader perspective when evaluating the impact of smart services in a multi-actor setting. It shows that next to the impact on the value network and the business models of the involved actors, also qualitative effects and the societal context contribute to the success and sustainability of the smart services.

The paper highlights the proposed methodology and discusses some of the outcomes. In what follows, the different methodological steps are discussed in more detail. Figure 6-1 displays the four main steps:

A. Target population modelling:
B. PEST analysis
C. Service impact evaluation
D. Service guideline recommendation

A. Target population modelling

In the first step, the potential magnitude of different market segments (target customers) these services address is modelled. The potential magnitude of the targeted market segments is a result of narrowing down or filtering the current national or international population size based on the type of target customers (e.g. 1) diabetics in Belgium, 2) aged over 60 years, 3) live at home) and the different requirements of the service (e.g. 4) have internet access, 5) own a smartphone). For each of these filters a different projected evolution over time can be modelled via for instance a Bass or Gompertz learning curve. For instance the adoption of smart phones could affect the growth of the target customer segment. The outcome of this step are time functions that describe the magnitude of the potential market segments over time. In Figure 6-2 illustrates this process.

B. PEST analysis

And essential part of the evaluation of the smart services is getting insight in the effects and costs (both the investment and recurring subscription costs) these services hold for the involved actors. The ratio between these effects and costs is conceptualized as ‘the service adoption ratio’ per actor (formula 1.1) and will influence the service adoption curve.

$$Adoption\ ratio = \frac{Quantitative + Qualitative\ effects}{Upfront\ investment + recurring\ fee} \qquad [1.1]$$

The effects are broken down into quantitative and qualitative effects. Quantitative effects have a direct monetary impact and include for instance the decrease in transportation time and costs, decrease in administration, less check-up calls, etc. These effects can be positive or negative (e.g. additional time investment required is a negative effect). Quantitative effects can be added per actor, will depend on the smart service and are expressed as euro per month.

Qualitative effects on the other hand are more subjective experiences and include: 1) Patient mobility, 2) peace of mind, 3) social contact, 4) self-care and 5) Vitality. For care providers, the quality of care and employee satisfaction have been defined as important areas of impact. Via a visual analog scale (VAS) the different actors can grade different qualitative effects from -3 to +3. The monetary value of these qualitative effects can be derived from the willingness to pay for these services and is also expressed as euro per month.

Although the main parameters are identified and quantified to derive the ‘attractiveness’ of the service for the different actors, ignoring the effect the broader societal context in which the service is offered would lead to an under or overestimation of the value of the service. This is because aspects such as privacy, regulatory uncertainty, possibility for reimbursement, ethics, technological illiteracy and economic prosperity are not included in the costs and effects of the service, but have also an indirect impact on the success and sustainability of the service.

In the proposed methodology, these contextual aspects are included via a PEST correction (Political, Economic, Social and Technological) for both the effects and the costs. The PEST factors can include following of components (non exhaustive list):

1. **Political factor (P)**
   - Potential percentage of reimbursement
   - Possibility for subsidizing
   - Impact of barriers such as privacy, responsibility, data ownership
2. **Economic factor (E)**
   - Current economic prosperity
   - Magnitude of grants for home care
   - State of pension
   - Net wage of informal care provider
3. **Social factor (S)**
   - Importance of privacy
   - Importance of social contact
   - Importance of qualitative effects for care providers
4. **Technological factor (T)**
   - Availability and access to internet
   - Overall literacy of new information technologies

The T-factor is already covered in the first step: target population modelling. By grading the several PEST factors, the service adoption ratio can be adjusted to the socio-economic context in which the service is launched (formula 1.2).

$$Adoption\ ratio = E\ \times \frac{Quantitative\ effects \times S \times P + Qualitative\ effects \times S}{Upfront\ investment + recurring\ fee} \qquad [1.2]$$

This adjusted ratio not only gives insights in how the different actors experience the service, but it also is used to model the expected adoption. It can be expected that a service with a high adoption ratio will be much faster adopted by the target segment than a service with a low service adoption rate. The overall adoption of the service follows a push/block principle, which means that if one actor encounters a negative adoption ratio, this actor will block further adoption. On the other hand, if no actors encounter a negative ratio, the adoption will be pushed by the most interested actor.

The outcome of this second step is twofold: 1) a projected adoption of the service, adjusted to the socio-economic context, and 2) the adjusted adoption rates (attractiveness rate) of all actor per service modelled.

C. Service impact evaluation

Per service included, the costs for the service provider are described**.** These costs can include both CapEx (e.g. initial investments in infrastructure) and OpEx (e.g. service maintenance). These cost can be fixed or variable according to the number of customers and can therefore vary over time. The model can also model cost erosions functions (such as decreased cost for service installation due to learning effects) and economies of scale effects.

Based on these cost data and the expected adjusted adoption of the service, an economic analysis is performed in the form of a net present value analysis from the perspective of the service provider. Via the NPV analysis the expected economic performance of one or combinations (e.g. platform approach) of multiple eCare services can be compared one another.

Next to the NPV also other KPIs are included to evaluate the service or service package. These KPIs include: 1) the maximum market potential, the payback period, the cost per client, the absolute costs, the adoption rate, cash flow analysis, the critical mass of clients to have a payback shorter than 3 year and the qualitative and quantitative effects for the different actors (Performance Indicators). The latter is shown in Figure 6-5, the cumulative PI value is the sum of the qualitative and quantitative effects per actor as described in the second step: PEST analysis. This KPI provides insights in the value of the service or service package for the different actors.

D. Service guideline recommendations

The adjusted service adoption ratio, which has been determined per actor in the second step (see formula 1.2), provides insights in the attractiveness of the service or service package per actor (See Table 6-1). Because of the block/push principle of service adoption it is important that no actor encounters a negative rate. If this would be the case, the service would not be adopted at all because the negative impacted actor will block it. At least a neutral cost/effect ratio is required for a sustainable adoption of the service or service package.

Table 6-1: Example of overview of the adjusted service adoption ratios per actor

Service	***Patient***	***Informal caregiver***	***Formal Caregiver***
Service A	Positive	Positive	Negative
Service B	Positive	Negative	Neutral
Service C	Negative	Neutral	Positive
Service package	Positive	Positive	Neutral

A sustainable service requires that the actor which encounters a negative service adoption ratio, should be compensated in one way or another in other to increase the ratio to at least a cost-effect neutral level.

To bridge or to compensate the negative gap, the four different components of the adjusted service adoption ratio can be changed. These four components are the upfront cost, 2) the service costs or recurring fee, 3) the quantitative effects and 4) the qualitative effects.

It is the service provider who has to decide which components should be adjusted, but the model provides also an automated suggestion. For instance if the gap for the patient is 50 euro per month, the service provider can be advised to lower the monthly recurring fee with 20 euro, the upfront cost with 20 euro and to remodel the service to increase the quantitative effects for this actor.

7
Conclusion

This chapter summarizes the main conclusions from the previous chapters and provides directions for future research on these topics.

7.1 Summary of the main conclusions

Overall interest in smart services is growing at a fast pace. This is not only driven by technological developments in the field of IoT and Cloud computing, but also by societal challenges such as increasing health care expenditures and changing perceptions towards for instance mobility and vehicle ownership.

Numerous smart services are already available in a variety of sectors. These services not only impact the way business actors and customers are interacting with each other, they also can directly impact the business models of the involved actors. This wave of new services demands actors to rethink their positions and roles within the value network. Not all sectors can easily adapt their business models or are not willing to do so because these new services can threaten their established businesses. At the same time smart services open new opportunities for many actors. To be able to evaluate the potential viability and impact of smart services, we need to understand how they impact the way businesses co-operate or compete, what their impact is on traditional business models of the individual actors, what potential barriers are for adoption and how to overcome them.

Therefore the overall goal of this PhD is to get insights in the impact of the smart services and to formulate a methodology to evaluate this impact.

The proposed methodology first focuses on identifying and formulating sustainable value networks for the smart services. Secondly, we narrowed the broader scope of value networks analysis down to analyzing the impact of smart services on the business models of individual actors. At last, the viability of a smart services is evaluated by taken into account the multi-actor aspect of smart services and the PEST factors (political, economic, social and technical) that could result in a decreased or even blocked adoption of the service.

7.1.1 Value network analysis of smart services

In contrast with many product centric business, the total added value of smart services is often a combination of added values provided by multiple actors (e.g. see the case of Nest in Section 1.4.1.a). To be able to understand how smart services affect the way actors are co-operating with each other to offer value to their customers, a first step is to describe the value network. This not only allows us to identify the roles and responsibilities of each actor involved, but also provides insights in what types of value that are interchanged with each other.

In Chapter 2, we identified various roles that should be fulfilled by the different actors involved in a home care setting in order to provide cloud-like eCare platforms to the clients which are in this case care-receivers and their relatives. This identification process was the result of multiple interviews and workshops with all involved actors and formed basis for the formulation of following different go-to market strategies: eCare platform provided by the care organization, eCare platform provided by service flats providers, eCare platform as billing and scheduling tool for care organizations, and eCare platform with government reimbursement. After describing the value for each actor, the go-to market strategy in which the eCare platform would be offered as tool for simplifying the billing and care scheduling processes was indicated as most viable. But in this scenario only a fraction of the full potential of this smart service is being used. In addition several barriers for adoption were identified. These include: lack of evidence of its added value, technological barriers, privacy and legal concerns, lack of financial structures, and a low willingness to pay. To overcome these barriers a migration path was developed that suggests a stepwise integration and slow release of all the eCare platform functionalities in order to achieve true patient centric care. This migration path proposes a four step integration of the eCare platforms to evolve from an organization-centered model towards a patient-centric care provisioning. These steps are: 1) home care organizations use the eCare platform purely as tool for simplifying the billing and care scheduling processes, 2) the care organizations start using other functionalities of the care eCare platform such as the shared care record, this allows better quality of care due to better information, 3) The eCare platform opens up its several functionalities to other care providers such as general practitioners, nurses and care providers. This is a first step to cross-organizational collaboration via the eCare platform. At last, in step four, the eCare platforms can also be used by the patients themselves to interact with their relatives and both formal and informal care providers. This is seen as the last step because by that time more elderly people will be familiar with these technologies and will be supported to use it because all their home care providers are already using it.

Also in other domains of smart services this step of the proposed methodology, value network analysis, can help to uncover the real sources of added value and to identify the roles and value exchanges between the actors. For instance, many smart services generate revenue from the data they capture. Although value of data can be much larger than the profitability of offering the service to the end users, it is often not visible or known by them. Digital customer loyalty card programs, context capturing mobile applications or IoT devices (see Section 1.4.1.a, the case of Nest), and smart mobility services are just a glimpse of them.

7.1.2 Evaluating the impact of smart services on operational processes, business models and analyzing the costs

Smart services and their value network can only be viable on the condition these services do not harm current revenue streams of the actors. Except for radical changes in the business strategy it is unlikely an actor would be willing to shift away from a revenue generating business model to a new business model that results in a decreased revenue stream. To determine the impact smart services have on the business models of an individual actor, we argued that the effects of the smart service on the business strategy and operational process should be identified and quantified as well as the effects on the cost structures.

In Chapter 3, a discrete event simulation (DES) model was developed that allows to evaluate the effects of an ontology-based nurse call system on the operational processes of nurses in eight different scenarios. This service includes ‘smartness’ in traditional nurse call systems, installed in elderly homes and hospitals, by assigning calls to nurses based on context information such as trust relationship, type of call, and staff competences. The DES model simulated patient calls (events) based on realistic historical data. These calls triggered the nursing staff to act what could be immediate response and going to the specific patient room or redirecting the call. The performance of the system was measured via different key performance indicators (KPI) such as balance of the workload, maximum waiting time before answering a call, number of redirected calls, and distance walked per shift. Comparing the KPIs of both traditional nurse call systems and an ontology-based nurse call systems showed that the latter can result in increased operational performance in specific scenarios.
This DES modelling approach therefore proves to be useful for managers to determine the potential impact of smart services on the operational processes.

This is certainly the case when the flow of the operational processes depends on several attributes and nonlinear characteristics of the product, event triggering data, or person involved in the process (e.g. trust relationship, type of alert, previous state of the product). Also in case the process is subjected to time-varying uncertainties (e.g. seasonality) DES can be useful to model the impact of the smart service on the process performance. Other domains in which DES could provide insights in the impact of smart services are smart transportation (e.g. smart traffic lights).

Next to considering the impact of smart services on the operational processes, also cost aspects of providing IoT-enabled smart services have been focused on. In Section 1.2, we argued that IoT is a major driver for smart services. But introducing IoT-functionalities such as context monitoring and controlling actuators impacts the cost structures of the business models. Not only capital expenditures are required for purchasing and developing the hardware, firmware and eventually backend infrastructure (see Section 1.2.1). In many cases, IoT-enabled smart services can result in additional operational processes and costs for the service providers. These operational expenditures can include: periodically replacing or charging batteries, management and maintenance of the IoT-devices, cost for tele-communications, and maintaining the IoT-network infrastructure. Depending on the chosen network technology, these costs can have a significant impact on the cost structure, certainly in case of large scale deployments. Therefore a two-step methodology was presented in Chapter 3 that guides IoT-developers and providers in choosing an appropriate IoT-connectivity technology. A wide set of technologies, which is continuously expanding, is available. All these different technologies (e.g. LoraWAN, Sigfox, BLE, Satellite based communications, GSM and LTE) have different characteristics both in functionalities and cost related aspects. The first step of the presented methodology narrows down the available choice set based on mismatches between the functional requirements of the smart service and the functional characteristics of the IoT-connectivity networks. To do so, a questionnaire had been developed, which eliminates IoT-connectivity networks based on requirements of the IoT-application such as data or payload requirements, and end node related requirements such as the need for over-the-air (OTA) updates. As a second step the methodology proposed an economic comparison of the CapEx and OpEx costs resulting from the remaining IoT-connectivity alternatives. The model was been applied on the case of the port of Antwerp, in which the goal was to optimize operations by tracking and monitoring the containers. The proposed methodology could be used for a various set of IoT-enabled smart services ranging from personal health monitoring to nationally deployed smart water meters.

Next, in Chapter 5, an overall economic evaluation of the eCare platform introduced in Chapter 2 is performed from the perspective of a home care organization. By analyzing the impact smart eCare platforms have on the various stakeholders, it was found that home care organizations would experience direct quantitative impact due to the simplification and optimization of the their billing and care scheduling processes. Both processes proved to be very time- and labor intensive. By breaking down the activities and processes of a home care organization using BPMN, the process steps, affected by the smart care platform could be detected. Quantification of the total impact on the operational processes was done via comparing the traditional ‘as-is’ and future ‘to-be’ scenarios with integration of the smart services. Combining this impact or benefit with the modelled costs (CapEx and OpEx) required for integrating smart services allows evaluating the economic impact for the care organization. The economic evaluation was followed by a sensitivity analysis to monitor the effect of input uncertainties. When applied to a home care organization in East-Flanders, the results of this research indicate that a direct cost reduction of 38% can be expected. On top of that, smart care platforms could free up a lot of time for the care providers due to decreased administration. This could therefore increase the quality of care or could result in more clients. Because home care organizations benefit from integrating smart care platforms, it is likely they will contribute or stimulate future adoption of these smart services.

Although the different methodologies presented in Chapters 3-5, have been validated via cases in the smart health application domain, their approach is generic. The methodologies not only focus on identifying added values and quantifying the impact of smart services on the operational processes and overall business performance, but also on the cost aspect for integrating these services. Therefore these methodologies can also be applied to evaluate the impact of smart services of individual actors in a wide range of domains. Examples in which these methodologies have been applied are: evaluating the impact of smart dairy monitoring systems for a dairy farmer, and quantifying the value of smart container monitoring services from a shipper’s perspective.

7.1.3 **Detecting barriers and evaluating overall multi-actor viability of the smart service**

A positive impact on the business model or service experience of one of the actors within the value network is the absolute minimum requirement for a smart service to be value adding. But this is certainly no guarantee for a sustainable value network of the smart service. If the business models of one of the involved actors is impacted negatively compared to the traditional model (e.g. reduced visitor frequency, reduced revenue stream, unbalanced cost-benefit allocation) chances exist this actor will not adopt or even block further adoption of this service. In a final evaluation step presented in Chapter 6, the added values and benefits of the involved actors are compared one another. This step also includes the identification and quantification of potential PEST-barriers. Depending on the perspective of the actors involved in the smart service, both quantitative (e.g. decrease of anxiety and increased peace of mind) and qualitative (simplified processes, increased customer visit frequency) Performance Indicators (PI) could be identified. These PIs then are clustered according to the PEST-barriers. These barriers can for instance be 1) the lack of a political or legal framework (e.g. data ownership, legal ambiguities on tax structures in a sharing-economy), 2) economic barriers such as the required investment and a lack of viable revenue streams, 3) social barriers such as service reluctance because of privacy concerns and at last 4) technological barriers (e.g. digital illiteracy of elderly). These PEST-barriers will influence the total added value of the smart service for one or more actors and can therefore be used to compare the overall viability of several services. In addition, the methodology also presented high level guidelines based on the type and magnitude of these barriers in order to be able to formulate a viable smart service offer for the involved actors. These guidelines or suggestions for improvement include for example: service subscription cost should be lowered by a certain amount, the qualitative added value of the service should be increased or the upfront investment is too high.

In conclusion, the work provided in this dissertation presented a methodology to gain insights in the total impact smart services have on the value network of involved actors, their operational processes, cost structures, individual business models, and formulated high level guidelines to overcome potential barriers for smart service adoption.

The cases described in this dissertation are mainly situated in the area of eCare. This is because these innovative smart services are believed to have a significant potential to overcome current societal challenges but at the same time it can be hard to identify and quantify there potential impact. Therefore these cases are not only suited as use cases, but the outcome of this work can also contribute to future evaluation methodologies for both eCare service providers as well as policymakers.

But due to its generic approach the methodology can be applied to the broad field of smart services as a whole. Smart services in many different application domains (e.g. smart homes, smart offices, smart agriculture) face similar challenges concerning quantifying the impact, which need to be clarified in order to formulate a sustainable smart service offer.

7.2 Future research

Due to the broad scope of the field of smart services and the generic methodology to evaluate them, we believe that future research tracks can lead to even better insights in specific characteristics of several application domains of smart services (e.g. the strong regulated healthcare market versus the competitive market of the Industry 4.0 domain).

A first extension is on the **identification and categorization of application domain related characteristics of smart services**. Describing, listing and specifying multiple characteristics of smart services which have been identified via our evaluation could be valuable for providing more specific guidelines to overcome certain barriers related to specific domain applications of smart services. Also, such a structured description of the smart services can be used to investigate the possibility to transfer smart service business models from one domain to another (e.g. Can typical value network configurations of smart home services be applied to the field of smart health services?). Categorizing smart services will require the formulation of generic service characteristics and key performance indicators. The categorization methodology should allow grouping services with similar characteristics or KPIs dynamically.

Second, the PEST aspects of the context in which the service is provided can have such an important impact on the service that it can be **worthwhile to further elaborate on these PEST context barriers**. Transaction costs between different actors, the impact of General Data Protection Regulation (GDPR) of the European Commission concerning data processing, ownership and privacy, the importance of social awareness (e.g. ecology) and the effect of a fast changing technological landscape versus slow adopting users are just a glimpse of additional aspects which can contribute to the success or failure of novel smart services.

A third extension is on the **quantification of the value of data**. As noted in this dissertation, for many smart service offerings the gathered data becomes an important resource. This is illustrated by the interest of for instance Google in Nest. Also recently the U.S. Senate approved Internet Service Providers (ISPs) to sell the web browsing history of their clients to third parties. However, the inability to quantify the value of data streams forms currently a gap in both the value network and economic analyses. Proxy-methodologies such as asset valuation techniques via historic, market and utility values, described by Moody and Walsh [41] are available but need to be validated. Also it is uncertain these retrospective methodologies can be applied to innovative smart services. Data resulting from smart service can range from raw sensor readings of millions of devices to complete profiles of a niche group of smart service users. Data characteristics such as volume (magnitude of data stream and storage), variety (type of data: structured versus unstructured, discrete versus continuous), velocity (how fast must the data be handled) and veracity (data certainty and precision) will depend heavily on the type of smart service and will all impact the value of it. This research gap could therefore be an opportunity for future research.

At last, a fourth extension is on researching new methodologies for quantifying the value of qualitative effects of smart services. As indicated in Section 1.6.2 and Section 2.3.2, for smart care services there exist scoring methods to quantify the quality of life and derive the societal willingness-to-pay for a year in perfect health. These methodologies allow us to express the impact on qualitative effects in financial value. However smart services will also affect other personal experiences. Privacy protection or intrusion is such a qualitative aspect of which the importance is still increasing. Several smart services require or gather directly or indirectly a lot of personal data. Depending on the service and the level of person related data gathering, this can result in reluctance towards the smart service and even and adoption barrier. To be able to quantify this effect, future research on such methodologies is required to capture the value of privacy and other qualitative effects.