Universiteit Leiden

ICT in Business

An IT Healthcare Platform Driving Improvements in the Dutch Healthcare Process

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MASTER'S THESIS

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"*It is the mark of an educated mind to be able to entertain a thought without accepting it."*

Aristotle

"Education is the most powerful weapon which you can use to change the world."

Nelson Mandela

Abstract

Today we observe that a lot of people have no possibility of going to hospital due their age or financial situation. Others need constant monitoring and their daily movements are painful due to serious diseases. Moreover, a lot of people are victims of serious accidents in their daily life or suffer from chronic conditions. As a result, they all are in need of immediate help either at home or in public areas.

Personal Health Systems are a very promising and critical solution in the new healthcare industry development. Such systems can assist applications such as chronic disease management, life-style management, remote monitoring and emergency handling offering the comfort of independent living. Such systems are about to play a vital role in the near future, as healthcare industry is moving towards a patient-centric care, and knowledge distribution, supported from the Internet of Things, is rapidly increasing.

Our research focus is a home based personal health system (In-Home Box) that could facilitate patients' life via a unique comprehensive solution for the overall medical and medication management needs. This system, composed of various devices, will be equipped with a software platform for the support of the promising healthcare service delivery in the emerging IoT cloud-based ecosystem. The system, although designed to have a bigger vision, was adjusted as an incremental step to the Dutch health care process. We tested the systems architectural design and components, as well as the impact of using it in the Dutch healthcare process for resolving existing bottlenecks and problems. The results of the hypothesis are clearly described in the final chapters and further recommendations are made in order to expand the system from a business and societal perspective.

Keywords: Internet of Things, IoT, Healthcare platform, Dutch Healthcare Process, Patient oriented platform, In-home treatment, Distant monitoring

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1. Introduction

This Research Thesis will focus on the “Internet of Things” in the healthcare industry. Our research will consist of three basic parts. Firstly, we will propose an architecture for an IT platform which will be located in the home of the patient. Secondly, we will focus our work on identifying problems in the existing process of the Dutch healthcare. Finally, we will analyze how the proposed platform can be included in various inefficient steps of the healthcare process in order to improve and support it.

In the following chapter we will try to explain the roots of our research and the reasons that stimulated it. Moreover we will analyze the means that will be used for the analysis of the identified problems.

1.1 Background

In the last ten years there is a sharp increase in the number of portable devices that are used everyday life [1], from laptops to smartphones and tablets. According to Cisco IBSG research, the numbers of those devices will reach a number of 6.48 devices per person in 2020 [2]. The latter, in addition to the increase in the number of devices that are connected to the internet, and thus interconnected among them, is leading us to a new era where everything will be connected to the internet [3]. This phenomenon is better known as “Internet of things”, from now on mentioned as IoT, and due to characteristics such as keeping up in a constantly changing environment and managing a huge amount of diverse data it is described by great complexity [4].

The main issue, to the above described phenomenon, is the way in which all those devices will be connected. Questions such as, ”what kind of technical infrastructure is needed?”, “what security measures will be used?” and “what regulations will govern the ecosystem, inside which those devices will be connected?” are still to be answered. The major problem that did not allowed the development of IoT earlier has to do with the complexity of the ecosystem and the number of players that are part of it [5]. The above described problems and issues are even more easily recognized in an industry such as the Healthcare Industry that is considered “uncharted waters” [4] in an IoT perspective.

Implementing IoT technology in the healthcare industry can face a lot of obstacles. On the one hand we have new emerging trends of healthcare related problems

that have to be addressed and on the other hand we have to deal with problems from the existing processes in the healthcare.

Today we observe that a lot of people do not have the possibility of going to hospital due to their age or financial situation. Sometimes they are obliged to stay longer at the hospital, which increases their medical expenses and costs [6] [7] [8]. Chronic disease patients need constant monitoring and many times they are in constant pain due to their daily movement needs [9]. Moreover a lot of people are victims of serious accidents in their daily life or suffer from a chronic medical condition. Due to all the previously mentioned issues there is an emerging need for constant help either at home or in public areas.

The second challenge we are facing has to do with the problems in the existing process of the healthcare environment. Problems like the communication between patient and various players of the ecosystem [10] [11], the communication among the different platforms that are used [12], the repetitive steps, the patient's frustration and the data sharing concerns are growing and thus becoming even more difficult to be dealt with.

1.2 Research Objectives

For our study we will focus on three basic pillars. Those are, The Proposed Architecture, The Analysis of the Dutch Healthcare Process and the Facilitation of the Dutch Healthcare through the Proposed Architecture.

The above described pillars can be further analyzed in the below listed objectives that consist the base for our research.

1. The primary objective is to propose a heath IoT platform that will facilitate the patients' everyday life.
2. The second objective is to measure the functionality of the platform in regard to the architectural decisions, as well as evaluate its' performance based on the patient's needs.
3. Identify the Dutch healthcare process and define the existing bottlenecks and problems that are present at the moment.
4. Pinpoint steps of the Dutch healthcare process in which the proposed platform can be included and improve them.
5. Evaluate the possible outcome from the proposed changes and measure the effect on the industry players.

1.3 Research Questions

The research questions and sub questions that are emerging from the above defined background and objectives are the following:

- Research Question 1: *"What architecture can support a patient-centric In-Home Internet of Things platform?"*

  Question 2.1: What are the basic components of the platform?

  Question 2.2: What are the secondary devices that can be used for such a platform?
- Research Question 2: *"What are the architectural choices for creating a patient-centric in home Internet of Things platform?"*

  Question 2.1: Which technologies (e.g. protocols, software) are used and why?
- Research Question 3: *"Which are the most important bottlenecks/problems in the Dutch Healthcare Process?"*
- Research Question 4: *"How do we improve the Dutch healthcare process for chronic disease patients via a patient-centric in home Internet of Things platform?"*

  Question 4.1: What are the needed changes?

1.4 Research Relevance

Very little research has been conducted so far in the topic of Internet of Things. Most of the researches are focusing on the technological needs for implementing and combining such systems, but very little focus has been paid to the relationship between the different players of such an ecosystem and their cooperation [13]. In addition to the above, efforts to apply IoT in the previous years were unsuccessful [14]. Internet of Things is even more unexploited in an industry like healthcare, where there are great concerns in regard to patient's data sharing, great degree of resistance to change and huge multinationals companies with different interests. Due to the limited research in the above described points it becomes clear that a need, for further and deeper research about the IoT in the healthcare industry, is emerging. Therefore the first contribution of this study has to do with setting up solid foundations for future research in this topic.

On the other hand, according to Everett Koop [15] the health-care system reforms can change the current status quo of the industry. Healthcare is moving from centralized large hospitals towards a much more home-centric and patient –centric care, as economy of scales for all the participants in the industry is becoming of the utmost importance. Consequently the idea of in home healthcare services supported by various technological devices is more urgent than ever. Already efforts, either from huge companies of the technological industry [14] or by researchers [16] and small startups are made but almost no one tried to provide a more complete solution. As part of our research we will like to propose an architecture that will be able to offer a concrete healthcare platform serving all the needs of the patient. Our research regarding the architectural choices can prove to be a good starting point, as flaws and functional problems will be identified, allowing the future researcher develop much more secure and efficient platforms.

Finally, for the last couple of decades governments are investing huge amounts of money in IT systems that can facilitate the healthcare process and by that minimize the costs for all the actors in the industry, from patients to hospitals and insurance companies [8]. Despite all the technologies and systems that are developed in that direction, most of them either fail to reach the expected result or are not used due to constrains from the regulations and the unwillingness of the actors in the industry to use them. In our research we will try to define the bottlenecks and problems in the Dutch healthcare process and following that we will propose some minor changes that can improve the communication of the various players and the process in total. That part of our work can help future research by mapping some steps of process and needs of the patients. Thus allowing them to have an understanding of the research mindset change applied on their projects in order to add value for the patient that is most the important “element” in the healthcare ecosystem.

2. Thesis Outline

This thesis is organized as follows. The first chapter is introductory to the reader, it describes the reason of the study and it provides a review of the current situation, both in regard to the academic and business research. In that part of the thesis the reader will get a clear picture of the existing problems through the presented research questions.

In the third chapter we describe how we will tackle the previously described problems, in other words we analyze the used research methodologies and designs, as well as the data collection means.

Chapter four and five present the proposed platform architecture and the analyzed process based on our research. Chapter 6 includes the changes in the process and actually embeds the two previous parts of the study into a solid and more tangible result. Chapter seven follows with an analysis of all the hypotheses that will be tested. These hypotheses are based on existing literature and parts of our work.

The final two chapters are about the analysis of the data, testing the hypotheses and reaching conclusions for this study.

2.1 Research Stages

Our research will follow the below described stages. Those stages can be listed in seven steps (see figure 1):

1. Background and Research Questions
2. Hypotheses based on proposed scenarios
    a. Proposed Architecture
    b. Identification of Dutch Healthcare Process
    c. Proposed changes in the Process
    d. Hypotheses Definition
3. Survey Formulation
4. Data Collection and Analysis
5. Hypotheses Testing
6. Conclusions
7. Recommendations and Future Research

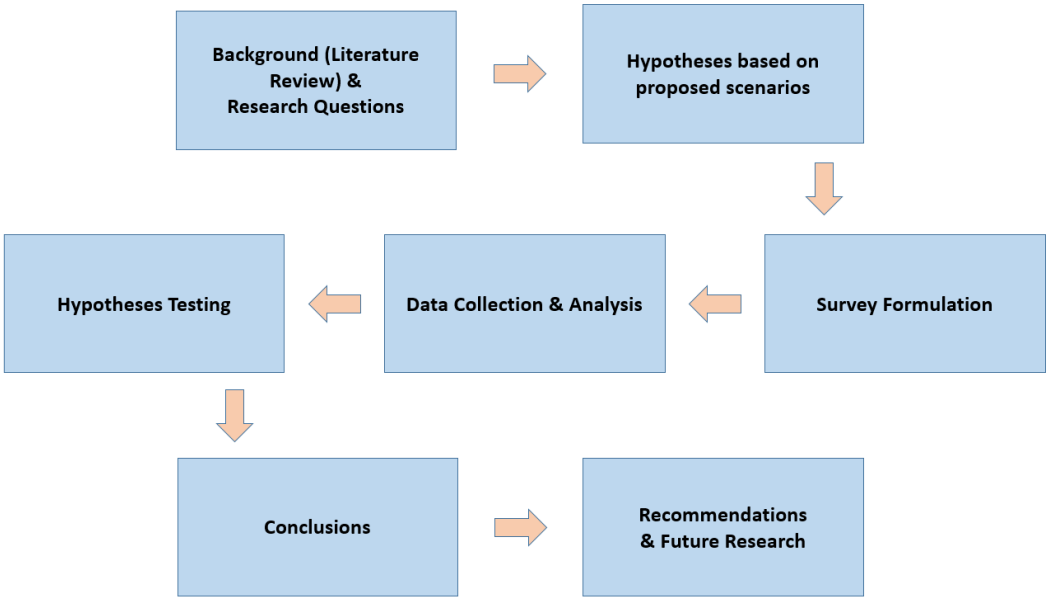


Figure 1. Research stages flow.

3. Method

3.1 Research Methodology

In this chapter we will focus on explaining the research design we will use for our research, as well as the methodologies and the objectives. Moreover we will give a description of the “to be formulated” survey and the sample of the participants and its size.

3.1.1 Research Design

The goal of this research is to create a connection between the IoT technology and the healthcare industry by proposing an in home, patient – centric platform. After that we will research ways of making use of that platform in the healthcare ecosystem. Therefore, we will use an exploratory research design as the investigated topics are quite new and unexplored. Research questions one and two, as well as their sub questions, are focusing on validating the proposed architecture and what technological choices should be made in the future for building such a platform.

The second part of the research will be a literature review, in which with use of existing literature we will analyze, in a stepwise approach, the Dutch Healthcare Process of chronic disease patients for receiving care services. The outcome will be to list the most important problems/bottlenecks of the process. This stage of the research will give answer to question three.

The third and final part of our work will be an exploratory research design. Based on the previously completed work we will aim on improving the Dutch Healthcare Process. More specifically, we will try apply various functionalities of the proposed InHome platform either inside the process or complementary to the existing process in order to improve issues identified in the second part of the research. For validating our work we will conduct a survey research which will be addressing most of the key players in the industry asking for their opinion of the proposed changes and their impact on patients and various actors of the ecosystem.

3.1.2 Research Methods

For collecting the data for the two part of our research the following methods, see picture 1.1 and 1.2, will be used:

3.1.2.1 Research Method Proposed Platform & Architecture

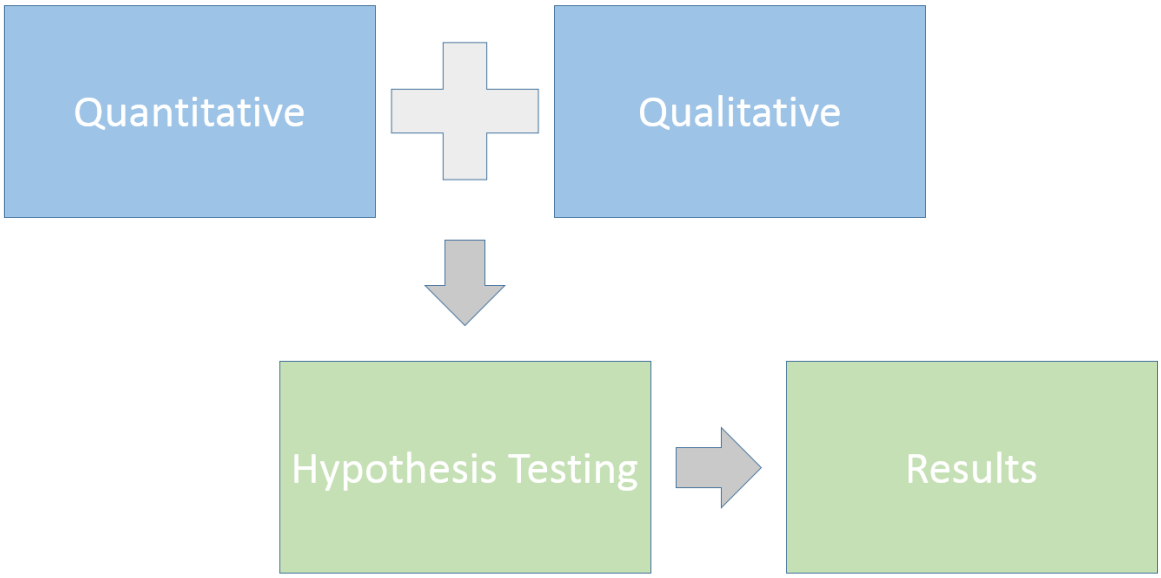


Figure 2. Research Method of Proposed Architecture Part

In this stage of our research we will make use of multiple methods. For collecting our data we will use surveys. In an effort to have more accurate data and for reaching more concrete results, the survey will include both category type, ordinal type and continuous questions, which by being answered provide quantitative data, and open questions that can give us greater details. The sample group we are aiming is technical or a combination of technical/sales professional that have field experience and can give us insight of the usability of the platform.

After collecting and analyzing the data we will compare the results with the architectural choices we made in the “building” process of the platform. For the evaluation and analysis of the data we will make a hypothesis testing.

3.1.2.2 Proposed Changes in the healthcare process

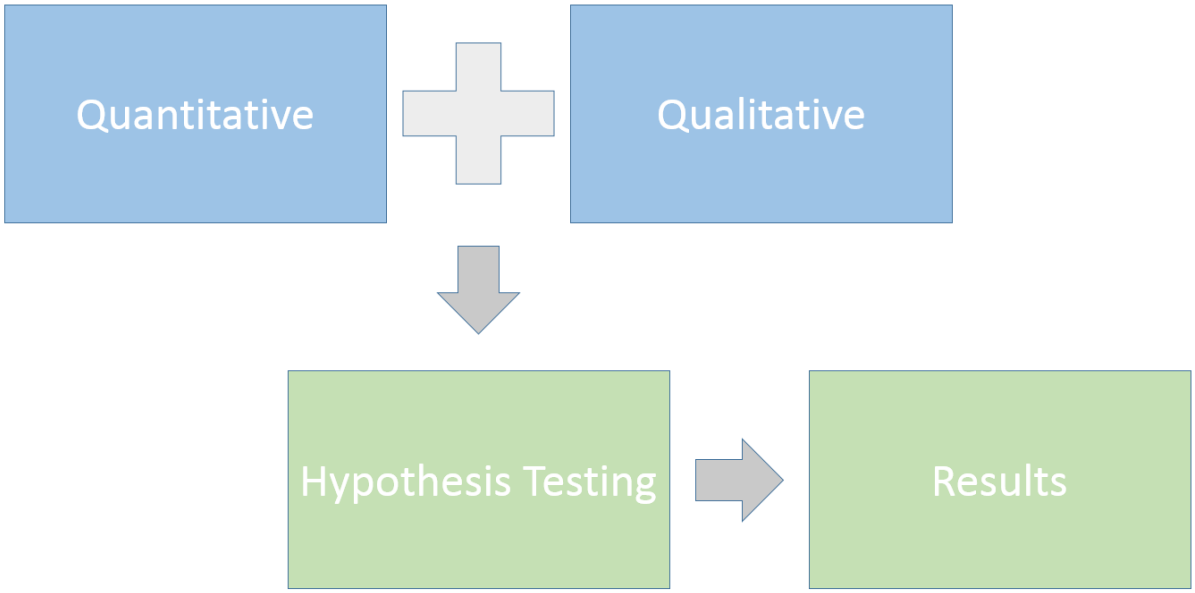


Figure 3. Research Method of Proposed Changes in Healthcare Process Part

For evaluating the proposed changes we will also make use of multiple methods. The data collection will be completed by both interviews and surveys. The reason for that choice has to do with the difficulty of approaching the aimed sample group. We previously mentioned that the participants of the research will be healthcare industry players, from patients and general practitioners to hospitals and insurance companies. So in order to tackle the unwillingness of participants we decided to collect data through interviews whenever that is possible, in an effort to increase the accuracy of the research, and surveys for all the other participants.

The next step, as soon as the data analysis is completed, we will be to test the hypothesis that emerged from the literature and our work.

3.2 Survey

In this paragraph we will give a description of the surveys formats and contents. Furthermore information regarding the questionnaires formulation in regard to the expected results is added. Finally, we will provide description of the aimed participants sample and its size.

3.2.1 Survey Details

3.2.1.1 Architecture Survey

The survey will be designed with the following structure: The first questions will aim on providing some information in regard to the participant's information. Such questions can allow us to make connection between the results and the background of the participants.

After that we will include some more general questions about IoT technologies and their connection to the healthcare industry, they will serve as an introduction to the topic for the participants. In the next part of the questionnaire more focused questions will be included, which will be designed for validating the architecture and testing the hypotheses. Most of them will be scale, check box or multiple choices questions. The reason for this choice is our aim to receive as clear results as possible in order to "shed light" in that foggy part of our research. In addition to the previously mentioned questions we will also include open questions in the questionnaire in an effort to gather more details, which can prove very useful for our conclusions and future researches. The final part of the survey will include some concluding question that will be asking participants for their overall opinion for the choices and hypotheses that were made.

3.2.1.2 Process Proposed Changes Survey

The survey has been designed with the following structure: The first questions will be aiming on providing some information in regard to the participant's information. Such questions can allow us to make connection between the results and the background of the participants, as well as provide some insight about the knowledge level of the participant in the researched topic.

Following that we will tackle the main issue of the proposed changes in the Dutch Healthcare Process. Questions, like scale, check box, multiple choices and open questions will be formulated in order to get answers to the proposed changes and their impact for all the player and the process.

Finally as in the previous survey we will include the concluding question that will be asking participants for their overall opinion for the choices and hypotheses that were made.

3.2.2 Survey Respondents Selection

3.2.2.1 Architecture Survey

The survey participants, as described in previous paragraphs, have to be technical specialists or technical/sales professional with experience in one of the following fields, electronics/automation/telecommunications engineering, information technology architects or sales of technical equipment in the healthcare industry.

Therefore, the survey will be sent to professional from Cisco and Philips, two of the biggest providers of technical healthcare equipment. Also various individual professionals, from medium and small technical companies but with experience in electronics and networks, will be contacted. Due to the needed connection of the professional with healthcare industry there will be limitations and maybe unwillingness to participate in such study. As a result we consider a sample size of about ten participants enough for the moment. A bigger number of ten research participants for this architecture survey could be considered as a first positive and satisfactory result.

3.2.2.2 Process Proposed Changes Survey

The participants of this survey are much broader sample group. The survey has as a goal to evaluate the validity and impact of the proposed changes. Therefore, the focus group apart from patients has to include all the other major players in the ecosystem, such as hospitals, insurance companies and general practitioners.

The main focus will be in chronic disease patients and people from the remaining categories that are working in related tasks with the above mentioned patient group. Here the limitations are even greater than the other part of our study because not only there is no willingness of participation but also there are very few people with a clear understanding of the overall healthcare process. As a result, we are aiming on a number of eight to ten collected surveys. Here it is worth mentioning that instead of just filling the questionnaire, we will try to interview, whenever possible, those participants in order to retrieve more information and results despite their limited number. A bigger number of ten research participants for this process survey could be considered as a first positive and satisfactory result.

4. Proposed In-Home Healthcare Platform

The architecture of the proposed In-Home system will fully support the patient at home offering the possibility to automate steps of the healthcare process aligned with the future expectations of the healthcare industry for home-centric care.

4.1 Proposed Architecture

4.1.1 High Level Architecture Description

The proposed architecture describes a system that will be located in the home of the patient. The main device of the system is called the "InHome Box" and complementary to it we will connect various devices, both primary and secondary. Those devices will facilitate the functionalities of the box and support the everyday life of the patient.

The architecture of the InHome Box consists of three layers supporting the three level network architecture.

1. The first layer is **the Patient layer** where the user/patient is acting transferring his/her medical data through the sensors (wearable medical devices) and multimedia components to the health box. There are various connectivity links and communication technologies that support the data collecting methods. Some of the proposed technologies are the ZigBee WSN protocol, to support the communication between the medical devices and the InHome Box, the RFID (Radio Frequency Identification) technology used for the smart pillbox, Wi-Fi for tele-conference, and access to the web and NFC to authenticate the user trying to log into the in-Home Box and make use of the services.

When the data are collected from this layer they are transferred to the second layer where they are stored to the platform of the in-Home Box which acts as the InHome healthcare gateway for the user.

2. The second layer is the **InHome Box layer** where the data are collected through the previous layer via the previously described channels (ports) connected to the integrated smart tablet that is designed to support professional health applications. The data are mainly processed through the bio-circuit and the smart pillbox and finally transferred to the local medical database of the in-Home Box.

This layer is also supporting the data processing and encryption of data. The design parts of the box consist of medicine blocks with the smart pillbox at the bottom, an ultra-high frequency (UHF, Ultra High Frequency) RFID reader, an RFID antenna, a Wi-Fi antenna, a ZigBee receiver and an integrated touch tablet communicating respectively through wireless technologies with all types of devices. The bio-circuit is collecting all the vital signals coming from the medical devices, converts them into a digital format and transmits them wirelessly to the local database or to the platform for real time display for the doctor. Under the pillbox we use a weight sensor to track the weight variation of the medicine packs used from the patient and calculate the remaining/correct dose that is stored in the database.

The data that are stored to the InHome Box will be handled centrally from the patient and only a mirror of this data will be also copied to a private cloud accessible at first place from GP and in future from various key health players.

3. The third layer is the **private cloud layer**. This layer is supported from the platform of the in-Home Box in order to provide access not only to the patient but also to GP to check the copy of the medical data from the local database. This mirror of patient's data is fully synchronized with local database of the box. The authentication that will be provided will be the most secure in order to enable only the authenticated GP or a 3rd party to access the data.

This layer will act as the smart medical layer where the authenticated 3rd parties will login in order to check the data of the patient and provide the health service in an automated way.

A description of all the components of the architecture for each layer follows in chapter 4.1.2.

4.1.2 Analytical description of the Architecture: Components per layer

The architecture of the In-Home Box is an open platform consisting of a 3 layer architecture, namely the Patient Layer, the InHome Box Layer (functional system architecture) and the Private Cloud Layer. The components that are described below are divided per Layer and fully support the technical consistency of a unique healthcare home centric-platform:

LAYER 1: Patient Layer

Primary Devices

- **i-tag**

The i-tag is a wearable wrist module that can be connected to the box using a wireless body sensor network (WBSN) interface. WBSN consists of a number of sensor nodes that are intended for sensing electrocardiogram, electromyogram, body temperature, blood pressure and so on. Thus, i-tag main purpose is to control the sensors, which collect physical data from the patient and store them locally when the user is in public areas. The i-tag itself can detect basic vitals like pulse rate. It will be able to track the location of the patient and connect also to Wi-Fi and 4G. The alerting signal with the location can be transferred to the In-Home Box and the latter will notify the emergency services, GP or relative via SMS using the GPRS function. The SMS does not include a lot of information, only the location and an alert code which corresponds to a specific incident (e.g. cardiac arrest) [17].

Secondary devices

Devices and their functionality that can add extra usage on the described system:

- **Smart TVs**

New technologies such as smart TVs offer limitless opportunities and expansions of functionalities for the system. Smart TVs offer various applications like online calls, interaction with the user etc. All those functionalities can expand the interaction between the patient and devices, as well as the patient and other player like doctors, relatives and care providers.

Secondary portable devices

Secondary portable devices include devices that can add extra usage on the described system. In the following we will describe their contribution to the system and their main functionalities in stepwise approach.

- **Smartphones & Tablets**

1. Can have the role of the bridge between the sensors/i-tag and the InHome Box when the user out of home. As an alternative with this functionality the i-tag can transmit the data to a customized complementary version of mobile or tablet application. The data will be stored and locked locally and when the user is at home the application

will be able to be synchronized with the box and transfer the data to medical database of the box.

2. Can be used to access the InHome Box as a remote control. Through the mobile application the patient will be able to unlock the box remotely and manage part of his data from distance. In this way s/he will be able to retrieve from distance a medical record which is not the full patient file but a needed record to be shown to services in case of emergency outside Netherlands. Because the mobile phone or tablet could be easily stolen or lost the application will provide secure ways of self-lock based on time threshold.
3. With a professional mobile health application as a second complementary version of the software of the box, patients will be able to monitor their own vitals locally at the phone or tablet. Today's smartphones or tablets give the chance, with the increased local CPU power, to be able to track the vital signs and monitor all physical data with mobility.

- **Wireless Body Sensors and Networks (Bio-patch/sensor)**

With the use of ZigBee technology [24], various sensors could be placed in key body parts of the patient (depending the disease) in order to monitor the vitals 24/7. A solution developed at paper [17] [18] is a bio-patch. The bio sensor module is placed on patient chest collecting vitals and coupled with an integrated bio-circuit the signal is converted to a digital form and is sent to the InHome Box platform for real time monitoring. This signals are stored also in the local medical database. As the medical sensors could be many and could transmit data at the same time to the platform, ZigBee protocol is considered to be a solid secure communication solution according to US Homeland Security study [19].

ZigBee wireless technology developed as an open global standard is capable to address low-power and low-cost wireless networks supporting intelligent route discovery [20]. A key component of the ZigBee technology is that it can support mesh networking. Within such type of decentralized networks, called mesh networks, nodes are connected with other nodes (interconnection) so that multiple pathways connect each single node. The connections between the nodes are updated dynamically and mainly optimized through a smart routing table. This means that if the various body sensors of the patient (medical nodes) could transfer data to the box using this type of network, because of its decentralized nature the nodes are able to self-discover and reconfigure network paths based on the new network structure from the sophisticated

routing table. As a result, such network topology characteristics and ad-hoc routing increase the stability of the network that changes conditions and protect the loss of data due to failure of one or many nodes.

- **Secure Flash Drive (Included in the "InHome Box")**

For security reasons the patient will be provided with a secure flash drive at the purchase of his/her box. The drive will be able to carry data if the patient prefers to store them in this way and transfer them accordingly to the GP. The flash drive will be coupled with the same security policies as the InHome Box. When the flash drive is plugged into a new device, login credentials are needed in order to view and extract the data. If an unauthorized user logs in more than 3 times incorrectly the drive will erase all the data on it. Moreover only with the use of our InHome Box software the medical data can be stored on the flash drive. For this type of transfer, the medical data that are transferred do not consist the complete medical records but only a summary of the most recent parameters retrieved from the medical database of the box.

LAYER 2: InHome Box Layer (functional system components)

The "InHome Box" is the core system of the architecture. It works as medication inventory, as a medication inspector, as a database of the clients' information (physical and personal) and as home switching point for connecting all the primary and secondary devices. It is the home gateway of the patient connecting layer 1 and 3, which are the layers of the patient and the private cloud server layer. The box as the healthcare home gateway will act as our fixed node that captures and connects medical sensor nodes at home and mobile agents (like mobile phones and tablets). The bridge connection of layer 2 to layer 3 (Private Cloud Server) is a functionality that provides the chance to other parties to access the patient data in the cloud (with tight restrictions).

The components and their functionality are listed and described below:

- **Smart Pill Box**

The Smart Pill box is a smart integrated circuit placed under the medication chambers of the box and is facilitating the medication management, inventory and refill. This smart circuit [17] is collecting all the events that are triggered from patients related to the medication doses. The Smart Pill is using Radio Frequency Identification (RFID)

technology [25]. This technology makes use of radio waves for automatically identifying physical objects. The RFID tag placed on the box captures all the activities executed on the pill box and assigns unique ID numbers to the medication packs. Then integrated antenna on the Pill box transmits the data to the UHF RFID receiver placed also in the box. This way all medication activity is captured and sent to the Medical Local Database. From this point the system follows various procedures, which will described later to the handle the medication process.

- **Integrated Bio-Circuit**

The bio-circuit is located also in the box and is collecting all the raw data coming from the wearable module (bio-patch) wirelessly, converts them into a digital format and transmits them to the InHome Box screen for real time display for the doctor. The communication is done via ZigBee technology. [17]

- **Weight sensor coupled to Smart Pill box: Medication Inventory/Inspector**

The basic functionality of the weight sensor under the pill box chambers [17] [23], will be to maintain an inventory of the medication doses that are stored in the box chambers. Therefore implementation logic should be: 1) Measure the weight of medication pack based on the latest medication use. Knowing the weight of pack and each pill (registered in the local database) calculate the current dose; 2) Keep log file of the current weight value; 3) Trigger a new event if the chamber is opened to pick up a new pill from the medication pack; 4) After the medication pack is placed back measure its weight and using the registered pill weight, calculate the remaining dose and the dose received; 5) Finally, check the received dose against the electronic medical form stored in the local database. 6) Inform the GP or relative with SMS in case of if the incorrect dose is picked up. The SMS includes the unique ID number (received from the RFID tag) of the pack and the time of the event.

At a later stage the idea for the implementation of a secure mechanism is considered where the pillbox controls timely the box chambers from the electronic medical form and opens the chambers only at the time of the dose. However, this triggers some serious concerns as our initial target group will be chronic patients and any mistake is not acceptable. This needs further testing on the platform. In the same way if the patient picks multiple doses or medication portions that are not scheduled within that day the chambers should lock for that day and an emergency SMS should be

sent to GP and registered relatives. The Pillbox stores a complete time log of pill removal events, and transmits the record to the medical database. This can be achieved when the RFID tag captures the events on the pillbox and through the antenna transmits the data to the RFID reader of the box (using also an integrated RFID antenna). From this point the medication data and time events are transferred to the local medical database and stored accordingly. (Analytical steps found in the proposed changes chapter)

- **Smart Pill box: Medication refill/ordering Functionality**

This functionality is directly related with the inventory functionality. The main purpose of this functionality will be to evaluate the medication needs and if necessary inform the GP and after her/his sign-off within electronic medication form, the box will order the medicines from the co-operating pharmacy. In the medication inventory and inspector function we described that when the medication is picked up from the chamber the pill box triggers a process where at the end a log file with all events of remaining doses is kept in the local database. When the database receives as input the data from the inventory functionality the system evaluates what medication needs to be refilled. When the GP logs in into the private cloud, s/he is able to update the medical form and sign it off in digital form. When the form is signed off it is synchronized with the local medical database. In this way the platform (system) is updated and able to schedule an order from the pharmacy. Only if this process is completed the system can send via email (attaches also GP's email) the needed medication from the co-operating pharmacy. In the email the pharmacist can see the digital signed form and the needed doses. As soon as the new medicines are received. The patient or one of the relatives can place them into the box. (Analytical steps found in the proposed changes chapter)

- **Wi-Fi Antenna**

The box has to be connected 24/7 with the internet and the various secondary devices so that the data can be transferred to the box. When connecting to Wi-Fi the patient will be able to schedule conference calls with the physicians or complete various online digital forms online which are needed during many steps of the healthcare process. The connection with the private cloud server in order that the data formats are synchronized consider this functionality very crucial.

- **RFID Reader and Antenna**

The RFID reader and the RFID antenna will be both integrated in the health box in order to support mainly the connection with the Smart Pill box RFID tag/antenna for the transfer of all medication activities to the local medical database of the box. [17]. An optional functionality for increasing security is to combine RFID antenna with the smart camera of the box, in case any medication pack is moved out of the antenna range the camera is turned on to capture the event. [35]

- **Health box port tool**

This component is merging all the hardware interfaces in the platform. This is an extension port of the platform hub [32] coupled with a software tool in order to manage and monitor all the needed hardware devices and provide via an application the detailed information in the UI of the box [29].

- **SIM card, GPRS, GPS application: Emergency Functionality**

The InHome Box is considered to be designed in order to support also the use of SIM card. In this way the box has the ability to make phone calls to the GP, relative or to the emergency services. As this involves the connection to a carrier, namely operator, the messages that are going to be used when the SMS Gateway is reached through GPRS link will only include data that could not reveal any sensitive information about the patient.

A customized application embedded for patient groups that must be tracked 24/7 will support the need of location recognition. When the i-tag wrist sensor detects any serious abnormalities it will automatically send via Wi-Fi or 3G/4G the location (geographical coordinates) of the patient to the InHome Box web application. The location can be always tracked via web application from the InHome Box. The system is pre-configured in case of alerts to self-activate and trigger an alerting SMS with patient's name, alert code and location received from the application. (Analytical steps found in the proposed changes chapter)

- **Local Medical Database (including Personal Documents Functionality)**

It is a database that will be located inside the InHome Box. It is used to store all the data of the patient. It is actually an in-house storage unit of the patient's Electronic Health Record (EHR) and any other collected data. Every time there is an update the data will also be updated in the private cloud server. The Local Medical Database connected to the platform systems is processing the data of the patient that were

received from various external and internal sources and triggers events that are directly related with the GP, relative and pharmacy. The database of the Box will include all the official documents that have to be filled from the patient's side while going through the care services registration. So instead of going through that process repeatedly the information can be send electronically with all the necessary documentation to the relevant organization automatically filled from home. (Analytical steps found in the proposed changes chapter)

- **UI Retina Screen**

It is the basic way through which the patient can access his/her data, access his/her medication or adjust the setting, configure the system and extract physical data information that he/she might want to share with a physician or care provider. The main interaction with the medical box.

- **USB port**

The USB port will be used for the flash drive to input or extract information. The flash drive credentials in order to protect the medical data, are described in the patient layer.

- **ID card: Authentication via NFC functionality**

The use of an ID card is very crucial as it supports a unique user to be matched to the specific health box. Thus, together with the InHome Box the ID card will be a complementary security measure to protect the login procedure and additionally the data stored in the local database. The authentication process is a very sensitive security shield in order to enable only authorized users take control over the box and its services [26]. After the card is authenticated and coupled with the mobile application (following the process below, with the touch of the mobile phone on a pad near the box) the latter automatically proceeds to authenticate the user. Apart from the authentication with the ID card there must be also some alternative methods to login into the box such as a pattern unlock, retina identification or even a fingerprint and password unlock displayed on the user interface.

When the patient receives the health box s/he is provided with a smart ID card and only for the first time s/he visits a website which requests the customer ID, the serial number of the box and the BSN number in order to activate ID card. If the card is activated the patient can use it with the mobile phone to log in the health box. The

following process is executed only for the first time: 1) by the time the user opens the screen of the box the installed software asks the patient with a message displayed on the screen to authenticate; 2) When the user clicks on the authenticate button of the UI on the box s/he receives a challenge which consists 7 unpredictable numbers on the screen; 3) Patient runs the customized mobile application and places the activated ID card at the back of the mobile phone to authenticate the card. 4) Holding the card at the phone, the application enables user to insert the serial number of the box to the authenticate match to the card; 5) Patient clicks 7 digit unpredictable challenge that was received initially. This way the ID is coupled to the application. 6) The customized application generates a numeric number that the user types to the health box to log in and unlock the software. 7) From this point the user places only the mobile phone next to the box in order to use Near Field Communication (NFC) to authenticate.

Used software and their functionalities:

- **Software (including Personal Data update functionality)**

The open platform of the InHome Box will facilitate a software coupled with all those requirements to support medical professional applications and will provide, through an integrated touch screen of a tablet, the main user interface for any interaction or communication. The software will support the different interfaces of the medical devices and will be able to provide a conference tool so that the patient can be monitored from distance by showing a display of the shared screen during the call. The platform will control the local medical database and act upon if needed, when the medical data is processed and stored. Finally the proposed platform of the box will be responsible for “talking” with the private cloud server via login portal. When the report of the specialist is ready and sent to the GP the information is also stored on the database of the hospital, where GP has access. The professional health software will include personal calendar recording all activities in the database. When the patient returns from the appointment s/he confirms the visit to the specialist through the calendar. The system will send a message to the GP that s/he visited the specialist and an update of patient’s data is expected. The message will contain the Citizen Service Number (BSN), the serial number of the InHome Box and only the name of the care provider in order for the doctor to know which system he/she has to access.
(Analytical steps found in the proposed changes chapter)

- **PAZIO (Connectivity to the existing e-health platform)**

The health box of the patient will also possibility for an interconnection to other platforms such as “PAZIO” (Patient Oriented Healthcare Information Environment) which is an e-health portal that was developed by the University Medical Center Utrecht (UMCU) in cooperation with innovative ICT partners. This is a very important step in order to embed the health box in the e-health information environment that the patient uses with all healthcare providers.

The portal provides access to a range of patient centered services for primary and secondary care and it offers access to basic applications and additional applications. The portal enables the patient to interact electronically with their care provider. PAZIO enables access and provides interaction with basic applications: Scheduling appointments, prescription refills, online lab results, online consulting.

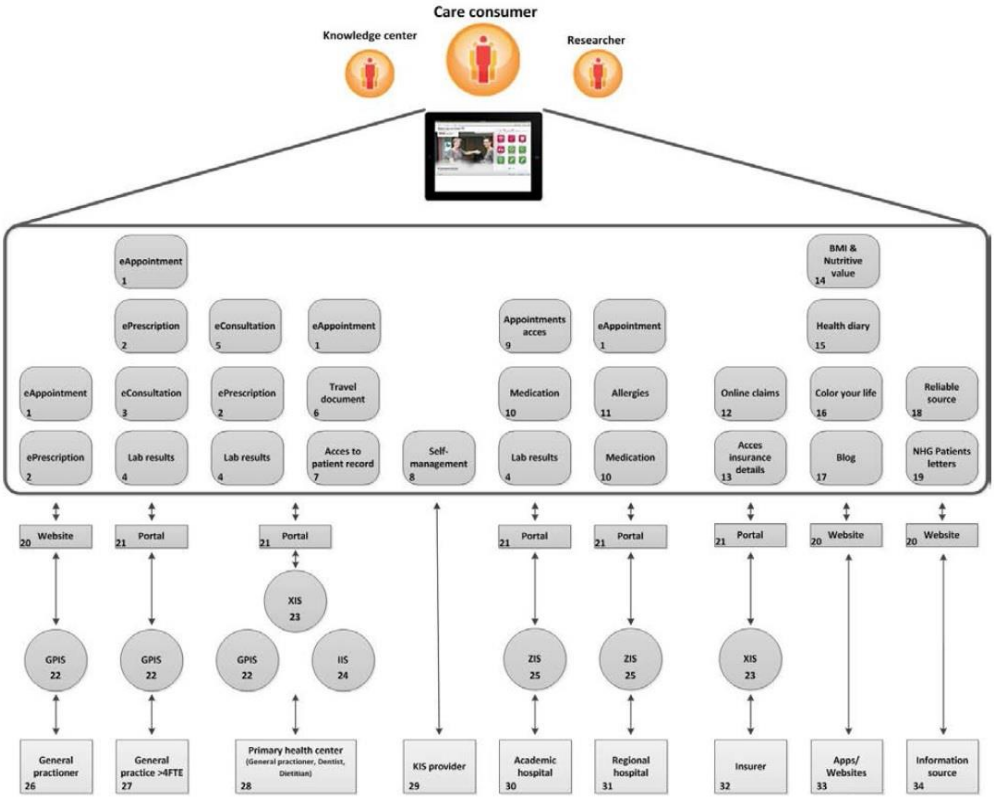


Figure 4. Illustration of PAZIO connectivity. [22]

LAYER 3: Private Cloud Server

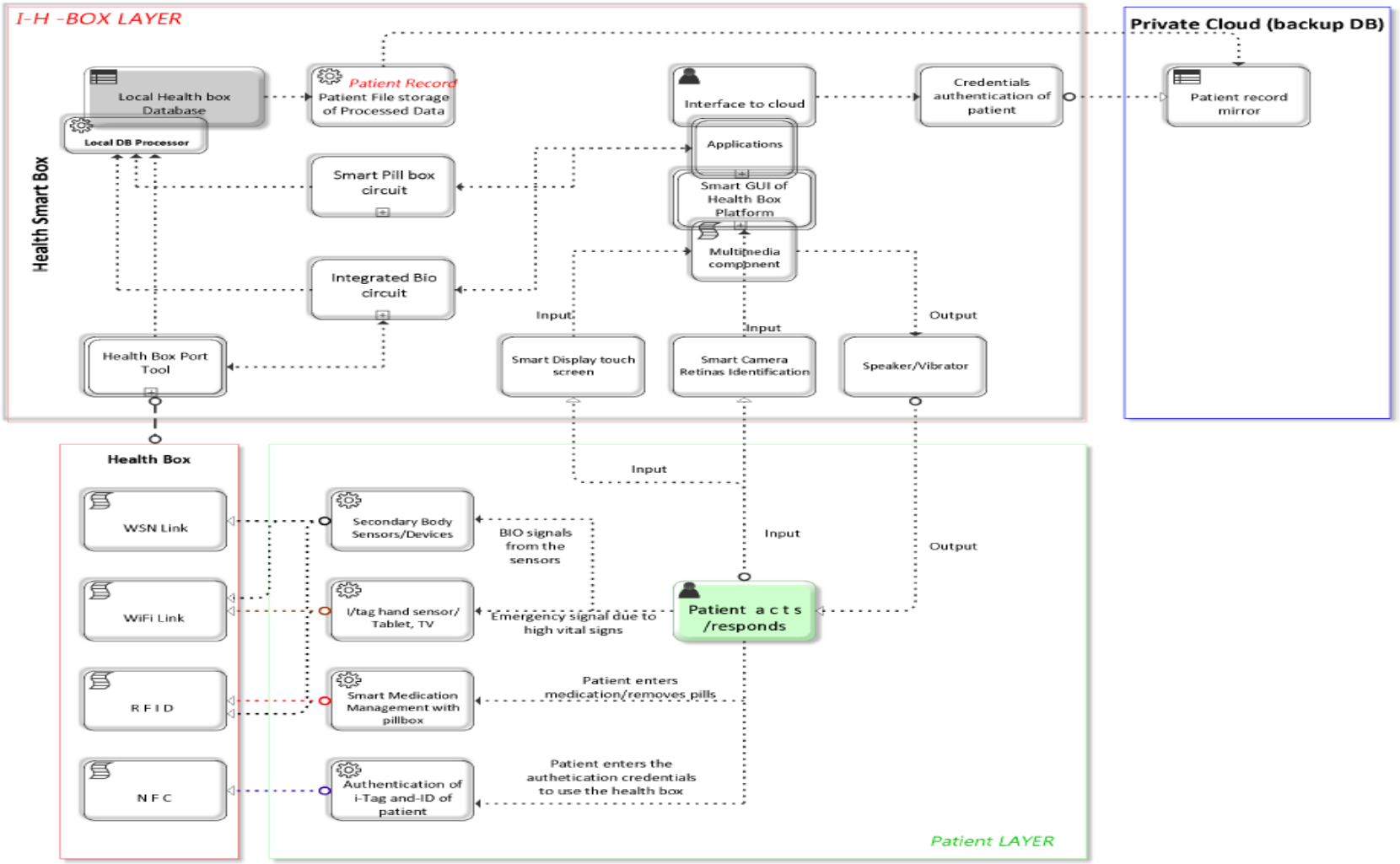
For the moment that server will serve more as a backup database and in the future can be used for allowing access to patient information to various players. Through the In-Home platform the user will be able to login in the private cloud server via secure interface portal. A first security mechanism will be the authentication of the patient in order to access the InHome Box via NFC or another authentication pattern. However, we would like to increase the security shield and for this reason an additional user name and password will be needed in order to access the cloud data through the login portal. One of the main functionalities that will be included in the platform, will be to give GP access to the platform/cloud server in order to maintain remotely patient's medication via a secure authentication interface to the cloud. By that he/she can process the e-prescription, which in terms will be copied to the local database of the health box.

We consider implementing the authentication with OTP (One-Time-Password) which uses a 2-factor authentication with a one-time password login. The doctor's mobile will work as the authentication device. To generate the OTP for the cloud webpage three components are needed to be hashed together from the Java app when running on the doctor's phone. The three components are: 1) 4 digit PIN code that doctor will enter (unique for each InHome Box); 2) a secret random number that was generated during the device/app initialization that only exists on the mobile phone of the doctor; and 3) the current time of attempt. [41]

In the future we consider, for security reasons, that the data should be first stored on the local database, located at the "InHome Box", and then transmitted to the private cloud which will be accessible by the insurance companies, the local hospitals and the chronic diseases patients' services providers.

The private Cloud will be located to the municipality area that the patient belongs to. Moreover only the departments of the insurance companies, hospitals and doctors that are operating in that specific area will have access to the cloud.

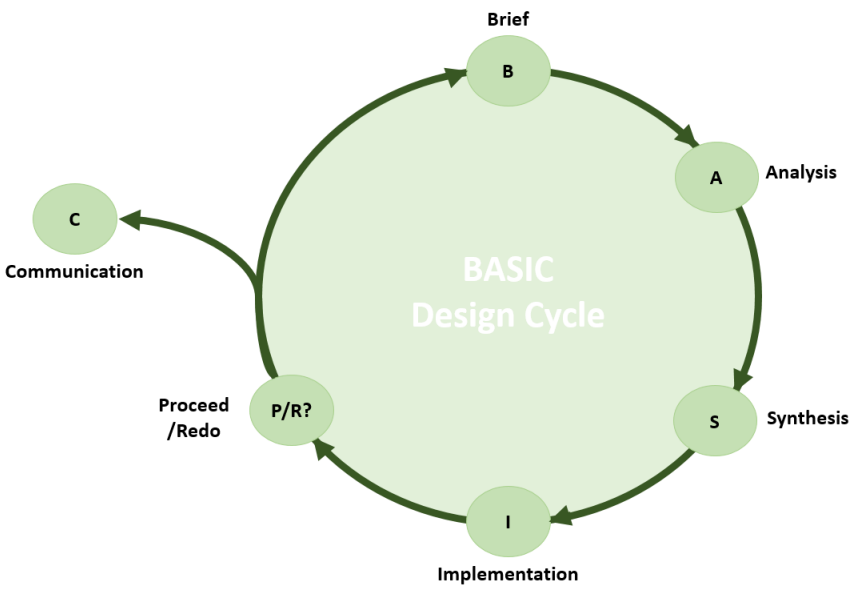
4.2 Proposed Architecture Schema



4.3 Justification of proposed Architecture Schema

4.3.1 Introduction to the design cycle

In order to result in this architecture we followed the design cycle of James C. Snyder which includes the following steps: Brief, Analysis, Synthesis, Implementation and Communication. For the brief, which is the first step, we firstly investigated the present and future needs of the healthcare service delivery in regard to the emerging technological changes (e.g. the Internet of things). We specifically observed the urgent need for personal health systems that will make use of innovative technologies in order to cover the increasing knowledge distribution [15]. Within the next step, namely the Analysis, we made a research on self- management platforms [16][17][18] and noted their specific technological characteristics and components that covered the present and future needs of the healthcare industry. The best platform, which we used as foundation for our development, was iMed Box. In step three, the Synthesis, we designed the architecture with the suitable communication technologies and use cases investigated in step 2 and aligned them in a schema with the same logic of a system which involves constant measurement of vital parameters resulting in early alerts [22]. The implementation step was not touched at the moment as we did not make any attempts for a system design to make field trials. The last step namely, the communication was done through our research participants as we tested the system architecture by validating it's functionalities through the used components and communication methods.



4.3.2 Briefing

An important first step is to understand how things evolved and what created the urgency for a different research mindset on such architectures and platforms. According to a very useful schema presented by C. Everret Koop [15] in “Future Delivery of Health Care: Cybercare” research article, until 2008 Private Health, Public Health and National Security were sectors not combined together in the Healthcare System. In this system few hospitals were aggregating all healthcare knowledge that was physically delivered to the community due to lack of Information and Communication Technologies. With the introduction of new communication technologies and telemedicine we observe new characteristics emerging for creating a different Healthcare System by 2018, where the Private and Public health are combined with National Security. Knowledge is easily distributed to many local hospital players which deliver healthcare services to the community. A balance of knowledge sharing is created due to rapid technological advances. What makes the difference is that from 2028 we move from a knowledge distribution to a healthcare distribution which means that the healthcare delivery is moved out from hospital directly to the community. This system forces us to have a different research mindset as we are talking about a net-centric healthcare system.

As a result, the eco-system is demanding self-management health systems that would facilitate this type of home healthcare delivery in order to collect all patient’s data and be able to communicate with the participating healthcare players. This type of platforms do not eliminate hospitals which will be still needed for specialized services (tomography scanning, transplantation etc.). However, they target mainly the preventive healthcare where vital parameter control and monitoring will be done from home.

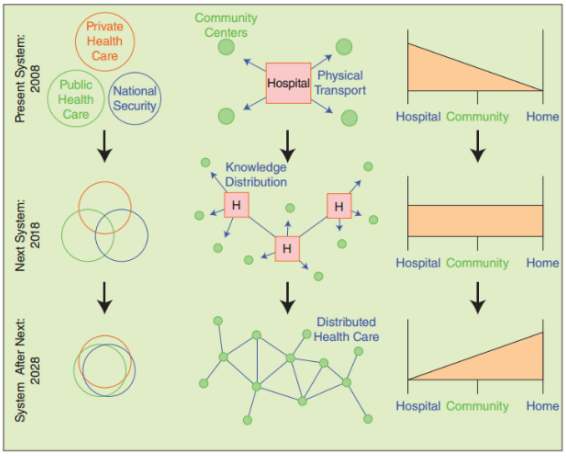


Figure 5. Present health-care system and its proposed change to a net - centric health-care system. [15]

4.3.3 Analysis

Based on the previous step the research scope starts to be shaped in the direction of an architecture that could support this knowledge distribution. The patient must be able to collect his physical data from various devices at home and this data must be collected from a system that acts as comprehensive healthcare solution. We investigated and analyzed what this system should be based on existing platforms in the literature [17]. A very detailed analysis of the layers, components and technologies is made in the chapter 4.1.1 and 4.1.2. In this chapters we included all references for all technological choices including the patient, the In-Home box and the private cloud layer.

4.3.4 Synthesis

Using the analyzed components and technologies in 4.3.3 we aligned our architecture with the design logic of an implemented system as included here. The architecture presented by Srijani Mukherjee, Koustabh Dolui and Soumya Kanti Datta in their paper “Patient Health Management System using e-Health Monitoring Architecture” [22], describes the design and implementation of a system which makes use of the integrated wireless sensor network for real time analysis of patient’s vital signs. The system architecture facilitates the tele-monitoring of the patient and caregivers’ look over investigation for emergencies.

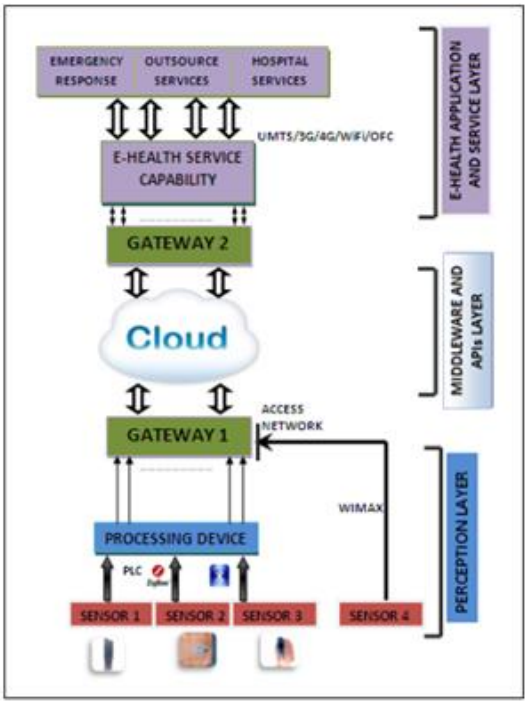


Figure 6. Architecture logic of the implemented system [22]

The first layer of this system architecture is the perception layer that includes the various sensors placed at the patient's body or the surrounding environment to monitor real time data. The information aggregated from the sensors is transferred to a powerful processing device that stores and processes patients data. Making use of this architecture logic in the perception layer 1 we reformed this layer by dividing it to the patient layer and the InHome Box layer. The first includes the various sensors and medical devices collecting all the medical data at patient's environment and the second is a powerful base station unit that is processing all data of the patient acting as the healthcare gateway. The communication of the layers 1 and 2 is done with the same logic as pictured in the paper. The central transceiver unit is our described wearable module our described flexible bio-patch placed [18] at the patient's body collecting all the raw data from different medical sensors. This wearable module is transmitting the raw data to the central base station which is the InHome Box and specifically to our described bio- circuit [17]. The bio-circuit is transforming the data to digital format in order to be used in real time from the InHome Box and stored in the local medical database. The i-tag is also able to send data via Wi-Fi/3G or Bluetooth to the InHome Box as it is a wearable wrist sensor when the patient is away from home. The communication between the wearable unit or bio-patch and the In-Home Box is done

through a short range wireless communication protocol (e.g. ZigBee) enabling the use of Wireless Sensor Network.

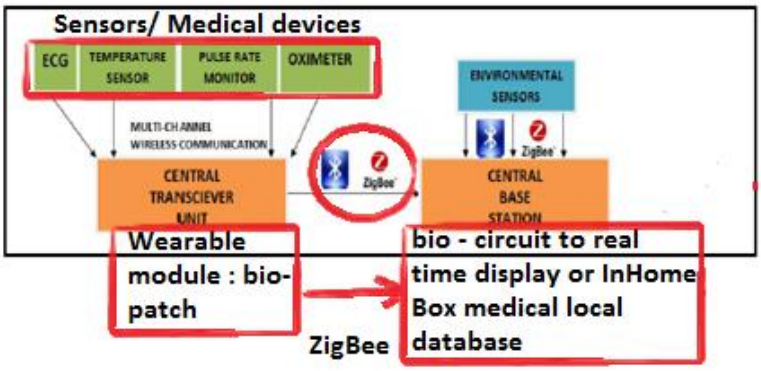


Figure 7. Architecture logic of layers 1and 2: patient layer and InHome Box layer

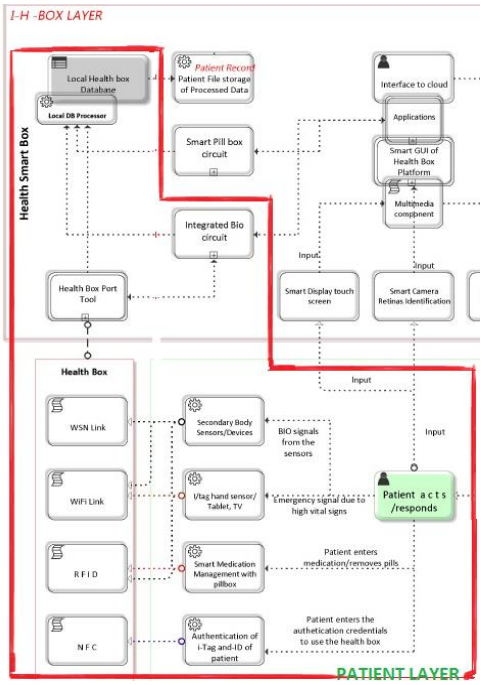


Figure 8. Architecture at our proposed platform based on this concept

The cloud storage holds the medical profile record of the patient and the medication from the electronic form in local medical database. The purpose of the private cloud (as a health service) will be at the moment limited to give access to the GP get the latest vital parameters from the patient and sign off the on-line prescription for the pharmacy, (when the box detects a medication refill). The GP will login into the

cloud with a procedure described in chapter 2. However the targeting point would be that on this layer 3 to enable all players (insurance companies, pharmacies, and hospital) connect with their Enterprise Information Systems with a tight security restriction schema and control as presented [5]. This could lead to a fully automated service delivery under IoT technologies. For the moment in our research scope we consider implementing the private cloud with a more secure approach due to including highly sensitive data and other security concerns.

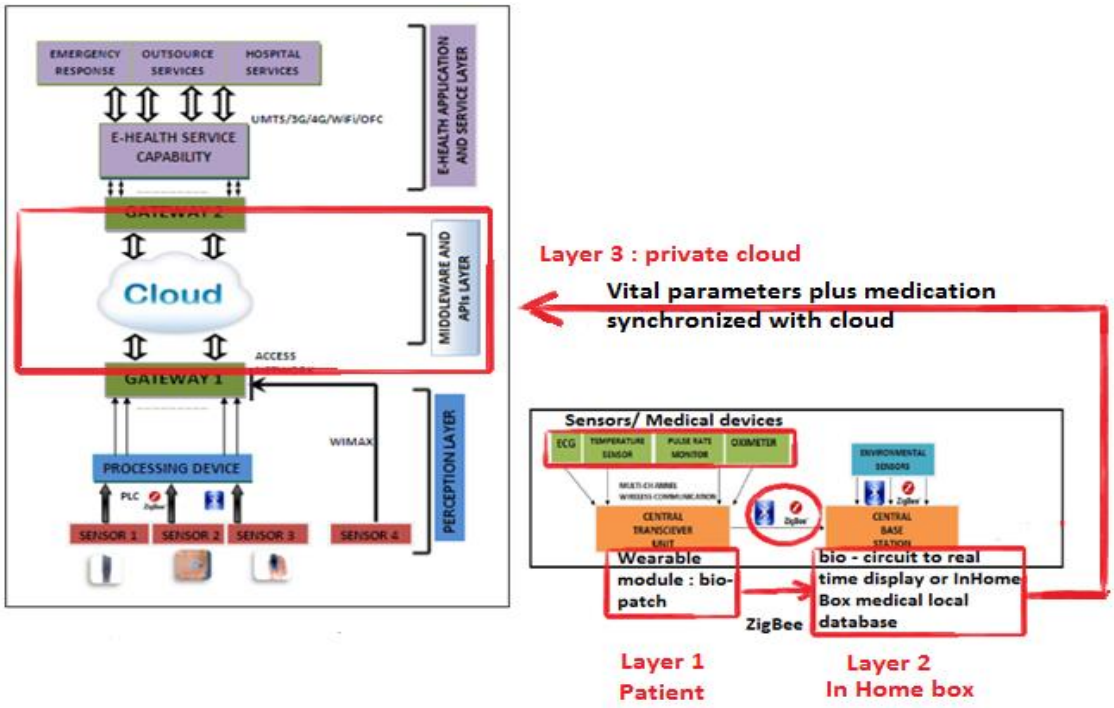


Figure 9. Architecture connecting layer 2 and 3

4.3.5 Communication

This step is achieved via the validation of the architecture with our research participants. In the hypothesis testing chapter we analyzed the results for evaluating the architecture design through the received feedback of the surveys.

5. Dutch Healthcare Services Process

In this chapter we will try to identify the Dutch healthcare process for chronic disease patients. The process will be described and illustrated in a stepwise approach.

5.1 Existing Process Description

Based on the existing researches we were able to identify the needed steps a chronic disease patient has to go through in order to receive medical care services. According to Leyden Academy on vitality and aging [27] [28] reports, the process for receiving medical care consists of 50 steps, which are listed further below.

Moreover we consider that the process steps consist of three major categories. The first category, steps 1 to 17, "Core medical process" which is the initial subscription of the patient to his/her GP and the evaluation of his/her condition. Following that, if the patient is diagnosed with a chronic disease we have the "Long Term Care Services Process". In the latter category the patient has to communicate with various institutions and agencies that will evaluate his/her condition and will decide the level of the services that have to be offered. The final category is the "Social Support Act WMO process", where patients/citizens that have limitations, either movement or physical limitations, are contacting WMO in order to receive health services and financial support. WMO is the social support Act that offers service to citizens with limitations in society. The group of people receiving support from the WMO may include the elderly, disabled or people with psychological problems.

In this chapter we list the steps of the process:

NOTE: For explanation of the acronyms please check Appendix A.

1st Part: Core Medical Process

1. Patient reaches the GP and shares with her/him information on personal data, health and wellbeing progress.
2. GP stores all the information of the patient in the Health Information system, called HIS. GP from this point on acts as a "gate keeper" with a central role in the system

to update and collect all data for the patient, including physiological and psychological illnesses, prescribed medication, lab results etc.

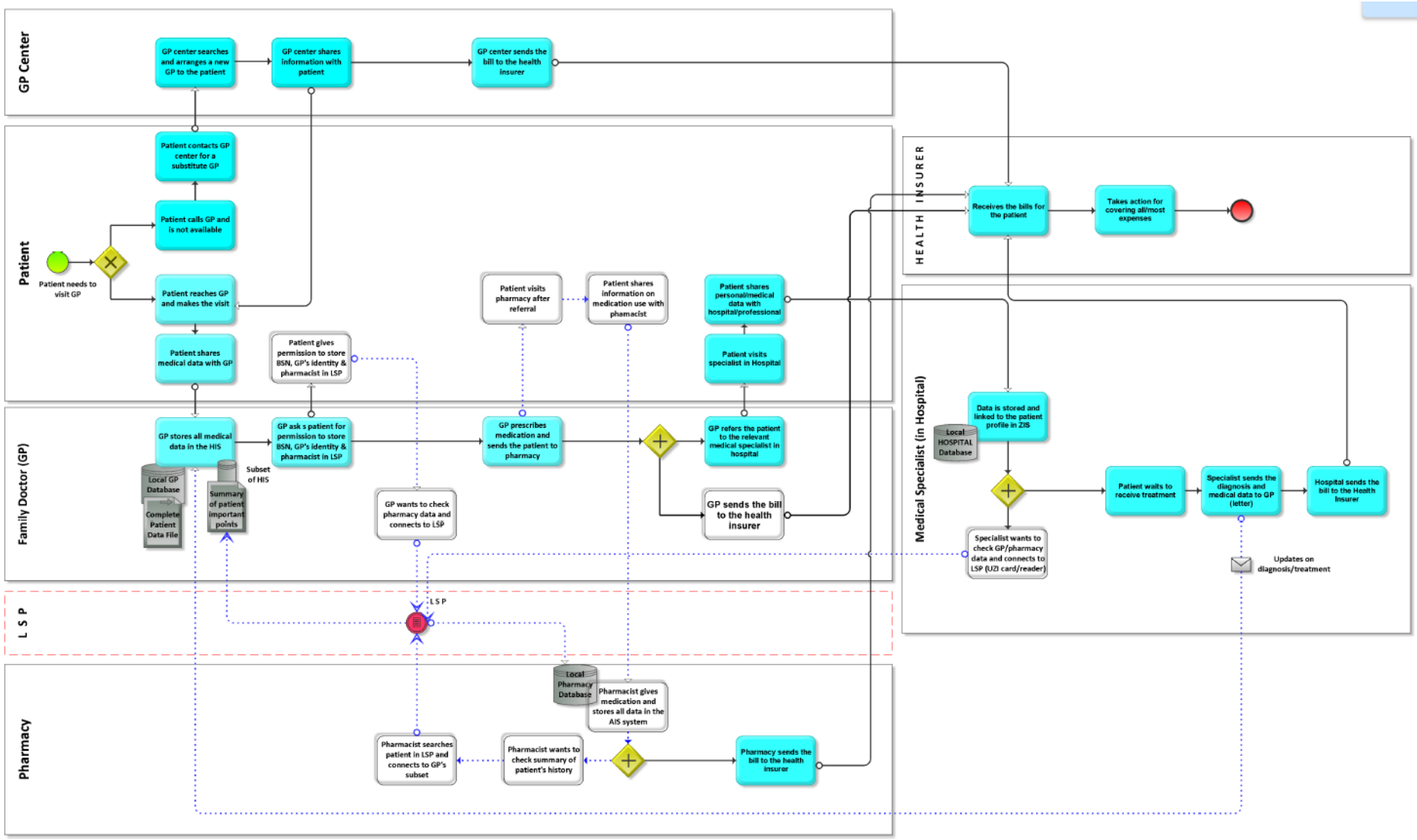
3. In the subset of HIS of the GP all the medical data of the patient are stored. From those data, only the most important diagnoses, treatments and aspects of the patient's medical history are included in the basic summary which is accessible to the pharmacy and medical professionals (specialists) through the LSP platform.
4. When GP prescribes any type of medication to the patient then s/he makes a referral to the pharmacist. Following to the referral the patient shares the information with the pharmacist and takes the medication. Information related to the used medication and potential side-effects from that are stored in the Information System of the pharmacy, called AIS. This platform can be also accessed by the GP through the LSP.
5. GPs and pharmacists, who collaborate with the LSP, ask for the written permission of the patient to include his/her personal information on the LSP. Those information includes only patients' BSN and the identity of their GPs and pharmacists. No medical information on treatments, medication use, allergies, are stored in the LSP. For that reason the installment of the LSP is not considered an electronic patient record (EPR), but a shared Health IT infrastructure.
6. In the next step the GP refers the patient to the relevant medical professional (specialist) located in a hospital.
7. The patient visits the specialist and shares all the following data with the care provider.
    - BSN (citizen service number)
    - Name
    - Address
    - Date of birth
    - Health insurer
    - Specific health insurance number
    - Important other personal data.
8. Medical data about a client are linked to the above mentioned personal data. Only authorized personnel of a health care provider may log into the information system, called ZIS, for tracking individual patient data.
9. After the consult, the specialist sends a letter to the GP, in which she/he summarizes the client's visit in terms of new diagnoses, medication, tests, scan results and others.

10. GP receives the information and updates the records.
11. If necessary, the specialist can check important medical information of the client with the GP or pharmacist through the LSP/RSP. A health care professional may only log into the LSP with an UZI-card plus the UZI-card reader, and with the right credentials/certifications assigned to its access rights.

- The medical professional finds patient in the LSP search engine on the basis of the patient's BSN.
- The medical professional logs in with a password and the use of a UZI-card (this card is like a credit card).The UZI-card grants the user authority to access patient information, depending on the region and the profession of the user.
- When the identity of patient and the user of the LSP is confirmed, the user can access the database of other health care providers. The user can only see a summary of medical information about the selected patient and not the complete and detailed patient file.

NOTE: A very important fact is that in some areas (e.g. Zoetermeer) there is no UZI-card but a region/local Electronic file for Substituting GPs (EWH or Electronic Medication File (EMD)) is applied, and GPs have access to these records only when data is stored there, always with the patients' permission.

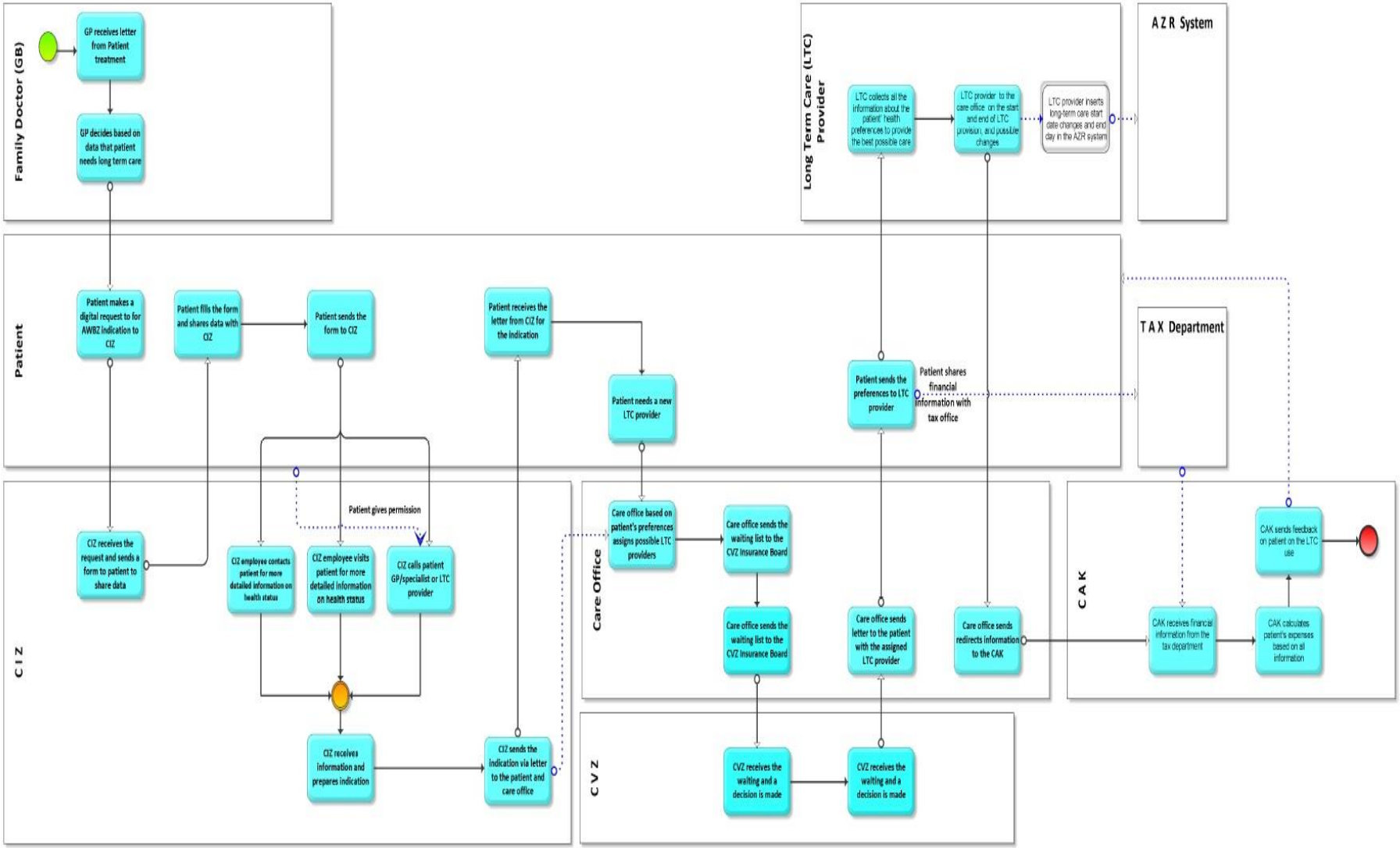
12. In case of an emergency that the GP cannot be reached then the patient can refer to GP center.
13. The substituting GP found from the GP center can also check important information with the GP or pharmacist through the RSP/LSP.
14. Substitute GP can follow the same procedure from 1-10.
15. The GP, the GP center, the pharmacist, the care provider and all the other participated medical providers send the bills for their services to the patient's health insurer.
16. The health care insurer from his side covers all expenses or decides, based on contract policies, to send some expenses to the patient.


GP Center
GP center searches and arranges a new GP to the patient
GP center shares information with patient
GP center sends the bill to the health insurer
Patient
Patient needs to visit GP
Patient contacts GP center for a substitute GP
Patient calls GP and is not available
Patient reaches GP and makes the visit
Patient shares medical data with GP
Patient gives permission to store BSN, GP's identity & pharmacist in LSP
Patient visits pharmacy after referral
Patient shares information on medication use with phamacist
Patient shares personal/medical data with hospital/professional
Patient visits specialist in Hospital
Family Doctor (GP)
GP stores all medical data in the HIS
Local GP Database
Complete Patient Data File
Summary of patient important points
Subset of HIS
GP ask s patient for permission to store BSN, GP's identity & pharmacist in LSP
GP prescribes medication and sends the patient to pharmacy
GP refers the patient to the relevant medical specialist in hospital
GP sends the bill to the health insurer
GP wants to check pharmacy data and connects to LSP
L S P
Pharmacy
Local Pharmacy Database
Pharmacist gives medication and stores all data in the AIS system
Pharmacist searches patient in LSP and connects to GP's subset
Pharmacist wants to check summary of patient's history
Pharmacy sends the bill to the health insurer
HEALTH INSURER
Receives the bills for the patient
Takes action for covering all/most expenses
Medical Specialist (in Hospital)
Data is stored and linked to the patient profile in ZIS
Local HOSPITAL Database
Specialist wants to check GP/pharmacy data and connects to LSP (UZI card/reader)
Patient waits to receive treatment
Specialist sends the diagnosis and medical data to GP (letter)
Hospital sends the bill to the Health Insurer
Updates on diagnosis/treatment

2nd Part: Long Term Care Services Process

17. The AWBZ Care Registration system (AZR) is the information-sharing platform for the different institutions that are active in AWBZ care, namely the CIZ, the CVZ and the CAK. If the patient requests an AWBZ indication, s/he or someone on patient's behalf makes a request for an indication at CIZ. The request is made most of the times digitally.
18. A form is sent to the patient as soon as the request has been made. The patient shares his/her personal data and information with CIZ.
19. After filling in the form, a CIZ employee either calls or visits the patient, or contact the healthcare professional that is treating the patient (GP, specialist, LTC) in order to receive a more detailed picture of patient's health status. The patient has to give permission for his/her personal data that are exchanged between care providers and CIZ institution.
20. The CIZ prepares the indication and sends the indication decision for this status in a letter to the patient or someone who acts on behalf of him/her.
21. The CIZ sends the indication decision to the care office.
22. If needed the care office checks and appoints a long-term care provider to the patient, depending on the care demands and personal preferences of the patient.
23. The care office sends the potential waiting list of LTC providers to the CVZ.
24. The patient or someone on behalf of the patient informs the care office on her/his LTC preferences and special needs.
25. The care office sends a letter to the patient, in which the officially assigned long-term care provider is mentioned.
26. The LTC provider collects all the information about the patient's health, wellbeing and personal preferences to provide the best possible care.
27. Patient shares financial information with the tax department filing tax declarations.
28. The LTC provider sends messages to the care office, containing information on the start and end of LTC provision, and possible changes.
29. The LTC provider reports the date that long-term care started, changed or ended in the AZR system.
30. The care office redirects information concerning the start, change or end of long-term care provision to the CAK.

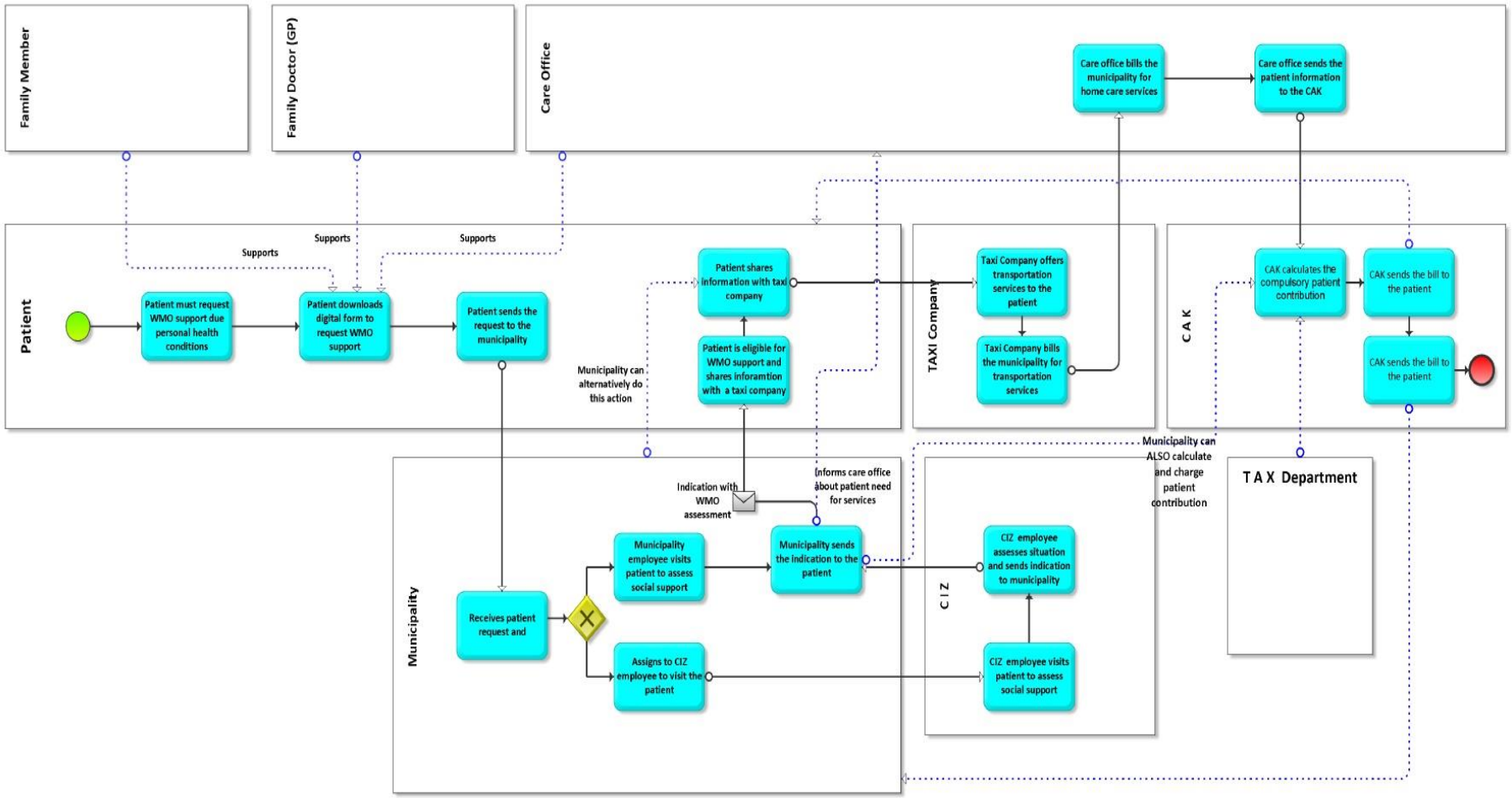
31. The CAK receives financial information on the patient's income status from the tax department.
32. The CAK calculates the compulsory patient contribution for received AWBZ care on the basis of the information from the care office and the tax department.
33. The CAK gives feedback to patient on the LTC provider use, including the calculated charges.


Family Doctor (GB)
GP receives letter from Patient treatment
GP decides based on data that patient needs long term care
Long Term Care (LTC) Provider
LTC collects all the information about the patient' health preferences to provide the best possible care
LTC provider to the care office on the start and end of LTC provision, and possible changes
LTC provider inserts long-term care start date changes and end day in the AZR system
A Z R System
Patient
Patient makes a digital request to for AWBZ indication to CIZ
Patient fills the form and shares data with CIZ
Patient sends the form to CIZ
Patient receives the letter from CIZ for the indication
Patient needs a new LTC provider
Patient sends the preferences to LTC provider
Patient shares financial information with tax office
T A X Department
C I Z
CIZ receives the request and sends a form to patient to share data
Patient gives permission
CIZ employee contacts patient for more detailed information on health status
CIZ employee visits patient for more detailed Information on health status
CIZ calls patient GP/specialist or LTC provider
CIZ receives information and prepares indication
CIZ sends the indication via letter to the patient and care office
Care Office
Care office based on patient's preferences assigns possible LTC providers
Care office sends the waiting list to the CVZ Insurance Board
Care office sends the waiting list to the CVZ Insurance Board
Care office sends letter to the patient with the assigned LTC provider
Care office sends redirects information to the CAK
C A K
CAK receives financial information from the tax department
CAK calculates patient's expenses based on all information
CAK sends feedback on patient on the LTC use
C V Z
CVZ receives the waiting and a decision is made
CVZ receives the waiting and a decision is made

3rd Part: Limitation patients process

34. The patient or someone on behalf of the patient applies for WMO support by filling in a form at the front desk of the municipality either within the municipality at “WMO-reception” or with digital forms downloaded and sent through the municipality’s website.
35. If such case, a friend or family-member, the general practitioner, or the care organization help the patient with requesting a WMO-indication.
36. After a request has been made, either an employee from the municipality or the CIZ employee will meet the patient to assess his/her needs for social support because the municipality asked CIZ to make the indication.
37. After the CIZ assessed the patient's situation and there is a need for social support, the advised indication is sent to the municipality.
38. The municipality sends a letter about the indication decision to the patient.
39. The municipality sends a notification to the home care provider that the patient is in need of services, and shares with the provider information for the patient’s needs.
40. When the patient is eligible for other services from the WMO (such as instrumental aids), this is forwarded to the assigned care provider.
41. Depending on the municipality, information about the use of transportation services is done either by the patient or the taxi company for billing purposes.
42. The taxi company then provides transportation services for the patient.
43. The taxi company bills the municipality for transportation services provided for the WMO to the patient.
44. The patient can give feedback on the quality of the WMO services.
45. The home care provider bills the municipality for domiciliary care services provided for the WMO to the patient
46. The home care provider sends patient data about services hours to the CAK. Alternatively, municipalities can choose to calculate and charge the patient contributions, but this is often seconded to the CAK.
47. The CAK uses information on the patient financial status from the tax department.
48. The CAK calculates the compulsory patient contribution for received home care based on the information from the homecare company and the tax department.
49. The CAK sends the bill to the patient.

50. The CAK sends the received patient contribution to the municipality.


Family Member
Family Doctor (GP)
Care Office
Care office bills the municipality for home care services
Care office sends the patient information to the CAK
Patient
Supports
Supports
Supports
Patient must request WMO support due personal health conditions
Patient downloads digital form to request WMO support
Patient sends the request to the municipality
Patient shares information with taxi company
Patient is eligible for WMO support and shares inforamtion with a taxi company
Municipality can alternatively do this action
TAXI Company
Taxi Company offers transportation services to the patient
Taxi Company bills the municipality for transportation services
C A K
CAK calculates the compulsory patient contribution
CAK sends the bill to the patient
CAK sends the bill to the patient
Municipality can ALSO calculate and charge patient contribution
T A X Department
Indication with WMO assessment
Informs care office about patient need for services
Municipality
Receives patient request and
Municipality employee visits patient to assess social support
Assigns to CIZ employee to visit the patient
Municipality sends the indication to the patient
C I Z
CIZ employee assesses situation and sends indication to municipality
CIZ employee visits patient to assess social support

5.2 Identified Problems

According to the research made by Leyden Academy on vitality and aging [27] three major problems were identified. From those three only two of them could be affected by the functionalities and improved from our system.

At the moment few changes can be made as we believe that in the future we can improve the process even further, but due to law and regulation restrictions we will try to make changes that will force the least changes in the existing infrastructure and laws.

As described by Herbert Rolden, “Clients with multiple care and support needs, often have to tell the same story about their physical and personal circumstances to different institutions” and continues “Municipalities, care offices, long-term care providers, and social support providers could gain access to one database, where the CIZ reports indication decisions and the client’s care and support needs, the client would only have to tell his/her story once to the CIZ.” [27].

“A more central role for the client, and more financial transparency for the client. Letting the client arrange many of his/her own required services is a way to decrease information-sharing “backstage” and diminish overhead costs. In the AWBZ and WMO policies can become more oriented towards personal budgets. This way, municipalities and care offices are only concerned with paying out personal budgets and monitoring the use of personal budgets, rather than arranging all the long-term care or social support for the client.” [27].

1st Identified Problem:

Based on the conducted research a very crucial issue of the existing process is that patients are repeatedly forced to give their personal and physical information many times during different steps of the health process. The latter increases the difficulty of the process for chronic disease patients and especially for patients with movement problems.

2nd Identified Problem:

Another very important problem of the process is the communication between the specialist and the GP. Whenever the patient visits a specialist, the GP has to wait for the letter of the specialist to update the data and most of the times the information of the patient remain not updated for a loner time, sometimes crucial for the health status of the patient (e.g with chronic disease). This issue can be recognized as a bottleneck for the process, because despite the fact that the report of the specialist is ready the GP has to wait for it and most of the times not aware of the specialist decisions.

3rd Identified Problem:

The 3rd identified problem is that the patient has to keep going to his/her GP in order to have the needed medication prescribed and then visit the pharmacy to receive the medication. The previously described problem translates into lost time for both the patient and the doctor, as well as increased complexity for the process. The constant movement of the patient or a relative is also increasing transport costs that could be avoided in most of the cases.

6. Facilitation of Healthcare process through the Proposed Architecture

Chapter six will bring together the two parts of our research so far. More specifically we will try to find ways of facilitating the existing process by making use of the proposed platform.

6.1 Proposed Changes

We will like to highlight at this point that our proposed solutions for the moment are minor and perhaps does not have a great impact on patient's life, but we consider it to be the first needed step. As soon as the proposed architecture have a high acceptance rate we can proceed at improve the process through our system even further. Many of the previously described functionalities, that are not activated at the below listed solutions, can help out the patient and the process significantly.

The main reason of taking small steps is the nature of healthcare industry, which is not very open to changes and it includes very sensitive personal data.

1st Solution – Medication refill/ordering Functionality

The first major difference is related to the medication ordering and refill. Instead of the patient having to go to the doctor in order to get a prescription and then go to the pharmacy for buying the needed medication, the InHome Box will be able to facilitate this process as follows:

1. The RFID reader receives and records a new event when the medication pack is picked up. Optional: If the medication package is moved out of the RFID antenna range then the system is turning on the smart camera of the box to capture the event [35]; additionally it can send an alert message to the relatives;
2. The weight sensor placed under the box chambers calculates the remaining dose for the medication packages.
3. The system takes the unique RFID number for the medication pack.
4. The calculated values are stored at the local medical database matched to the RFID number of the package.

5. The system compares the current weight of the medication package with the minimum allowed weight (pre-configured with pill weight values at the first loading)
6. A notification is sent to the platform that the medication is running out.
7. The InHome Box is preconfigured to send an email to the GP. The email contains the BSN of the patient, the serial number of the box.
8. The GP checks the patient's details and box number.
9. The GP logs into the private cloud and checks remotely the medication inventory in the medication history file.
10. The GP fills the e-prescription stored in the cloud and signs-off the form for official approval.
11. The filled form is synchronized with the medical database of the InHome Box.
12. The InHome Box detects the updated e-prescription values and sends it via email to the pharmacy.
13. Pharmacy receives the order.
14. Pharmacy sends the medication to the patient's house.
15. The patient or an authorized relative, by showing his/her official documents, receives the medication and places it into the Box.

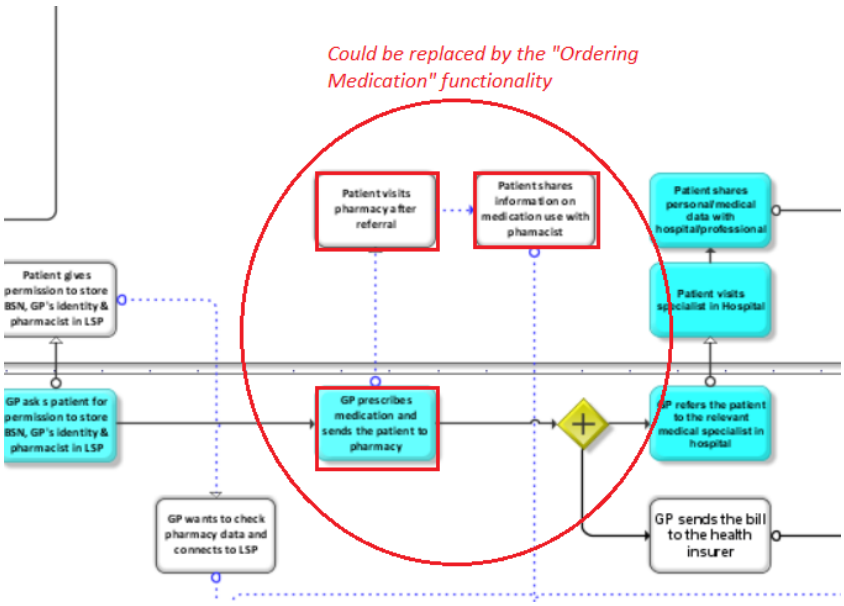


Figure 10. Impact on the process from the Ordering Medication Functionality

2nd Solution – Personal Documents functionality

The software of the Box will include all the official documents that has to be filled from the patient's part while going through the care services registration period. Also in the Box patients will stored all their basic personal and physical information. So instead going through that process repeatedly all the time they can send electronically all the necessary documentation to the relevant organization from home with all the information automatically filled.

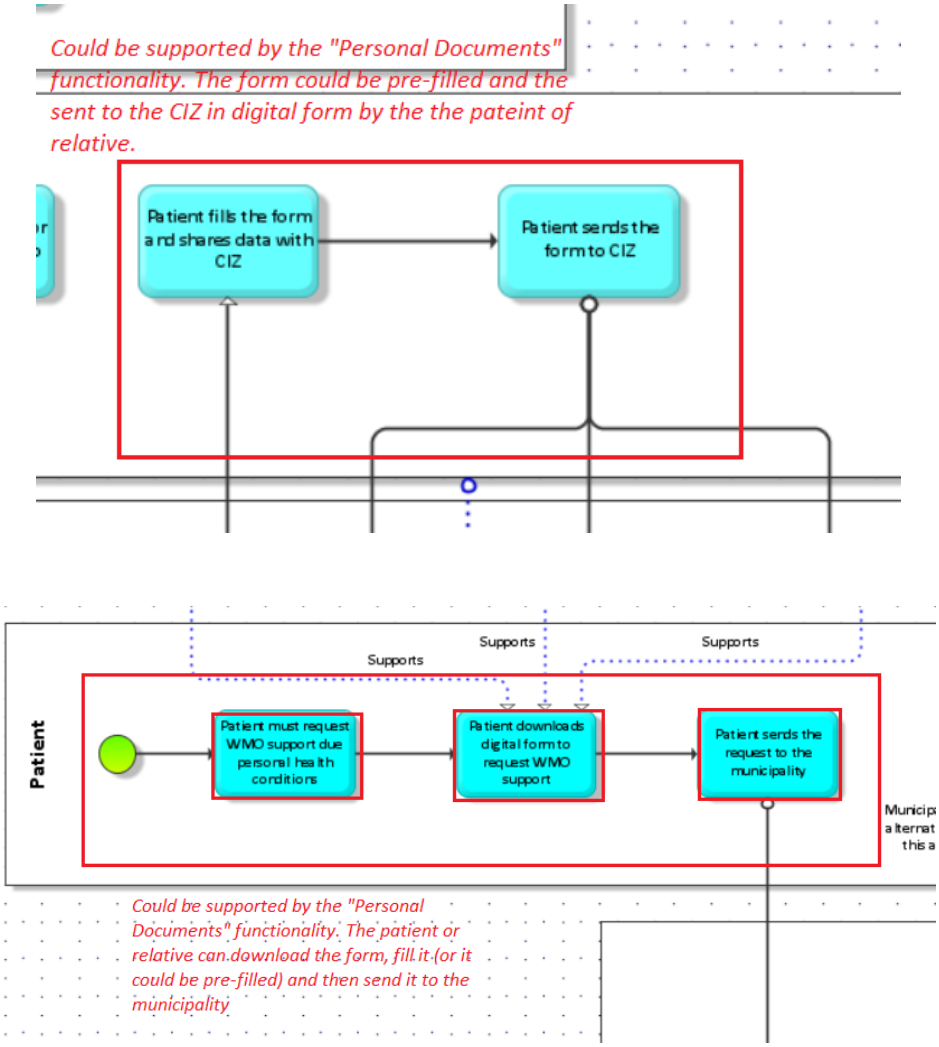


Figure 11. Impact on the process from the Personal Documents Functionality

3rd Solution – Personal Data Update Functionality

One of the biggest bottleneck in the process is the waiting time when the specialist sends his report/diagnosis to the GP (see step 9 and 10 of the process). Our system can improve that process slightly.

1. The specialist at the hospital prepares the report with the outcome of the appointment.
2. The professional health software at the InHome Box will include a personal calendar recording all activities in the database. When the patient returns from the appointment s/he confirms the visit to the specialist through the calendar.
3. The system will sends an e-mail to the GP (for urgency the application could send also an SMS to GP) that the patient visited the specialist and an update of patient's data is expected. The email will contain the BSN, the serial number of the InHome Box and a pre-configured text that the patient has been to the appointment.

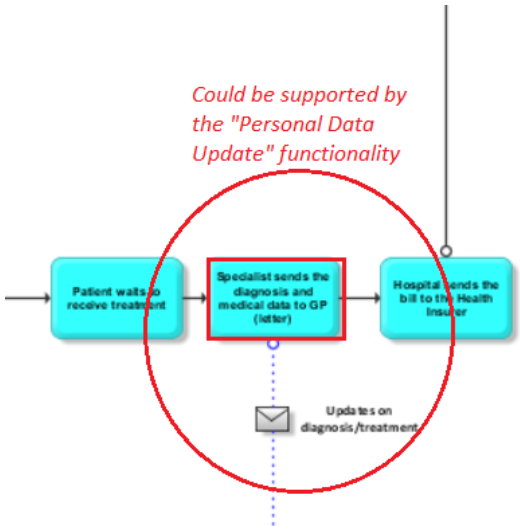


Figure 12. Impact on the process from the Personal Data Update Functionality

4th Solution – Emergency Functionality

The InHome Box as already described comes with an i-tag. This wrist device will control the body sensors , but also work together with the mobile application as an alerting service for informing emergency services, relatives and doctor in case of an emergency.

The steps of that process are the following:

1. The i-tag receives the detected abnormality from the body sensors. (It can store locally the vital parameters).

2. The i-tag is coupled with the mobile application which receives all the data only in an emergency case.
3. When the mobile application receives the alert from the i-tag it can send messages with the location of the patient and a code (universal code connected to a specific emergency).
4. The mobile application sends three messages based on the contact information that are stored in the application. The first message is for the emergency services, the second for the doctor and the third for the relatives.

7. Hypotheses

This chapter will describe all the hypotheses we are planning to test with our research. Each hypothesis will be justified and explained based on our work in the previous chapters. Moreover, additional support and relevance will be provided by existing literature in the related topics.

7.1 Architecture Hypotheses

In this section we would like to develop the hypothetical scenarios for the architecture of our system. The hypothesis will include the testing options from a general to more specific perspective in order to cover the core technologies and implementation choices.

Architecture Hypothesis #1

"The InHome Box as a home centric and patient oriented platform offers important improvements on future healthcare needs"

The ageing population is increasing very fast according to Pothuganti and Chitneni [30], also there are several other evaluated factors which lead to medication non-compliance [38]. The healthcare costs are rising [31] and patients with serious diseases (e.g chronic) have not always the ability to visit hospitals for a treatment. Due to this factors and with the revolution of IoT [32][39] there is a need to build systems that could support all these health needs and at the same time functioning within the new innovative technological environment.

Architecture Hypothesis #2

"The proposed system with the described technologies and design is able to play a central role in the future healthcare service (IoT) ecosystem"

The explosion of IoT will bring major changes in the way the health industry is working as a co-operating system offering a different type of service [5]. Furthermore the knowledge distribution based on this type of technologies is moving from hospitals to the homes until 2028 [15]. Thus the platform is built with this research direction and mindset.

Architecture Hypothesis #3

“The proposed platform is a more comprehensive healthcare solution (systems) solving multiple issues, not simply health problem focused”

Our system will be able to include a general health performance file of the patient targeting the preventive healthcare. The proposed architecture is focusing on chronic disease patients or with multiple health issues and is able to collect data from various medical devices with standardized interfaces [5][17].

Architecture Hypothesis #4

“The implementation choice of an open platform will support the interoperability and application integration”

We consider that in the future healthcare industry, open platforms could support automated healthcare services in cooperation with Internet of Things in a new defined collaborative/co-operative ecosystem [5][40]. In an open platform with primary objectives “interoperability and integration” developers are able to add features or functionality with new applications. As we already use the cloud option, the future idea is to support multiple integration of Enterprise Information Systems of various players under common rules on the IoT cloud to offer seamless service options to the patient using the In Home Box platform [5] [17].

Architecture Hypothesis #5

"ZigBee technology is an ideal solution for sensors collecting patient’s physical data in a healthcare platform."

ZigBee provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime. [30] ZigBee is widely used for the data collection and sensor layer in smart environments considered to be a secure protocol [19][20].

Architecture Hypothesis #6

“RFID technology is very effective for identifying changes in physical objects, like medication packages and pills.”

RFID technology is widely used technology in the pharmaceutical industry for tracking medication packs. There have been several implementation that prove RFID as a very suitable solution to track medicine bottles [17][25][36] or even testing its performance in smart health environments [34]. It can be used in combination with other technologies like triggering the system turn on the camera to continue detecting the medicine bottle in case of moved out of the range of the RFID antenna [35].

Architecture Hypothesis #7

"RFID and weight sensors, in a medication inventory chamber/box, are technologies that can be used for tackling issues, such as patients' medication non-compliance and inventory control."

This functionality uses the weight sensors as in [17] in order to control the medicine inventory and prevent patient take doses that are not prescribed from the doctor intentionally or unintentionally.

Architecture Hypothesis #8

"In a medication management platform, the system should be preconfigured to provide only the prescribed doses and only at the relevant time of the day."

This security functionality as presented in "ImedBox" paper [17] is an extra security measure allowing patient take the medicine only on prescribed time. This also helps people with eye impairment to take pills by touching the opened chamber.

Architecture Hypothesis #9

"NFC technology can be used as authentication mechanism for logging in securely into the software of a private healthcare platform."

NFC is considered to be one of the most commonly used authentication technologies. Password based authentication systems are neither secure nor particularly convenient for users. Using NFC-enabled mobile phone [27] or box reader users are able to login in with smart cards allowing solid authentication like in transactions.

Architecture Hypothesis #10

“Authenticating external user with One Time Password (OTP) is a very secure mechanism for giving access to a cloud server containing physical and personal data."

Implementing the authentication with OTP (One-Time-Password) [41] which uses a 2-factor authentication with a one-time password login. The doctor’s mobile will work as the authentication device and the Java app on the phone must combine 3 values in order to generate the password used for the login portal in the private cloud.

Architecture Hypothesis #11

“Providing access to a cloud server instead of the actual database containing physical and personal data, via a remote software is more secure, data wise.”

Implementing remote management applications or tools [17] is enabling the doctor to have a direct access on the local database of the box to monitor the medication. This is tested against the idea of a secure login of the GP in the private cloud in order update only the medical log file and the e-prescription.

7.2 Process Changes Hypotheses

In this paragraph we will focus on the hypotheses as they are emerging from the proposed changes in our work and the existing research in the topic.

Process Changes Hypothesis #1

“A patient-centric in home platform can improve the communication between the healthcare industry players.”

According to Dingley [43] “ineffective communication among health care professionals is one of the leading causes of medical errors and patient harm”. So by improving the communication inside the healthcare process and between the players we can improve the results of the treatment for the patient and complementary to that we can optimize important tasks of the players.

Process Changes Hypothesis #2

"Healthcare industry is an environment that is recognized from great unwillingness of cooperation."

One very important characteristic of the healthcare industry is the complexity of its problems, which according to Molleman et al [44], forces healthcare industry actors to cooperate. It is though, worth questioning the degree to which they are willing to work together. Through this hypothesis we will be evaluating how open they are in sharing information and making adjustments to their processes and systems, in the "road" for improving patients' life and treatment.

Process Changes Hypothesis #3

"The patients' frustration, from going through repetitive steps, is the number one problem in the healthcare process for chronic disease patients."

As described by Rolden [28] the most important problem for "clients with multiple care and support needs" is that they must repeatedly say the same things. More specifically, they have to provide their full physical and medical records in various different steps of the process. Moreover, patient have to go through the same steps every time they are moving in a different municipality, which triggers frustration explosions. This hypothesis is used for testing the previously described phenomenon in the process.

Process Changes Hypothesis #4

"Physical data stored in an In-Home healthcare platform will be considered trustful by all the players in the industry."

Blewett et al [45] in their work describe the benefits and concerns regarding the formulation of a health data warehouse. One of the biggest challenge in that effort is to collect all the needed patients' records. The latter leads to the most important question, "How can those data be trusted?", given that they originate from various different sources. At the moment only for gathering data for one patient you might have multiple source systems. This makes physical data unreliable and thus the solution can be provided by an in home platform that will be able to maintain the patient's physical data. Through this hypothesis we aim to test the validity of patient's physical records, when they are stored in an in home system.

Process Changes Hypothesis #5

"The most important change in the healthcare process, patient wise, is to decrease the number of times needed to provide their personal information."

We have already mentioned the issues created for the patient by having to provide their personal data throughout the process. Therefore this hypothesis is used for evaluating the benefits for the patient from the personal data functionality.

Process Changes Hypothesis #6

"The most important change in the healthcare process, insurance company wise, is to improve the communication with the emergency services."

According to The Netherlands Traffic Management Centre (VCNL) [46] the average response rate for ambulances in the Netherlands is fifteen minutes from the moment of receiving the call. In incidents like heart attacks the first few minutes can make the difference between life and death, as well as define the period of recovery. In that perspective we believe that insurance companies will be the most interested from the proposed emergency functionality and this is what we will try to measure with this hypothesis.

Process Changes Hypothesis #7

"The most important change in the healthcare process, hospital wise, is to improve the process of updating patients' data."

One of the most crucial tool for doctors and hospitals is data. Using correct and updated physical data of the patient can help specialists and physicians prevent serious complications during the patient's accommodation in a hospital. As mentioned in World Health Organization report [42], more updated records will decrease potential liabilities. Based on our research we recognized that improving the steps of the process related to patient's record updates, we can significantly support the work of hospitals.

Process Changes Hypothesis #8

"The most important change in the healthcare process, general practitioner wise, is to semi-automate the medication prescription steps of the process."

Based on our research and analysis of the process we identified that decreasing the time GP's spend on routine tasks, such as prescribing medication is of the utmost importance. Through that change the efficiency of the GP's time could be significantly improved. That alteration will allow GP being occupied with much more serious tasks like diagnostics, job differentiation with other GPs and disease prevention by cultivating a long-care relationship with the patient [47].

Process Changes Hypothesis #9

"An in home healthcare platform that is patient centric can improve, via its functionalities, the daily tasks of all the players in the industry."

This hypothesis emerges directly from our work and the previously analysed literature. As already mentioned in the previous chapter there is an urgent need for much more patient – centric healthcare services. As a result, we are assuming that our system with all the described functionalities will support firstly the patient and secondly will provide added value to the remaining key players in the industry.

8. Data Analysis and Hypotheses Testing

In the following paragraphs we will conduct the hypothesis testing process. In each of them, we will firstly explain the outcome of the testing per hypothesis and then, at the end of the paragraph a summary table with all the results and their basic information will be included.

As mentioned in paragraph 3.2 the surveys questions were designed in such a way that they tackled the hypotheses issues. As we aimed on having impulsive answers we tried to retrieve the needed answers not just from a single question but from various. Also instead of phrasing exactly the issue of each hypothesis in a question form, the questions are formulated in such a way that the hypothesis is tested from the emerging content. A clear example of that approach is architecture question 4, where the used question for answering architecture hypothesis #1 was "To what extend do you consider necessary the creation of a patient oriented platforms?", instead of asking the participants "How important improvements, for future healthcare needs, can the InHome Box as a home centric and patient oriented platform to offer?" that is the hypothesis in a question form.

In the illustration of the results we made use of the expressions ARPP (Architecture Research proof points) and PRPP (Process Research proof points). The Research Proof Points are in fact the questions of the surveys, specifically the ARPP#1 refers to architecture survey question number one and so on, while PRPP#1 is referring to process changes survey question one. The actual use of RPP is for making easier the link between the hypotheses and the survey question to the reader of our work.

8.1 Architecture Hypotheses Testing

Architecture Hypothesis #1 (ARPP4, ARPP21)

“The InHome Box as a home centric and patient oriented platform offers important improvements on future healthcare needs.”

ARPP#4	To what extend do you consider necessary the creation of a patient oriented platforms?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5 max absolutely necessary, low not necessary	Urgency of patient oriented platforms	4.33

Three out of six research participants considered in ARPP4 that in future it is absolutely necessary that health oriented platforms like the proposed system should be the main focus of development. The remaining considered it necessary enough. The average rating score of 4.33 out of 5 could prove our direction towards such platform as a first step for being able of supporting the future healthcare needs of the users.

ARPP#21	What is, in your opinion the biggest advantage for the patient by using this platform?		
Research participant	**Advantages (related to health needs)***	**Type of answer**	**Advantage Captured?**
1	Live independently, live longer	Open question	YES
2	Simplicity for the patient	Open question	YES
3	Automatic data transfer, save doctors' and hospitals	Open question	YES
4	Medication management/control	Open question	YES
5	Less errors, medical info during treatment, different medication mgt	Open question	YES
6	Mainly focuses on patient on many aspects	Open question	YES

All research participants in the open question ARPP21, which is targeting to define the biggest advantage of the platform, considered that it mainly focuses on the patient solving various healthcare needs as defined in column 2. This proves that such a platform could play an important role in the future based on the orientation of healthcare service delivery needs. The advantages captured from the participants could mainly prove our direction to such platform as a first step for being able to solve patient health needs related to medication control, mobility issues and rising costs.

Specifically, in the next table we can see that participants chose specific services from our platform that should be offered at first place based on their needs, a fact which

proves that the functionalities offered are urgently needed in the emerging healthcare landscape.

ARPP#6	Supposing the proposed home centric platform is the open platform and acts as the home healthcare gateway, which of the following services do you consider crucial to be firstly offered? Please choose the three most crucial services.		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Medication Management	6	Multiple Choice	100%
Connectivity with personal doctors system	4	Multiple Choice	50%
Alerting/emergency	3	Multiple Choice	50%
Communication with physicians	2	Multiple Choice	0%
Vital Sign Monitoring	2	Multiple Choice	33%
Communication with private cloud server	2	Multiple Choice	0%

Architecture Hypothesis #2 (ARPP16, ARPP18, ARPP19, ARPP20)
"The proposed system with the described technologies and design is able to play a central role in the future healthcare service (IoT) ecosystem"

ARPP#19	How would you rate the proposed platform in regard to the future applicability of the used technology?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5, max excellent, low bad	Future applicability	4

Four out of six research participants in ARPP19 rated the proposed platform in regard to the future applicability of the used technologies for solving healthcare needs with an average value of 4, which is a very important proof that our system can have a good applicability taking into account it's functionalities mapped with the future orientation of healthcare delivery. This increases the great potential of such platforms being embedded in the IoT oriented healthcare industry.

Research participants also liked the proposed functionalities of the box in general and rated them with a 4,5 out of in 5 in ARPP 16. The latter is a supporting and

encouraging result that the design pattern of the box is coupled with the future orientation of IoT services.

ARPP#16	How would you rate the general idea of the proposed platform and its functionalities?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5, max excellent, low bad	Proposed Functionalities	4,5

Furthermore, four out of six participants in ARPP20 rated the used communication methods with a very good score, namely 4 out of 5. But still the average is low for us as communication methods are a vital parameter for our platform scope.

ARPP#20	How would you rate the proposed platform in regard to devices' communication methods??		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5, max excellent, low bad	Communication Methods	3,67

This could prove partially the fact that the box could function well in the IoT ecosystem. However two of them considered the communication methods average, scored with 3 out of 5 and this mainly connects with their concerns related to the external connection with the private cloud server (ARRP10). As described in the previous chapters the system has been localized at the moment but it has the basis for an IoT oriented health service delivery. At this point more research is needed on this as communication is crucial for the IoT ecosystem, especially for the connection of the box with external tools and players, but also for some internal components communication with the GP.

In connection to the previous rating, participants also rated the components used a 3,83 out of 5 in ARPP 18. As explained before further research is needed as the components used can play a crucial roles in the internal and external communication.

ARPP#18	How would you rate the proposed platform in regard to the used components?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5, max excellent, low bad	Components used	3,83

Architecture Hypothesis #3 (ARPP3, ARPP16)

"The proposed platform is a more comprehensive healthcare solution (systems) solving multiple issues, not simply health problem focused"

ARPP#3	Today we observe that a lot of health systems (or apps) focus on solving a specific healthcare problem by improving a specific condition, which covers limited aspects of healthcare. According to your experience how urgent is a more comprehensive home healthcare solution?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5 max urgent, low not urgent	Urgency of comprehensive solution like the proposed system	4,5

This hypothesis is proved valid from ARPP3, as the research participants considered the existence of such a solutions urgent and its implementation even more urgent. Taking into account the average score of 4.5 out of 5, they actually seem to agree, in a certain level, that most of the existing applications or systems today focus on specific healthcare problem rather than a complete health solution.

ARPP#16	How would you rate the general idea of the proposed platform and its functionalities?		
Number of replies	**Type of answer**	**Number of replies**	**Type of answer**
6	Scale 1-5 max urgent, low not urgent	General idea of the proposed system	4,5

Furthermore when we look the results of the table below, four out of six participant considered the general idea of this platform offering a comprehensive health solution very good and above, two of them excellent. Both points prove that this system is focusing on the patient, trying to offer a more complete healthcare service and aggregate/analyze many information for him/her to be used during the treatment, while maintaining in the same time extensive patient record file up to date.

Architecture Hypothesis #4 (ARPP2)

"The implementation choice of an open platform will support the interoperability and application integration"

ARPP#2	The expecting revolution within the Healthcare industry due to IoT (Internet of Things) will bring also a lot of changes in the research mindset and the way systems and applications are being developed. Being aware of security and privacy risks, how important do you think that the developed health platforms in future should be open platforms fully supporting IoT services with standardized interfaces in order to enable seamless application integrations?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5 max very important, low not important	Importance of open platforms to support standardization in the IoT ecosystem	4.5

Three out of six participant considered the importance of open platforms like the proposed system very important, rating them with 5. The remaining three rated the creation of such platform for standardization with a 4, which is quite important. The participants agree that despite the issues on privacy and security, such type of platforms are very much needed in the future within the new orientation of the healthcare industry. The average score proves that our system should be built in this way to function within the innovative healthcare industry coupled with the expected IoT services. Open platforms are considered as the potential solution to achieve the ultimate scope of standardization and interoperability and seamless application integration from the developers point of view.

Architecture Hypothesis #5 (ARPP 7)

"ZigBee technology is an ideal solution for sensors collecting patient's physical data in a healthcare platform."

ARPP#7	Many alternative technologies have been developed in the latest years for Wireless Sensor Area Networks, known as WSAN's. Supposing we would like to use a standardized technology, which of the following do you think would be the most suitable for the sensor and data collecting layer of an in-home integrated health care platform? Please pick the two options you find more suitable.		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Bluetooth Low Energy	4	Multiple Choice	66,7%
IEEE 802.15.65	2	Multiple Choice	33,3%
Zigbee (proposed)	0	Multiple Choice	0%
WirelessHART	0	Multiple Choice	0%
ISA100	0	Multiple Choice	0%
WIA-PA	0	Multiple Choice	0%
6LoWPAN	0	Multiple Choice	0%
Other	0	Multiple Choice	0%

During our implementation planning we highly considered ZigBee protocol as the most likely solution for the sensor and data collecting layer based on our research from the existing scientific papers and the comparison between ZigBee and other protocols. However this hypothesis is proved to be an inappropriate choice according to our research participants. Four out of six, which represents the 66,7%, considered the use of Bluetooth Low Energy technology as the best solution for the sensor and data collection layer. This choice is mostly considered to be secure for data collection and reliable in communication with the box. Second option of the participants with a percentage of 33,3% is the IEEE 802.15.65, as being very popular and easy to use. Following that direction the most dominant choice would be the BLE, however further research is needed before the implementation.

Architecture Hypothesis #6 (ARPP 12)

"RFID technology is very effective for identifying changes in physical objects, like medication packages and pills."

ARPP#12	One of the core functionalities of the box will be the medication management though RFID technology. The RFID reader (that communicates with the backend system) is connected to the antenna (actual RF hardware) via cable in the box and the latter communicates with the antenna on the tag (placed on the pillbox) to facilitate the data stream. Would you consider technically this a correct choice for the smart pillbox (also cheap solution)? If no, please indicate based on your experience the reason and what would you propose to be deployed.		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Yes	2	Open Question	33,3%
No	1	Open Question	16,7%
Not Aware or Not Applicable	2	Open Question	33,3%
Need more data to evaluate	1	Open Question	16,7%

Two out of six participants (a 33,3% percent) consider the RFID technology a good solution for the connection of the pillbox and the platform to capture medication events. Only one participant clearly considers that it not a good solution, advising us to use a different method for this connection and data transfer (e.g finger/iris or real time camera identification). One of the participant needs more data of the developed system for evaluating it and one is not familiar with this kind of technology. As a result here we need to further investigate the connection method of the pillbox and the actual system.

Architecture Hypothesis #7 (ARPP 14)

"RFID and weight sensors, in a medication inventory chamber/box, are technologies that can be used for tackling issues, such as patients medication non-compliance and inventory control.""

ARPP#14	To measure the number of pills taken from bottles an idea could be to place an RFID tag under each bottle. By the time the patient picks up the

	bottle the RFID reader notes the event and calculates the weight difference via a weight sensor when the patient places back the bottle. The health box stores also the time of the event and notifies the doctor depending on frequency of error. Would you recommend this idea for the medication non-compliance control? (f.e. misuse (consider medication cheating) or in parallel help people with a visual impairment or hearing loss? If no, name the possible concerns behind it or propose an alternative idea.)		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Yes	4	Open Question	66,7%
No	2	Open Question	33,3%
Not Aware or Not Applicable	0	Open Question	0%
Need more data to evaluate	0	Open Question	0%

Using a weight sensor under the chambers of the box for the medication control is considered from most participants (4 out of six with a 66,7%) as a good solution to be implemented. 33,7% percent of the research participants do not agree with this functionality and clearly state the reason as an expensive and complex implementation or the difficulty of the sensor measuring this parameter, use of one time pill slot. One of the participants liked the choice and also proposed a better way for a smart holder during the implementation, together with an one time pill slot. We should reconsider this choice and make a further, deeper investigation on this functionality.

Architecture Hypothesis #8 (ARPP 13)

"In a medication management platform, the system should be preconfigured to provide only the prescribed doses and only at the relevant time of the day."

ARPP#13	When the e-prescription is stored on the database, the health box backend will then compare the medication coupled to a unique RFID number with the name and details on the prescription form. Thus, the system will be able to open only the chambers that must be opened for the patient at a specific moment of the prescribed doses, while alerting him in the same time. Would you recommend this security functionality to solve the medication reminder issue? If no, name the possible concerns behind it or propose an alternative idea.		
Question Choice	**Number of replies**	**Type of answer**	**Average value**

Yes	2	Open Question	33,3%
No	3	Open Question	50%
Not Aware or Not Applicable	1	Open Question	16,7%
Need more data to evaluate	0	Open Question	0%

This hypothesis is also proved to be in need of deeper research something that was one of our concerns as well. 50% of the asked research participants consider this functionality as a rather bad choice for various explained reasons, such as stolen RFID tag (thus the chamber will never open), variety of medication that must be managed/checked and whether this function is useful when the patient is out of home on on vacation. These concerns seem to be important enough for highlighting the need for a deeper investigation on this functionality as well. The 33,3 % however rated this as a good solution that is secure and reliable.

Architecture Hypothesis #9 (ARPP 9, ARPP 15)
"NFC technology can be used as authentication mechanism for logging in securely into the software of a private healthcare platform."

ARPP#9	In our architectural design we described that we make use of NFC technology for the authentication of the patient to the InHome Box. On your experience is NFC technology a good architectural decision, given the high sensitivity of data stored in the platform? If no please mention the reason and propose an alternative solution.		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Yes	3	Open Question	50 %
No	0	Open Question	0%
Not Aware or Not Applicable	3	Open Question	50%
Need more data to evaluate	0	Open Question	0%

Although we did not have any negative answers on that hypothesis, the research participants who rated in favor of this functionality in ARPP5, were 50% and explained that further testing is needed on the NFC. Some of them even proposed further research papers on this authentication method.

ARPP#15	What method, apart from the NFC identification, should the InHome Box use for a secure unlocking process in order to be accessible only by the authorized user(s)? (Security counter measure for preventing other users of the box of taking wrong and unsubscribed medication) Please choose up to 2 options.		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Retina identification	1	Multiple Choice	16,7%
Fingerprint unlock	4	Multiple Choice	66,7%
User Password	0	Multiple Choice	0%
Pattern unlock	0	Multiple Choice	0%
Other	1	Multiple Choice	16,7%

Moreover further research on the authentication is needed due to the ARPP15, which proves that a 66,7% of our participants proposed another additional method beside NFC to be used, namely the fingerprint unlock. One participant of this group proposed to consider of an alternative for people not being able to use fingerprint. Finally one participant, forming the 16.7%, proposed to still use NFC but with a security mechanism on top of that.

Architecture Hypothesis #10 (ARPP10, ARPP17)

"Authenticating external user with a One Time Password (OTP) is a very secure mechanism for giving access to a cloud server containing physical and personal data."

ARPP#10	Would you propose OTP authentication for a secure login? If not could you give an alternative solution (like dynamic knowledge based authentication- KBA)? In case of not having the needed background please write on your answer "Not applicable".		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Yes	3	Open Question	50 %

No	1	Open Question	16,7%
Not Aware or Not Applicable	2	Open Question	33,3%
Need more data to evaluate	0	Open Question	0%

50 percent of the research participant consider OTP as a good solution to be implemented and have seen this also in other systems. Most of them reacted with the comment that because this method uses PIN codes the doctor may have a problem handling these, which may result into a complex authentication for them. We consider that in this topic further investigation is needed although the method is rated with fairly good percentage for the proposed platform. Taking also into consideration that four out of six participants have concerns about the general security of a platform we should drive our attention more deeply into such authentication methods, similar to previous hypothesis 9 for the NFC security for the authentication with the health box.

ARPP#17	How would you rate the proposed platform in regard to security aspects?		
Number of replies	**Type of answer**	**Target**	**Average value**
6	Scale 1-5 max very excellent, low bad	General security of the platform	2.83

Architecture Hypothesis #11 (ARPP 11)

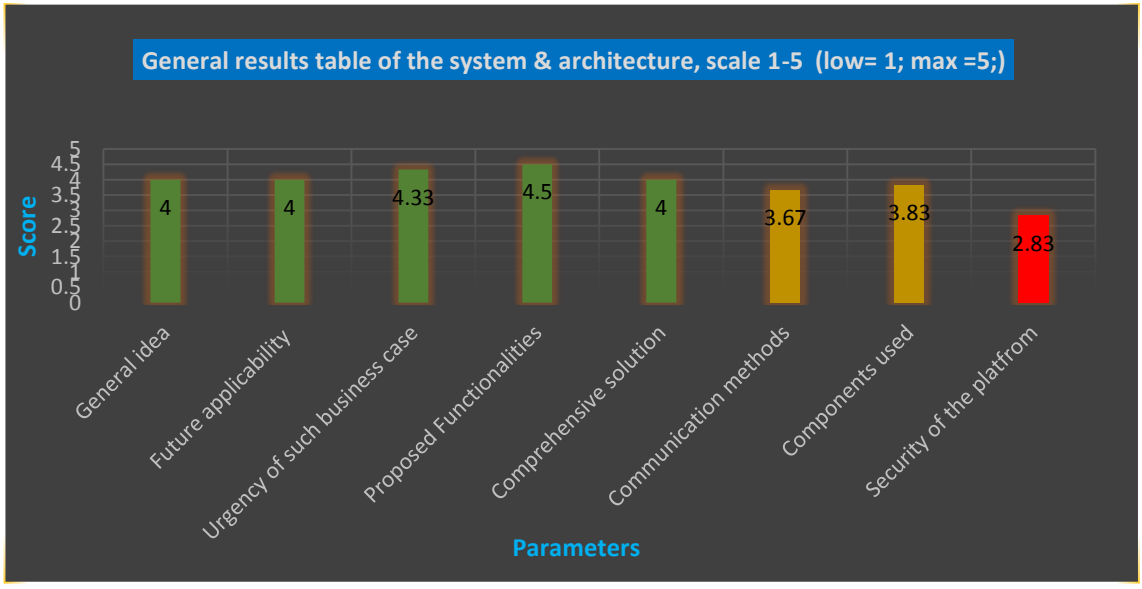
"Providing access to a cloud server instead of the actual database containing physical and personal data, via a remote software is more secure, data wise."

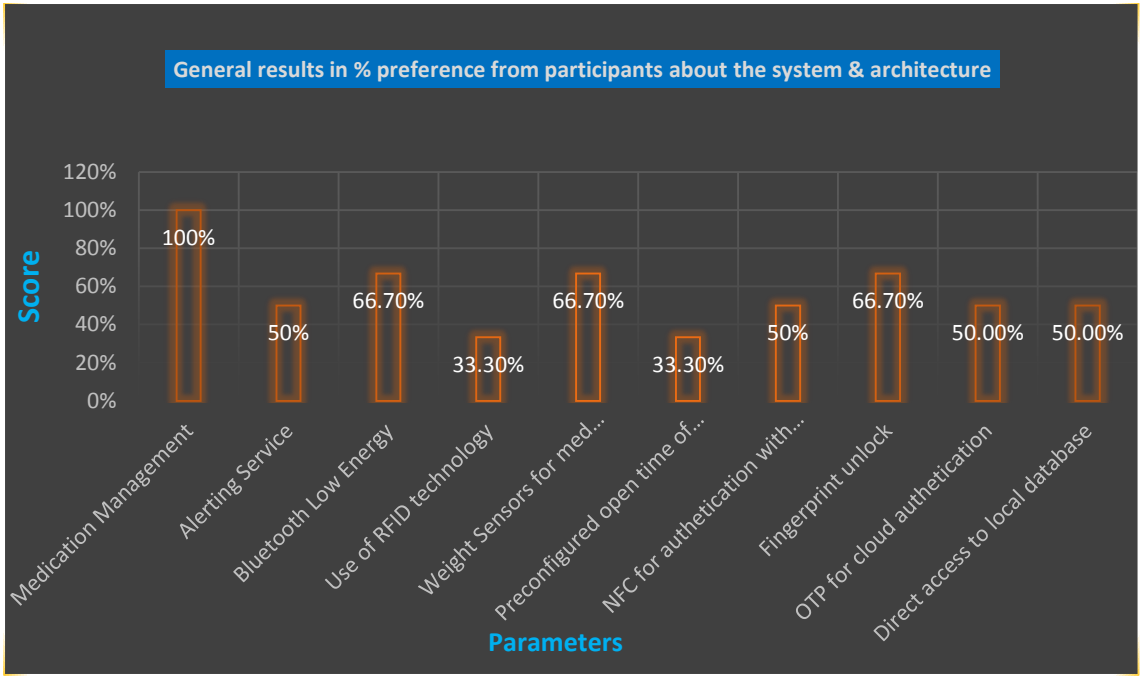
ARPP#11	Considering that an authenticated user (f.e. GP) can monitor the patient records via the cloud server. Would you consider a direct access permission to the local database of the InHome box a wiser architectural decision?		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Yes	3	Open Question	50 %
No	1	Open Question	16,7%
Not Aware or Not Applicable	2	Open Question	33,3%
Need more data to	0	Open Question	0%

evaluate			

50 percent of the research participants included in their choices that a direct access to the box should be established. This has to be taken into account and reconsider if a remote management software should be built in order to include this functionality. We made the assumption in the platform description that it better for us to use a private cloud in order to let the GP log in to update patient data. But maybe this option should be considered to be implemented together with the direct access to the local database as many participants thought the direct access good for emergency reasons or for having it as an additional option. The latter increase the control of the patient of giving permissions to the related caretakers.

Both tables below show the overview of the hypothesis testing results emerging from the previously analyzed data in this chapter for the system and the architecture. All scores and percentages in the tables outline the average scoring value given from all the research participants for the specific parameter. The first table is testing the actual system from multiple perspectives (parameters) with the best scores being colored in green (score >= 4), the medium scores colored in yellow (3 =< score < 4) and the low scores colored in red (score < 3). The second table presents the percentages calculated based on the answers received for each specific component and technology of the system. Each percentage here shows the specific preference for each component/technology from our research participants.




General results in % preference from participants about the system & architecture
Score
120%
100%
80%
60%
40%
20%
0%
100%
50%
66.70%
33.30%
66.70%
33.30%
50%
66.70%
50.00%
50.00%
Medication Management
Alerting Service
Bluetooth Low Energy
Use of RFID technology
Weight Sensors for med...
Preconfigured open time of...
NFC for authetication with...
Fingerprint unlock
OTP for cloud authetication
Direct access to local database
Parameters

8.2 Architecture Hypotheses Testing Summary

Hypotheses	Architecture Research proof points ARPPs (*)	Targeting Touchpoints (TTs)	Outcome based on the TT's	Status (**)
#H1. The InHome Box as a home centric and patient oriented platform offers important improvements on future healthcare needs.	ARPP4, ARPP21	Future health care needs; Orientation to such platforms;	First step → Urgency 4.33/5, 6 participants identified multiple healthcare needs as an advantage of this platform , Medication management → 100% as first service	
#H2. The proposed system with the described technologies and design is able to play a central role in the future healthcare service (IoT) ecosystem.	ARPP16, ARPP18, ARPP19, ARPP20	Testing the central role within IoT ecosystem;	Future applicability → 4/5 Proposed functionalities → 4,5/5 Communication methods → 3,67/5 needs further investigation internal & external communication methods; Proposed components → 3,83/5 needs further research on the components used for communication with the devices and external connections	
#H3. The proposed platform is a more comprehensive healthcare solution (systems) solving multiple issues, not simply health problem focused.	ARPP3, ARPP16	Comprehensive solution testing;	Urgency of comprehensive solution like the proposed system → 4,5/5 General idea of the proposed system → 4,5/5	
#H4. The implementation choice of an open platform will support the interoperability and application integration.	ARPP2	Interoperability achieved through open platforms; Standardization and application integration;	Importance of open platforms to support standardization in the IoT ecosystem → 4.5/5	

#H5. ZigBee technology is an ideal solution for sensors collecting patients physical data in a healthcare platform.	ARPP 7	ZigBee is the standard considered to be implemented;	Proposed ZigBee standard but participants had a different view: Bluetooth Low Energy → 66.7% out of our scope needs deep research IEEE 802.15.65→ 33,3%out of our scope needs deep research	
#H6. RFID technology is very effective for identifying changes in physical objects, like medication packages and pills.	ARPP12	RFID technology will be used for connection of the Smart Pill box and the platform;	Proposed RFID for the connection of Smart Pillbox. Yes→ 33,3% No → 16,7% → 16,7% Need more data to evaluate/not applicable. →33,3 % not aware, not applicable, no answer given Needs further research with a larger sample of participants.	
#H7. RFID and weight sensors, in a medication inventory chamber/box, are technologies that can be used for tackling issues, such as patients medication non-compliance and inventory control."	ARPP14	Weight Sensors will be used under the chambers for medication control;	Yes→ 67,7% but needs further research before implementation as concern rise up for the applicability of the weight sensor.	
#H8. In a medication management platform, the system should be preconfigured to provide only the prescribed doses and only at the relevant time of the day.	ARPP13	System pre-configured to open only on time of the doze the related medication chambers;	Proposed this functionality and participants had a different view : No → 50% needs deeper research as remarks stated in the related description; Yes→ 33,3%	

#H9. NFC technology can be used as authentication mechanism for logging in securely into the software of a private healthcare platform.	ARPP 9, ARPP 15	NFC for the authentication of the patient with the box;	Yes→ 50%, here we do not have negative answers although suggestions for further testing of NFC security. 66.7% → Fingerprint unlock as an alternative method	
#H10. Authenticating external user with an One Time Password (OTP) is a very secure mechanism for giving access to a cloud server containing physical and personal data.	ARPP10	Use of OTP authentication for the connection of the GP to the private cloud;	Yes→ 50% but further investigation if PIN codes are going to confuse doctors, evaluation of this method.	
#H11. Providing access to a cloud server instead of the actual database containing physical and personal data, via a remote software is more secure, data wise.	ARPP11	Implement the Direct access functionality to the local database.	Proposed only cloud connection but participants had a different view: Yes for direct access → 50% Further research needed for remote software implementation; out of our scope;	

* ARPP maps the hypothesis with the survey question, for example ARPP1 means that this hypothesis is test by survey question 1.

** On the status column green cell characterizes a correct proved Hypothesis, the orange a correct proved hypothesis but with further research needed and the red a rejected hypothesis.

8.3 Process Changes Hypotheses Testing

Process Changes Hypothesis #1 (PRPP4)

"A patient-centric in home platform can improve the communication between the healthcare industry players."

PRPP#4	Could such a platform improve the communication between chronic disease patients, that need constant monitoring, and various players (GP, hospital, insurances, pharmacies) of the healthcare process and to what degree?	
Number of replies	**Type of answer**	**Average value**
7	Scale max great improvement, low no improvement	4.14

All seven participants mentioned that our platform can improve greatly the communication between the healthcare industry players and the patient, one of the most important cause for the problems in the Dutch healthcare process. More specifically in a scale from one to five, with one being no improvement and five being great improvement, they rate it with an average 4.14. That score is very close to five and provides quite a clear conclusion of the role of the platform in regard to the communication issue. We can consider this hypothesis as confirmed.

Process Changes Hypothesis #2 (PRPP7)

"Healthcare industry is an environment that is recognized from great unwillingness of cooperation."

PRPP#3	To what degree do you consider applicable the communication between your systems and the proposed platform? (Patients can skip that question)	
Number of replies	**Type of answer**	**Average value**
4	Scale max extremely easy, low very difficult	3.25

From the seven participants only four replied to the question about the willingness of the industry players to make the necessary adjustment to their system in order to connect them with platform. The average score, in scale of one to five, was 3.25

something that proves the great resistance and uncertainty to cooperate for creating a better technical environment supporting the patient. So in this hypothesis the conclusion is not clear and further research should be done in that direction

Process Changes Hypothesis #3 (PRPP5, PRPP6, PRPP8)

"The patients' frustration, from going through repetitive steps, is the number one problem in the healthcare process for chronic disease patients."

PRPP#6	Do the systems used by hospitals and insurance companies for communicating (f.e. requests, contacting departments, complaints etc.) with the patient function with one time registration? Please choose one of the options below.			
Survey question	**Question Choice**	**Number of replies**	**Type of answer**	**Average value**
PRPP 6	Yes	2	Multiple Choice	29%
	No	1	Multiple Choice	14%
	Not Aware	4	Multiple Choice	57%

PRPP#5	What are the top problems/issues that chronic diseases patients are facing during the Dutch healthcare process? Please chose two of the following options.			
Survey question	**Question Choice**	**Number of replies**	**Type of answer**	**Average value**
PRPP 5	Repetitive Steps (f.e. different departments checking the same type of documents)	2	Multiple Choice	29%
	Discomfort from the constant movement between various offices and departments	4	Multiple Choice	57%
	Repeatedly providing personal information	1	Multiple Choice	14%
	Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist)	4	Multiple Choice	57%
	Time consuming medication ordering process	2	Multiple Choice	29%

PRPP#8	To what degree do you believe that a platform like ours, based on its proposed involvement to the current process, could decrease the frustration level of patients?		
Survey question	**Number of replies**	**Type of answer**	**Average value**
PRPP 8	7	Scale max very much, low not at all	3.71

In the question that tested the type of registration systems offered by health providers, only 29% used the one-time registration system. The remaining 71% were either unaware of the situation or replied negative, which actually proves that patients are not frustrated because they repeatedly provide their personal information. Also 57% of the subjects mentioned as the most important problem of the process for chronic disease patients to be the bottlenecks that delay the process (such as GP waiting for the letter from the specialist) and the discomfort from the constant movement between various offices and departments. Only 29% consider important the existence of the repetitive steps. This is also supports the conclusion that emerged from the previous question. Finally, the gathered participant results on solving the frustration issue of the patients with the proposed changes from the platform are quite questionable due to an average of 3.71 in a scale of one to five with five being complete resolving the problem.

Based on all the replies we can say that most likely although the frustration level exists, it is actually caused from the repetitive steps. But the results are unclear and therefore deeper investigation of this hypothesis will be needed in the future.

Process Changes Hypothesis #4 (PRPP11)

"Physical data stored in an In-Home healthcare platform will be considered trustful by all the players in the industry."

PRPP#11	How much would you trust patient data stored in such an In-Home healthcare platform?	
Number of replies	**Type of answer**	**Average value**
7	Scale max trustful, low unreliable	3.71

The average score on the level of trust for data originating from a platform like ours was 3.71, in a scale of one to five with five being trustful. This score reveals the fact that although most of them are trusting the platform there will be still a period

needed in order to prove the security and reliability of its functionality. Also trusted data are translated into future opportunities for exchanging information between the health providers' platforms and our system**.** We characterize Hypothesis #4 as proved but more study into the topic has to be done due to the relatively low score.

Process Changes Hypothesis #5 (PRPP13)

"The most important change in the healthcare process, patient wise, is to decrease the number of times needed to provide their personal information."

PRPP#13	In total, which of the proposed changes is the most important for the patients?		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Emergency Services Functionality	2	Multiple Choice	29%
Medication Ordering and Refill Functionality	1	Multiple Choice	14%
Personal Data Update Functionality	4	Multiple Choice	57%
Personal Documents Functionality	0	Multiple Choice	0%

Fifty seven percent of the participants believes that the most important benefits for the patients from the implementation of the changes in the process are coming from the personal data update functionality. The latter proves that improving the process of updating patients' data is more crucial for that player group. This hypothesis can be defined as disapproved.

Process Changes Hypothesis #6 (PRPP14)

"The most important change in the healthcare process, insurance company wise, is to improve the communication with the emergency services."

PRPP#14	In total, which of the proposed changes is the most important for the insurance companies?		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Emergency Services Functionality	0	Multiple Choice	0%
Medication Ordering and Refill Functionality	1	Multiple Choice	14%

Personal Data Update Functionality	2	Multiple Choice	29%
Personal Documents Functionality	4	Multiple Choice	57%

The information for defining this hypothesis were misinterpreted from our side. No participant considered important to improve the communication with the emergency services, from the insurance company point of view. On the contrary they foresee benefits for insurances by improving the bureaucratic paperwork that has to be filled by the patient. For the moment we cannot have a clear opinion for the reason of that choice and more focus should be paid in analysing the benefits criteria of the stakeholders.

Process Changes Hypothesis #7 (PRPP15)

"The most important change in the healthcare process, hospital wise, is to improve the process of updating patients' data."

PRPP#15	In total, which of the proposed changes is the most important for the hospitals?		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Emergency Services Functionality	1	Multiple Choice	14%
Medication Ordering and Refill Functionality	1	Multiple Choice	14%
Personal Data Update Functionality	3	Multiple Choice	43%
Personal Documents Functionality	2	Multiple Choice	29%

Hypothesis #7 was proved correct, as 43% of those questioned considered the personal data functionality the most beneficial of the proposed changes for the hospital. This pin points the need for reliable data and the problems that all players are facing with the many different systems.

Process Changes Hypothesis #8 (PRPP16)

"The most important change in the healthcare process, general practitioner wise, is to semi-automate the medication prescription steps of the process."

PRPP#16	In total, which of the proposed changes is the most important for the GP?

Question Choice	Number of replies	Type of answer	Average value
Emergency Services Functionality	0	Multiple Choice	0%
Medication Ordering and Refill Functionality	1	Multiple Choice	14%
Personal Data Update Functionality	5	Multiple Choice	71%
Personal Documents Functionality	1	Multiple Choice	14%

With an overwhelming 71% the participants chose as most important benefit for the GP to have a good process for updating the data. This comes in contrast to our assumption that the medication ordering functionality will be of the utmost importance for GPs by eliminating unnecessary time spent on bureaucratic tasks. Due to clarity of the results the hypothesis has to be rephrased as "The most important change in the healthcare process, general practitioner wise, is to improve the process of updating patients' data."

Process Changes Hypothesis #9 (PRPP17, PRPP18)

"An in home healthcare platform that is patient centric can improve, via its functionalities, the daily tasks of all the players in the industry."

PRPP#17	Overall, which player (hospital, patient etc.) do you believe will be the most benefited from the changes, if any?		
Question Choice	**Number of replies**	**Type of answer**	**Average value**
Hospitals	0	Multiple Choice	0%
Insurance Companies	0	Multiple Choice	0%
Patients	6	Multiple Choice	86%
GPs	1	Multiple Choice	14%

When we proposed this hypothesis we were expecting that the results in that question will be more balanced and better distributed in the four groups. After the research we state with great certainty that patient is the most benefited and that comes in support of the character of the platform that is patient – centric. Hypothesis #9 was disapproved but there is no need for further investigation as clearly it can now be

rephrased: “An in home healthcare platform that is patient centric can improve, via its functionalities, the daily tasks of patients”.

8.4 Process Changes Hypotheses Testing Summary

Hypotheses	Process Research proof points PRPPs (*)	Targeting Touchpoints (TTs)	Outcome based on the TT's	Status (***)
#H1. A patient-centric in home platform can improve the communication between the healthcare industry players.	PRPP4	Players communication issues	Impact of platform on improving communication among players → 4.14	
#H2. Healthcare industry is an environment that is recognized from great unwillingness of cooperation.	PRPP7, PRPP3(**)	Willingness to cooperate	Willingness to make systems communicating → 3.25	
#H3. The patients' frustration, from going through repetitive steps, is the number one problem in the healthcare process for chronic disease patients.	PRPP5, PRPP6, PRPP8	Repetitive steps in process, frustration of patient, chronic disease patients problems in process	Discomfort from the constant movement between various offices and departments → 57% Facing bottlenecks that delay the process → 57% Level of solving frustration due to repetitive steps → 3.71	
#H4. Physical data stored in an InHome healthcare platform will be considered trustful by all the players in the industry.	PRPP11	Data, trust, security, privacy	Level of data's trust → 3.71	
#H5. The most important change in the healthcare process, patient wise, is to decrease the number of times needed to provide their personal information.	PRPP13	Personal documents functionality	Personal Data Update Functionality → 57%	
#H6. The most important change in the healthcare process, insurance company wise, is to improve the communication with the emergency services.	PRPP14	Emergency services functionality	Personal Documents Functionality → 57%	

#H7. The most important change in the healthcare process, hospital wise, is to improve the process of updating patients' data.	PRPP15	Personal data update functionality	Personal Data Update Functionality → 43%	
#H8. The most important change in the healthcare process, general practitioner wise, is to semi-automate the medication prescription steps of the process.	PRPP16	Medication ordering and refill functionality	Personal Data Update Functionality → 71%	
#H9. An in home healthcare platform that is patient centric can improve, via its functionalities, the daily tasks of all the players in the industry.	PRPP17	Centre role of process, all players have benefits	Patients → 86%	

* PRPP maps the hypothesis with the survey question, for example PRPP1 means that this hypothesis is test by survey question 1.

** PRPP3 was partially used for Hypothesis #2

*** On the status column green cell characterizes a correct proved Hypothesis, the orange a correct proved hypothesis but with further research needed and the red a rejected hypothesis

9. Conclusions

In Chapter nine we will present the outcomes of our work. Conclusions and discussion in regard to the results of our project will be presented. Moreover recommendation and future work opportunities, as they emerged from the analysis of the study, will be included.

9.1 Research Questions Discussion

As we conducted an exploratory research most of our results could not reach an one hundred percent clear outcome. The first research question of our study was *"What architecture can support a patient-centric In-Home Internet of Things platform?"*, which was supported by the two sub questions "*What are the basic components of the platform?" and "What are the secondary devices that can be used for such a platform?".* Based on the answers of the participants to the survey we can conclude that an architecture like the one we are proposing can support the emerging needs of patient-centric IoT platforms. The proposed architecture had a relatively high acceptance rate and according to the subjects of the research, it tackled most of the crucial issue such as user friendliness, security, interoperability of the included component and easy access for all the stakeholders (patients, GP, other healthcare organizations). More specifically the participants considered the used components as good architectural choices, they found the idea of having a central box working as a medication management device, while also maintaining the personal and physical data of the patient, very efficient for the distant monitoring of the patient and his/her life. Also, the healthcare specialists that answered the survey were quite satisfied with the idea of using an i-tag, which pin points the importance of having the possibility of constantly monitoring the patient's vitals. On the other hand some of the components like ZigBee sensors, which were proposed to be used for monitoring the patient, were not considered very wise choices and other alternatives such as Bluetooth Low Energy sensors were chosen by the participants. Based on the existing technological options we proposed the use of some secondary supporting devices like smart TV, tablets and smartphones. Although most of the participants agreed on the necessity of connecting the platform with widely used devices for facilitating the everyday life of patients, still more research has to be done in that direction as emerging products like smart TV were considered relatively

insignificant. The most important emerging result from this sub question, in our point of view, is not to identify the needed secondary devices but to reach a specific level of interoperability between all the devices, existing and future, so that connectivity could be easily achieved. So, due to the constantly changing technological environment more global standards for building IT equipment have to be set in order to avoid constantly having to adjust the platform to new trends.

The second research question was *"What are the architectural choices for creating a patient-centric in home Internet of Things platform?"* that was complemented by the following sub question *" Which technologies (e.g. protocols, software) are used and why?"*. For the architectural choices we made, we considered four basic pillars. Firstly, the existing technologies that are either already available or emerging at the moment; secondly, we focused on the needs of chronic disease patients and how to facilitate their lives with the proposed platform; thirdly, we took under consideration the existing healthcare process and infrastructure and finally, the future applicability of such a system. Based on the collected results we observed that the participants in both surveys agreed on the importance of focusing on the patient needs as number one priority. They believed that if the platform serves the patient all the other stakeholders will accept it eventually. Moreover, on the used technology characteristics the only thing that mattered for the research participants was the security, due to the nature of the data that are included in the Box database and due to the impact from mistakes in the medication procedure. As already mentioned the future applicability of the platform was considered good but according to the received replies the most important aspect for them was to create common standards and increase the interoperability of the used devices/components. From the proposed protocols and software of the platform most of them were accepted, still the use of RFID for the medication inventory was questioned and further ways for applying this functionality should be researched. In addition to the above, we proposed the use of NFC for authorizing users to the InHome Box; that technology was considered secure but more alternative security measures were requested in order to create a concrete and stable system.

Research Question number three was *"Which are the most important bottlenecks/problems in the Dutch Healthcare Process?"* and in our analysis we defined three basic problems; the frustration of patients from constantly having to provide their personal and physical information, un-updated data from delays or bad communication in the process and repetitive steps related to the medication prescription and ordering process. In the surveys and interviews almost all the participants agreed on those

problems, especially people contacting patients directly for their daily tasks. From the three mentioned issues the repetitive steps from the medication prescription and ordering process although recognized wasn't considered equally important, as it impacted less the patients. More focus should be given in the future in various other problems of the process that have to be tackled.

The fourth research question was *"How do we improve the Dutch healthcare process for chronic disease patients via a patient-centric in home Internet of Things platform?"* that could be answered through the following sub question "*What are the needed changes?"*. As described in the previous paragraph the needed changes are connected with the identified problems in the process. Therefore we proposed four functionalities that could be supported by our system and at the same time they could provide a solution to a certain point. From those proposed changes, which were not altering the process but for the moment they would be running in parallel, we received very positive comments and almost the majority of the subjects of the study could foresee benefits from the changes for all the stakeholders. According to the received answers the most crucial changes that are needed are the personal data update functionality and the personal documents functionality. The latter highlights that more attention has to be given in facilitating the patient when he/she provides the personal and physical information, and on improving the patient's data maintenance procedure. The answer on research question four is that we have to adjust the process to an in home healthcare platform, which really facilitates the needs of the patients, and not vice versa. All the participants agreed that we first have to create a system that works for the patient and serves his/her needs, and then the process and its norms will be adjusted accordingly, as the ultimate goal is to serve the patient.

9.2 Discussion over the results and the emerging findings

In this part we will occupy ourselves with the architecture related discussion. The proposed system as a home centric platform is scored from the research participants as an idea which can actually act as a good potential for managing and solving future healthcare needs as it is mainly focused on the patient. The system is also considered to be a very comprehensive solution that offers many combined solutions on health and is not focused only on a single health issue as many systems and applications found in the market. Our choice for an open platform is scored as a wise choice for promoting interoperability, one of the most urgent requirements of the ICT orchestration in the

future delivery of healthcare services. All these prove our hypotheses H1, H3, H4 to be scored with a green color in the status.

Although according to the results to test Hypothesis 2 the system needs further research on topics related to its role within the IoT ecosystem. For this hypothesis although the future applicability in general and the proposed functionalities seem to be in favor of an IoT ecosystem when it comes to specific used components and communication methods participants scored in average with a approximately 3.7 out of 5.

Going more deeply we have highlighted specific points of these concerns starting from Hypothesis 10 where 50% of the participants agreed with the connection to a private cloud via OTP but expressed a possible drawback with PIN codes that will confuse the doctors. Furthermore in connection also to Hypothesis 11 it proves that a significant point to be investigated is the parallel implementation of a direct access to the local database with a remote software, which was not considered to be done at the start. Considering the relative low score of 2,83 which is slightly over the average on the security participants seem to be very concerned.

Additionally in the communication methods we can refer to Hypothesis 5 where we clearly stated the use of ZigBee protocol for the sensor and data collecting layer. This proved out to be not the appropriate choice as participants scored with a 66,7% the use of Bluetooth Low Energy as the most secure and reliable for communications or as an alternative the IEEE 802.15.65 for popularity and ease of use. Further and deeper investigation is needed on this protocols before being implemented.

In Hypothesis 6 we clearly described the use of RFID technology for the communication of the Smart Pill Box and the platform. Despite that only two of the six participant agreed with the RFID technology, the rest of low percentages here were not a disagreement with the technology but because some of the participants needed more data to evaluate the system or did not clearly state an answer to check it against the hypothesis. There were some concerns that if the RFID tag got stolen there will be a problem with the data transfer. According to our view this point needs to be evaluated with a bigger sample of participants to make the final decision as RFID is considered to be a good solution.

In Hypothesis 8 we proposed the use of weight sensors under the chambers in order to control the medication dozes in the pill boxes. 67,7% of the research participants scored this functionality as a very good choice. Although there should be a further investigation due to some concerns that the weight sensors might not be able to

track correctly the doze e.g very difficult to calculate the extracted 1g pill out of 150g pillbox so we should consider to apply single pill slots. The solution seemed also complex and expensive to implement for one participant. Furthermore an implementation proposal was here to consider the holder of the bottles to be smart, medicine A in a round bottle or Green Bottle, B square or red etc. The base can recognize which one is picked up and calculate the dose by measuring the weight. We should also consider pills released by button and special mechanism one pill at a time.

Following up with the Hypothesis 7 we considered that the system is preconfigured based on the prescribed doses to open the locked box chambers with the medication only at the time of the dose. This proved to be questioned as participants expressed difficulties on the RFID technology if the tag gets stolen or whether the box can manage all the different medication and open the correct chamber on time. Furthermore, some questions came up when the patient needs to be on vacation then this functionality may be a drawback for taking the pills. Taking all of these into consideration and because medication management is scored to be our best service further research is needed on this functionality as any mistake from the system could prohibit the patient to receive the medication at the time prescribed.

Finally when it comes to authentication testing with NFC in Hypothesis 9, 50% of our research participants were in favor of this authentication method although suggestions for further testing of NFC security were proposed [49].Complementary to this authentication method we would like to add that 66.7% of the participants proposed a parallel implementation of a fingerprint unlock as an alternative method and for mentally ill people a special batch card, which could be our health box ID card.

In this part we will occupy ourselves with the process related discussion. Despite the small sample size of the participants we can consider the results relatively accurate and reliable, the reason for that claim will be explained in this paragraph. The level of knowledge over the process can be considered quite high, given the difficulties of finding people with such a broad understanding of most of the process steps, while also having an understanding over IT systems. Namely the average score of the subjects knowledge over the Dutch healthcare process was 3.57, with five being expert knowledge. This score can offer some credibility over the results. One more thing that shows the range of the sample size and makes the validation more reliable is the fact that we had participants from almost every single stakeholder group: chronic disease patients, hospitals employees, doctors, specialists, hospitals executive officers with field

experience, insurance companies' senior managers with specialization on the healthcare process and healthcare equipment manufacturer and privacy officers. The only group that was missing, despite all our efforts, and has to be included in future work is GPs.

Also during the data collection process we identified some other organizations that should be contacted in the future as they play a crucial role in the process. Those organizations are the chronic disease foundations (one for each), some of them owned by the patients and some other with a more traditional structure. But their involvement will be of great importance and in the future they must be taken into account.

Moreover two of the participants replied to the survey through interviews. This allowed us to retrieve even more information about experts opinion over the process issues and their beliefs for IT's possible contribution to their work.

A very interesting conclusion emerging from the interviews is that doctors had a much better understanding of both the process and patients concerns, than insurance companies that see things in a more cost efficiency approach. Specialists contact patients regularly and observe them in their everyday life, which gives them the opportunity to understand in a better way the difficulties they face on a daily basis in regard to process steps and their convenience. As a result patients' frustration was not very obvious in to survey participants from insurance companies.

A lot of hospitals have already introduced EHR for their patients. The records are maintained by the hospital personnel but they are owned by the patients. In one of the biggest hospitals in The Hague they have even foreseen to allow access to the patient's GP on their demand, but only one of twenty GP really took advantage of that excellent functionality. The latter makes clear the unwillingness of the actors in the industry to cooperate and the resistance to change. Also in support of the previously mentioned comments, for question three of the survey six out of seven participants consider that there is a need for improving the cooperation among the healthcare industry. This result highlights the communication issues and to a certain degree the willingness to cooperate between them in order to improve the quality of patient's life.

A very useful comment from one of the interviewee that magnifies the importance of our system in the process is that information, both physical and personal, should be owned by the patients and not from all the other stakeholders, which is the status quo at the moment. Our system as patient centric platform supports exactly this statement.

One thing we previously described is that some health providers already offer electronic health records to their clients. Some even have a connectivity directly with

GPs, on which they send their reports, as soon as they are ready electronically. As result it is worth wondering why that connection is not expanded to all the players/stakeholders and make it common practice.

During the development of our work and after sending the surveys we came across a questionable step in the process. In our analysis we considered that chronic disease patients can arrange their appointment with the specialist, who treats them, by communicating directly with him/her, but after some discussion we started questioning that validity of this identified step. So, we decided to try retrieve this information from the interviews as it was easy to lead the conversation to that topic. The outcome was that our initial identification of the process was correct and truly patients that are treated by a specialist for a long time don't have to go through the administration office of the hospital, instead they can arrange the next appointment with their doctor and his/her secretary.

Something that emerged from the answers of the approached participants of the research is that further work needs to be done, investigating possible measures for securing the validity and reliability of both, the personal and physical data of the patients.

It is worth mentioning that this system, although patient oriented, something pin pointed by all the participants of the researched, should also find a way of becoming more "attractive" to the other stakeholders of the healthcare ecosystem. Therefore it of the utmost importance to make clear the added value it can offer to the business environment.

9.3 Limitations

In this paragraph we will present some limitations of the study. Part of those were known to us since the very first steps of our work and other parts of those became apparent during the development of the project but they could not be avoided.

The study for both parts of the research, architectural part and process related part, have been validated with a limited sample size. Namely we had six participants for the architecture survey and seven for the process survey. The latter has to do with the focus of our study, which is highly specialized and aims on professionals with deep understanding of their fields. On the one hand, for the architecture it was difficult to approach employees from big electronic manufacturing companies that had deep knowledge over the latest technologies and at the same time had worked on projects

related to healthcare platforms. Those two issues limited the possible candidates drastically. On the other hand, for the process part it was very challenging finding the right persons to answer all the key points touched by our work. The biggest obstacle to overcome, was to find people that had experience from the Dutch healthcare process and their understanding of the process was over the whole process and not just various part of it.

Another limitation, which is also connected with to the sample size is our access to research participants. Both of us are international students and therefore we hadn't the proper social channels at our disposal for getting in touch with healthcare specialists. The last point, in addition to the character and restrictions of the healthcare industry complicated our work even more than expected.

A very important limitation for the development of our work was the lack of prior research in the topic. Very few studies has been conducted so far in those fields and so we were moving towards "uncharted waters". Consequently this limitation decreased the number of possible research methods and design we could use. More specifically we followed an exploratory research method and we also made use of a hypothesis testing methodology for validating our work. Although based on the outcome we can conclude that those choices allowed us to have really good results in the investigated fields, still we were hampered from using better models and frameworks for the analysis of our research and for validating our proposals.

One last limitation that emerged during the data analysis process is that we could have form better measures for collecting our data. We regret not including some questions in the surveys, which could provide better and clearer results. The question we would ideally like to include in the process part is about the regulations that dictate the connection of the players' systems. Through that we would be able to define the needed changes either in the systems or in the regulations for making possible the connection between the different infrastructures.

9.4 Recommendations

This research focused on facilitating the innovation in the healthcare delivery that is ongoing the last few years. Efforts towards transferring the healthcare services from hospitals to the patient's home are already made. That new innovative thinking/approach also needs a change in the existing mindset, as now there is

knowledge distribution in which patients have access. So a new research philosophy is needed more than ever, something that emerged from our work also.

Based on our experiences from the research we concluded that apart from the development of a reliable technical platform, there is a need for other changes, both process related (regulatory) and social.

Therefore, we would like to form the structure of our recommendations in three basic levels that reflect the previously described points. Firstly we will present the technical level, then the systemic level will follow and finally the social level will be unveiled. Each of them is complementary to the other and changes in only one or two of them will not have any significant impact in the healthcare services landscape. In the final step we will try to bring all the levels together towards a business approach. In other words we will recommend the necessary changes in the healthcare business (sales, marketing and delivery) in order to add value, apart from the patient, to companies as well.

On the development and technical level the research mindset has to change in order to adapt the future proposed systems into the new scope of the healthcare delivery. Firstly, there should be a heavy focus on developing comprehensive health solutions that are aiming to deliver complete health services to patients. Those solutions should also be home centric, as they are becoming the center of focus for supporting the future healthcare delivery.

Moreover the developed systems in the future have to build and improve the interoperability of the devices, and the standardization of the used technical methods from all the different players participating in the industry. For achieving the proper functionality of a comprehensive solution it is necessary to work towards a cross organizational integration of the EIS (Enterprise Information Systems). A good way of achieving the latter would be organizing incremental technical demos supporting the previously described choices with the involvement of multiple players like IT companies, biomedical suppliers, healthcare providers, doctors' organizations etc. Finally, the last and maybe more challenging would be to orchestrate the ICT infrastructures used by the involved actors to work under a common and unique healthcare process.

A very important change worth mentioning is the need for creating a universal "language". With the latter we are referring to the need of setting standards not only on the communication layer but also on the semantic layer in order to have a common understanding of the data's meaning. We consider crucial when a healthcare provider

wants to apply a decision there must be a clear connection with potential restriction to patient's data directly provided by personal health systems via the common cloud infrastructure.

As mentioned earlier the second level includes the clear definition of the regulations, processes and laws that describe the system, this layer will be called systemic level. In this level we should have the creation of common regulations and policies for all municipalities and different areas. Here it of the utmost importance to highlight the need for investigating the existing barriers on self- management platforms at the moment, and then find means of over passing those barriers either by adjusting the existing regulations or by aligning the functionality of the systems with the regulations.

We already refer to the need of making the processes common and standardized for all the services and parts of the healthcare industry. Ideally this should start in a bottom up approach, meaning that the selection and design of the processes will be made centrally but the implementation will be made step by step, first in municipalities' level, then nationally and finally even globally. This part is perhaps the most challenging due to the differences in the policies from area to area and becomes even more apparent if the aim is a global implementation of the systems.

Finally, governments and all the involved parties/stakeholders should support institutions that are working on promoting the importance of interoperability in the used systems (e.g. interface standardization), such as CHA (Continua Health Alliance) and IHE (Integrating the Healthcare Enterprise).

The last but not least on importance layer is the social level. During our research we came across a lot of people with deep knowledge over the processes and the used systems but even they seemed very skeptical about trusting personal data stored on a common database, something expected, having in mind that the Dutch Senate voted down the use of a central EHR some time ago. Therefore we consider that there is a need, apart from all the other, for social innovation.

A lot of focus has to be paid on the needed education of the society aiming on achieving the social innovation. First of all, patients and healthcare personnel have to be informed about self-management platforms, as well as their functionality and security. This can solve the lack of trust on those systems that at the moment is observed in high levels. Secondly, the market at the moment is disoriented by the various smaller platforms existing. Thus, it is urgent to educate the criteria of selecting and purchasing such a device. Finally, an easy way of bringing together and educating all the related

players, about the self-management systems, can be achieved by designing customized prototype solutions of personal health system applications with explanations of their operating way for all targeting groups.

So how do those three level come together and what is their effect in business world?

The first change based on those three layers is to create new consumer channels for approaching market segment, like chronic disease patients and elderly, which at the moment are out of reach. The difficulty in that effort will be to find the appropriate way of contacting people in such a sensitive physical condition. So new ways of approaching the target market segments have to be investigated as the customer, namely the patients can have limited mobility and issues with their cognitive skills. All the above described points are very crucial for adding value to the products and companies that are working on those fields.

Also another very important change is that companies have to invest much more on research for personal health systems, this is the only way of creating efficient systems and only then they will be able to diffuse their products in the market. The latter will expand the market that at the moment has limited purchase opportunities. By succeeding to launch better and more patient oriented products, they will increase their profit something that will offer them the opportunity to invest more resources.

In this paragraph, although we observed a need for change in the different levels and further possible benefits for all the involved parties, we should not forget that they all are working towards the ultimate goal to provide benefits and improve the life of their main stakeholder, patient.

9.5 Future Work

Due to the character of this research most of the results and recommendations are not reaching a 100% clear conclusion and therefore there is a need for future work in various aspects of the study.

In the architectural part, it became apparent that in the future we need to further research the exact role of the platform within the IoT ecosystem. Although that the future applicability and the functionalities of proposed system seem to be in favor of operating within an IoT ecosystem, when it comes to specific used components and communication methods there is still uncertainty over the choices made, something that has to be investigated further.

Also about half of the subjects were positive on the idea of using a connection to a private cloud via an OTP method. Still most of them expressed their concerns from the use of a PIN code, those two aspects highlight the importance of focusing the future work on defining alternative authorization methods and improving the acceptance rate, security wise, of private clouds.

A very crucial point that emerged from the results of our study, which needs to be investigated, and that was not considered during the development of our project is the parallel implementation of a direct access to the local database with a remote software. Moreover, further and deeper investigation is needed on deciding the protocol used by the sensors' before being implemented, as the extracted results from the survey pin point quite a different choice than what was originally proposed by us.

A very important component of the architecture, which was questioned about some parts of its functionality were the weight sensors used under the chambers. According to the replies we received, due to the inefficiency of the used sensors in measuring correctly small doze like 1g (1 pill), more focus should be given in that element of the architecture and maybe some alternative technologies have to be considered.

Some other technical choices of the architecture that have to be researched further have to do with the concerns over NFC technology and specifically with the security on top of it, despite being a reliable authentication method . Also, concerns over the security of the RFID technology were underlined, especially in case when the RFID tag gets stolen from the pill box.

In the process related part, based on the extracted information we have to propose testing the changes and the impact of an IoT health management system in the healthcare process to a broader audience. More specifically focus has to be given on GP’s, which despite the fact of not participating in the healthcare services delivery, they were identified as the link between the patients and the care providers in most steps of the process. Also a new group that needs to be investigated in the future and included in the sample is the various disease foundations that are operating in the Netherlands. This group was not identified at the first stages of the research and based on the results of the interviews and surveys they have a great involvement in the Dutch healthcare process.

Another very interesting finding in our study was the existence of connectivity between different healthcare player systems. So, in the coming research we must firstly identify to what extent this is possible to be achieved at the moment. This also raised the question, which needs to be answered in future works, of why that connection is not

expanded to all the players/stakeholders and make it a common practice in the process, by implementing it to the existing infrastructure.

Maybe one of the most important problems that have to be investigated deeper in the future is the security issues. Possible measures for securing the validity and reliability of personal and physical data of the patients during the data transfer between the different systems have to be defined.

Finally, it is of the utmost importance to make clear the added value that the proposed platform can offer to the business environment. In this way the system can be more attractive to stakeholders, like insurance companies and hospitals, that are more cost efficient oriented.

It is worth mentioning here that all those proposals for future work and research should be aligned with the recommended three levels approach (see recommendation chapter). This structure will provide a better understanding of the ecosystem and a better building of the emerging environment.

Appendix A

Dutch Healthcare Process players/terms explanation

Actor Domain	Actor	Executed Tasks
Government	**Central Government**	• Sets the national health care budget • Decides the content of the basic health insurance package • Sets tariffs for the services not yet subject to free negotiations • Sets public health targets • Decides capacity in long-term care institutions • Safeguards affordability, efficiency, accessibility and quality of health care for the country.
Government	**Municipality**	• Sets local public health targets • Decides on budget for social support and home care
Advisory Body	**Dutch Health Care Authority (NZa)**	• Monitors the transparency and functioning of health care markets. • Establishes tariffs for non-negotiable care.
Advisory Body	**Health Care Insurance Board (CVZ)**	• Explains contents of benefit package • Promotes harmonized provision of health care in both curative and long-term care • Advises Ministry of Health, Welfare and Sport on contents of basic health insurance benefit package • Advises on including new medicines in medicine reimbursement system (GVS) • Advises Ministry of Health, Welfare and Sport on budget for long-term care (AWBZ) • Administers Health Insurance Fund and General Fund for Exceptional Medical Expenses (AFBZ) • Carries out risk adjustment

Advisory Body	**Health Council**	• Advises Ministry of Health, Welfare and Sport on preventive care and other health issues
Advisory Body	**Regional Support Structures (ROS)**	• Stimulates cooperation in primary care
Advisory Body	**Capacity body (Capaciteitsorgaan)**	• Advises Ministry of Health, Welfare and Sport on workforce planning for all specialized postgraduate training programs
Advisory Body	**Medicines Evaluation Board (CBG)**	• Evaluates safety, efficacy and quality of pharmaceuticals • Authorizes pharmaceuticals
Advisory Body	**Council for Public Health and Health Care (RVZ)**	• Advises Ministry of Health, Welfare and Sport on health policy agenda.
Supervisory Body	**Dutch Health Care Authority (NZa)**	• Enforcement of the Healthcare Market Regulation Act.(Wmg)
Supervisory Body	**Health Care Inspectorate (IGZ)**	• Inspects safety and quality of providers • Investigates complaints and accidents • Supervises implementation of Health Insurance Act (Zvw) and Exceptional Medical Expenses Act(AWBZ)
Supervisory Body	**Committee on Pharmaceutical Care (CFH) – part of CVZ**	• Assesses pharmaceuticals on efficacy, efficiency, side-effects, applicability and ease of use before inclusion in the benefit package
Professional bodies (self-regulation)	**Royal Dutch Medical Association (KNMG)**	• Postgraduate medical education • Accreditation of medical specialists (including GPs) • Promoting professional quality

Professional bodies (self-regulation)	**Dutch College of GPs (NHG) (part of KNMG)**	• Development of guidelines for GPs
Organization involved in AWBZ	**Central Administration Office (CAK)**	• The CAK calculates the patient contributions, on the basis information on income from the tax department. The CAK compensates the long-term care providers by request of the care office.
Organization involved in AWBZ	**Centre of Indication-setting Health care (CIZ)**	• Arranges the whole request procedure of a patient to receive long- term care and informs all related parties.
Organization involved in AWBZ	**Social Support Act (WMO)**	The goals of the WMO are divided into nine "performance fields", defined by law: • Improving social cohesion and live - ability of villages and neighborhoods. • Support to the youth and parents who experience problems with upbringing (prevention). • Giving information, advice, and support to clients. • Supporting informal caregivers and volunteers. • Promoting participation of people with chronic psychological or psychosocial problems or a physical limitation in society, as well as their independency. • Providing facilities and services for people with a chronic psychological or psychosocial problems or with a physical limitation to promote their independency and societal participation. • Offering shelters and implementing policies to combat domestic violence. • Improving public mental health care. • Improving addiction policies
Professional bodies (self-regulation)	**Association of Medical Specialists (OMS, part of KNMG)**	• Development of guidelines for medical specialists

Appendix B

Proposed Platform Architecture Survey

Universiteit Leiden

Due to aging population, chronic diseases and increasing healthcare costs, it is urgent in the near future for the whole healthcare industry to develop and take advantage of the related technologies and services and apply them directly in the home environment. This means to move to a Home-Centric healthcare by leveraging Information and Communication Technology. With this survey we would like to validate the architecture of an in-home health platform that will be patient oriented and act as a home integrated healthcare system. The platform will be connected with its' technologies and services to the Dutch healthcare process and infrastructure in an effort to solve identified process bottlenecks and support patient's health management.

Thank you for your time and effort to complete this survey.

This survey consists of 20 questions and will take approximately 15 to 20 minutes of your time. We will treat the information you shared with us with care and keep you anonymous. In return for your effort we will share with you the results of this survey.

(*) This survey is part of the final research project developed by students of ICT in Business master program and conducted at Leiden Institute of Advanced Computer Science (LIACS) within Leiden University. For more questions on the survey shared please contact: Stefanos Chatzistefanou (sfhadj@gmail.com) or Christos Siskos (ciscoschr@gmail.com)

Continue »

InHome Platform Description

With this study we would like to describe and define an in-home health platform that will be patient oriented and act as a home integrated healthcare system connecting various health devices. The main purpose of the platform is to enable the real time monitoring of the patient on medication and vital signs, the update of GP's patient data and the support of the (chronic) patient in various routine steps with the involved institutions, all from one single source system at home. The platform will facilitate technologies and services with a more local role at the first release supporting the Dutch healthcare process.

The InHome platform will be our In-Home Box and will facilitate the following:

- An integrated tablet coupled with the software supporting the UI of the professional health applications and access to web;
- Local Medical database storing all patients information (physical and personal);
- An integrated smart pill box that works as the basic medication inspector using Near Field Communication Technology (NFC);
- An integrated bio-circuit collecting all vital signs from the devices for real-time display or storage in the local database.
- A wrist sensor (i-tag) used to transfer data to the platform via WiFi or 4G when the patient is out of home in case of an emergency.
- Secondary devices as medical body sensors connected with WSN interface to the box;
- Secondary devices as smart phones, Smart TV's, tablets.
- Authentication card with a unique ID box number;
- Connection to other online health platforms.
- Connection to private cloud server to synchronize the patient's data. For the moment a private cloud will serve more as a data backup and offer authorization mainly to GPs to access the patient's data.

A description of the platform and its' basic components follows.

*Required

Question 1 *

What is your profession?

Question 2 *

The expecting revolution within the Healthcare industry due to IoT (Internet of Things) will bring also a lot of changes in the research mindset and the way systems and applications are being developed. Being aware of security and privacy risks, how important do you think that the developed health platforms in future should be open platforms fully supporting IoT services with standardized interfaces in order to enable seamless application integrations?

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

Question 3 *

Today we observe that a lot of health systems (or apps) focus on solving a specific healthcare problem by improving a specific condition, which covers limited aspects of healthcare. According to your experience how urgent is a more comprehensive home healthcare solution?

	1	2	3	4	5	
Not urgent	◯	◯	◯	◯	◯	Extremely urgent

Question 4 *

To what extend do you consider necessary the creation of a patient oriented platforms?

	1	2	3	4	5	
Not necessary	◯	◯	◯	◯	◯	Absolutely necessary

Question 5 *

At the moment big IT and HealthTech companies rule the ecosystem of healthcare devices. Do you consider possible a future cooperation among them, in an effort to create more "open platform friendly" devices?

	1	2	3	4	5	
Impossible	◯	◯	◯	◯	◯	Very possible

Question 6 *

Supposing the proposed home centric platform is the open platform and acts as the home healthcare gateway, which of the following services do you consider crucial to be firstly offered? Please choose the three most crucial services.

- ☐ Medication management via Smart pillbox
- ☐ Vital Sign Monitoring
- ☐ Social Networking
- ☐ Connectivity with personal doctor's system
- ☐ Communication with physicians/relatives
- ☐ Connectivity with private cloud server
- ☐ Alerting-Emergency
- ☐ Phychological Information collection

Question 7 *

Many alternative technologies have been developed in the latest years for Wireless Sensor Area Networks, known as WSAN's. Supposing we would like to use a standardized technology, which of the following do you think would be the most suitable for the sensor and data collecting layer of an in-home integrated health care platform? Please pick the two options you find more suitable.

- ◯ Bluetooth Low Energy
- ◯ IEEE 802.15.65
- ◯ Zigbee
- ◯ WirelessHART
- ◯ ISA100
- ◯ WIA-PA
- ◯ 6LoWPAN

Question 8 *

Please give a brief explanaition for your choices on question 6.

Question 9 *

In our architectural design we described that we make use of NFC technology for the authentication of the patient to the InHome Box. On your experience is NFC technology a good architectural decision, given the high sensitivity of data stored in the platform? If no please mention the reason and propose an alternative solution.

Question 10 *

One of the functionalities that will be included in the platform but with no plans of applying it at the first launch of the project, will be to give a GP access to the platform/cloud server in order to maintain remotely patient's medication. By that he/she can process the e-prescription, which will be synchronized to the local database of the health box. We consider implementing the following authentication method: "Authentication with One Time Password (OTP). Doctor's mobile will work as the authentication device. To generate the OTP for the cloud webpage three components are needed to be combined from the application when running on the doctor's phone. The three needed components are: 1. A 4 digit PIN code that doctor will enter (unique for each InHome box) 2. A secret random number that was generated during the device/app initialization that only exists on the mobile phone of the doctor. 3. The current time of attempt." Would you propose that authentication for a secure login? If not could you give an alternative solution (like dynamic knowledge based authentication- KBA)? In case of not having the needed background please write on your answer "Not applicable".

Question 11 *

Considering that an authenticated user (f.e. GP) can monitor the patient records via the cloud server. Would you consider a direct access permission to the local database of the InHome box a wiser architectural decision?

Question 12 *

One of the core functionalities of the box will be the medication management though RFID technology. The RFID reader (that communicates with the backend system) is connected to the antenna (actual RF hardware) via cable in the box and the latter communicates with the antenna on the tag (placed on the pillbox) to facilitate the data stream. Would you consider technically this a correct choice for the smart pillbox (also cheap solution)? If no, please indicate based on your experience the reason and what would you propose to be deployed.

Question 13 *

When the e-prescription is stored on the database, the health box backend will then compare the medication coupled to a unique RFID number with the name and details on the prescription form. Thus, the system will be able to open only the chambers that must be opened for the patient at a specific moment of the prescribed doses, while alerting him in the same time. Would you recommend this security functionality to solve the medication reminder issue? If no, name the possible concerns behind it or propose an alternative idea.

Question 14 *

To measure the number of pills taken from bottles an idea could be to place an RFID tag under each bottle. By the time the patient picks up the bottle the RFID reader notes the event and calculates the weight difference via a weight sensor when the patient places back the bottle. The health box stores also the time of the event and notifies the doctor depending on frequency of error. Would you recommend this idea for the medication non-compliance control? (f.e. misuse (consider medication cheating) or in parallel help people with a visual impairment or hearing loss? If no, name the possible concerns behind it or propose an alternative idea)

Question 15 *

What method, apart from the NFC identification, should the InHome Box use for a secure unlocking process in order to be accessible only by the authorized user(s)? (Security counter measure for preventing other users of the box of taking wrong and unsubscribed medication) Please choose up to 2 options.

- ◯ Retina identification
- ◯ Fingerprint unlock
- ◯ User Password
- ◯ Pattern unlock
- ◯ Other: _____

Question 16 *

How would you rate the general idea of the proposed platform and its functionalities?

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

Question 17 *

How would you rate the proposed platform in regard to security aspects?

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

Question 18 *

How would you rate the proposed platform in regard to the used components?

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Escellent

Question 19 *

How would you rate the proposed platform in regard to the future applicability of the used technology?

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

Question 20 *

How would you rate the proposed platform in regard to devices' communication methods??

	1	2	3	4	5	
Bad	◯	◯	◯	◯	◯	Excellent

Question 21 *

What is, in your opinion the biggest advantage for the patient by using this platform?

Question 22

If you would like to receive the results of the survey please share with us your email address.

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Appendix C

Proposed Healthcare Process Changes Survey

Universiteit Leiden

Due to aging population, chronic diseases and increasing healthcare costs, it is urgent in the near future for the whole healthcare industry to develop and take advantage of the related technologies and services and apply them directly in the home environment. This means to move to a Home-Centric healthcare by leveraging Information and Communication Technology. A question emerging from that problem is "How we can improve the current Dutch healthcare process for chronic disease patients through Home-Centric healthcare Platform?".

With this survey we would like to validate the changes we are proposing in the Dutch Healthcare process for chronic diseases patients by connecting a proposed architecture of an in-home health platform with its' technologies and services to the Dutch healthcare process and infrastructure in an effort to solve identified process bottlenecks and support patient's health management.

Thank you for your time and effort to complete this survey.

This survey consists of 18 questions and will take approximately 15 to 20 minutes of your time. We will treat the information you shared with us with care and keep you anonymous. In return for your effort we will share with you the results of this survey.

(*) This survey is part of the final research project developed by students of ICT in Business master program and conducted at Leiden Institute of Advanced Computer Science (LIACS) within Leiden University. For more questions on the survey shared please contact: Stefanos Chatzistefanou (sfhadj@gmail.com) or Christos Siskos (ciscoschr@gmail.com)

InHome Platform Description

With this study we would like to describe and define an in-home health platform that will be patient oriented and act as a home integrated healthcare system connecting various health devices. The main purpose of the platform is to enable the real time monitoring of the patient on medication and vital signs, the update of GP's patient data and the support of the (chronic) patient in various routine steps with the involved institutions, all from one single source system at home. The platform will facilitate technologies and services with a more local role at the first release supporting the Dutch healthcare process.

The InHome platform will be our In-Home Box and will facilitate the following:

- An integrated tablet coupled with the software supporting the UI of the professional health applications and access to web;
- Local Medical database storing all patients information (physical and personal);
- An integrated smart pill box that works as the basic medication inspector using Near Field Communication Technology (NFC);
- An integrated bio-circuit collecting all vital signs from the devices for real-time display or storage in the local database.
- A wrist sensor (i-tag) used to transfer data to the platform via WiFi or 4G when the patient is out of home in case of an emergency.
- Secondary devices as medical body sensors connected with WSN interface to the box;
- Secondary devices as smart phones, Smart TV's, tablets.
- Authentication card with a unique ID box number;
- Connection to other online health platforms.
- Connection to private cloud server to synchronize the patient's data. For the moment a private cloud will serve more as a data backup and offer authorization mainly to GPs to access the patient's data.

A description of the platform and its' basic components follows.

Dutch Healthcare process

Problems

Based on our research three are the most important problems/bottlenecks in the Dutch healthcare process. Those are:

1. Patients are repeatedly forced to provide their personal and physical information many times during different steps of the health process.
2. Bad communication between the specialist and the GP. The latter leads to non-updated records despite the fact that the report of the specialist is ready.
3. The patient has to constantly visit his/her GP in order to have the needed medication prescribed. The previously described problem translates into lost time for both the patient and the doctor, as well as increased complexity for the process.

Proposed changes

After the analysis of the problems we come up with following solution for the identified problems. The proposed alteration in the process are small for the moment, based on the possibilities of the platform, but this has to do with the restrictions of the healthcare industry. Below are listed the proposed changes.

1. The first major difference is related to the medication ordering and refill. Instead of the patient having to go to the doctor in order to get a prescription and then go to the pharmacy for buying the needed medication, the GP will fill a the e-prescription and the system will sent the medication order to the co-operating pharmacy. (Medication Ordering and Refill Functionality)
2. The database of the Box will include all the official documents that have to be filled from the patient's side while going through the care services registration. Also in the Box patients will store all their basic personal and physical information. So instead of going through that process repeatedly the information can be send electronically with all the necessary documentation to the relevant organization automatically filled from home. (Personal Documents Functionality)
3. When the report of the specialist is ready and sent to the GP the information is also stored on the database of the hospital, where GP has access. When the patient returns from the appointment s/he confirms the visit to the specialist through the calendar. The system will send a message to the GP that s/he visited the specialist and an update of patient's data is expected. The message will contain the BSN, the serial number of the InHome Box and only the name of the care provider in order for the doctor to know which system he/she has to access. (Personal Data Update Functionality)
4. The InHome Box as already described comes with an i-tag. This wrist device will act as a body sensor and will track the location of the patient informing emergency services, relatives and doctor in case of an emergency. (Emergency Services Functionality)

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*Required

Question 1 *

Please fill your profession and/or your role to the healthcare industry (patient, hospital, insurance company, GP).

Question 2 *

What is your knowledge of the Dutch healthcare process for chronic disease patients?

	1	2	3	4	5	
No knowledge	◯	◯	◯	◯	◯	Expert

Question 3 *

The above described changes are aiming on improving the existing problems in the process. What benefits do you see from the implementation of such a platform as an element of the existing process? Please choose the four most important benefits.

- ☐ Decreasing services costs
- ☐ Minimizing waiting time for an appointment
- ☐ Improving the communication between patient and various players in the healthcare industry
- ☐ Minimizing discomfort caused to patients with movement problems
- ☐ Decreasing percentage of deaths caused by bad/late communication with emergency services
- ☐ Improving cooperation between Insurance companies, GP and Hospitals
- ☐ Improving the medication ordering process
- ☐ Other:

Question 4 *

Could such a platform improve the communication between chronic disease patients, that need constant monitoring, and various players (GP, hospital, insurances, pharmacies) of the healthcare process and to what degree?

	1	2	3	4	5	
No improvement	◯	◯	◯	◯	◯	Great improvement

Question 5 *

What are the top problems/issues that chronic diseases patients are facing during the Dutch healthcare process? Please chose two of the following options.

- ☐ Repetitive Steps (f.e. different departments checking the same type of documents)
- ☐ Discomfort from the constant movement between various offices and departments
- ☐ Repeatedly providing personal information
- ☐ Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist)
- ☐ Time consuming medication ordering process

Question 6 *

Do the systems used by hospitals and insurance companies for communicating (f.e. requests, contacting departments, complaints etc.) with the patient function with one time registration? Please choose one of the options below.

- ◯ Yes
- ◯ No
- ◯ Not aware

Question 7

To what degree do you consider applicable the communication between your systems and the proposed platform? (Patients can skip that question)

	1	2	3	4	5	
Very difficult	◯	◯	◯	◯	◯	Extremely easy

Question 8 *

To what degree do you believe that a platform like ours, based on its proposed involvement to the current process, could decrease the frustration level of patients?

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very much

Question 9 *

Based on your experience do you propose any additional change(s) to facilitate the process?

Question 10 *

Based on your experience how useful could such a platform be for your work and process related tasks?Why?

Question 11 *

How much would you trust patient data stored in such an InHome healthcare platform?

	1	2	3	4	5	
Unreliable	◯	◯	◯	◯	◯	Trustfull

Question 12 *

On your opinion how useful could such a platform be for a patients everyday life?

Question 13 *

In total, which of the proposed changes is the most important for the patients?

- ◯ Emergency Services Functionality
- ◯ Medication Ordering and Refill Functionality
- ◯ Personal Data Update Functionality
- ◯ Personal Documents Functionality

Question 14 *

In total, which of the proposed changes is the most important for the insurance companies?

- ◯ Emergency Services Functionality
- ◯ Medication Ordering and Refill Functionality
- ◯ Personal Data Update Functionality
- ◯ Personal Documents Functionality

Question 15 *

In total, which of the proposed changes is the most important for the hospitals?

- ◯ Emergency Services Functionality
- ◯ Medication Ordering and Refill Functionality
- ◯ Personal Data Update Functionality
- ◯ Personal Documents Functionality

Question 16 *

In total, which of the proposed changes is the most important for the GP?

- ◯ Emergency Services Functionality
- ◯ Medication Ordering and Refill Functionality
- ◯ Personal Data Update Functionality
- ◯ Personal Documents Functionality

Question 17 *

Overall, which player (hospital, patient etc.) do you believe will be the most benefited from the changes, if any?

- ◯ Hospitals
- ◯ Insurance Companies
- ◯ Patients
- ◯ GPs

Question 18 *

Please briefly justify your choice on question 17.

Question 19

If you would like to receive the results of the survey please share with us your email address.

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Appendix D

Architecture Survey Results Table

Question 1	Question 2	Question 3	Question 4
Account Manager Healthcare	4	5	5
Electronic Engineer	5	4	3
Automation Engineer	5	4	5
PSS Collaboration at Cisco	5	5	4
IT architect	4	4	5
IT Security Expert	4	5	4

Question 5	Question 6	Question 7	Question 8
5	Medication management via Smart pillbox, Connectivity with personal doctor's system, Communication with physicians/relatives, Alerting-Emergency	Bluetooth Low Energy	These options are now offered by different solutions, would be great to have this in a comprehensive solution.
5	Medication management via Smart pillbox, Vital Sign Monitoring, Alerting-Emergency	IEEE 802.15.65	The most popular and easy to use.
2	Medication management via Smart pillbox, Connectivity with personal doctor's system, Connectivity with private cloud server	Bluetooth Low Energy	At first the end-user target group must be defined. Then, define priorities of services to offer. I arbitrarily set as target group, generally elder people with who can take care of themselves. So, we need to feed their personal medical files with all latest info, can send their data to their doctor and arrange the proper (in time) management of medication.
5	Medication management via Smart pillbox, Connectivity with personal doctor's system, Communication with physicians/relatives	IEEE 802.15.65	It is best to choose an already used system like the current Wlan technology. You can use the existing installed base. Also using something that is widely used and sold at many places is important to lower the investment that need to be done. I do not think that you need to define a new system. Make use of what we have. The EPD is more for doctors then for the patient. Make it the patient file (my own file). Then I can access it where ever I am. Focus on the customer interface that needs to be easy as possible. Add video and communication as open building blocks to the solution. Using standards like Webex (worldwide network that is existing).
3	Medication management via Smart pillbox, Vital Sign Monitoring, Alerting-Emergency	Bluetooth Low Energy	Wireless will be the communication to the handheld of the patient but between the sensors it will be BLE, zigbee and/or IEEE 802.15 BAN.
3	Medication management via Smart pillbox, Connectivity with personal doctor's system, Connectivity with private cloud server	Bluetooth Low Energy	Very secure and reliable.

Question 9	Question 10	Question 11	Question 12
I have no experience with that technology, my focus is on strategic and commercial goals with the customer.	not applicable	not applicable	not applicable
I think NFC is safe enough!	Anyway should more smart means used, As using the phones camera, iris recognition or skin resistance, even heart beat pattern.	Instead of building a big brother consider critical data to be stored and kept safe locally, the person can give permission to others to access them. Care should be taken for the not experienced users - common people - who are not familiar with the risks of IT tech.	RIFD consist of a transmitter that is scanning for a tag, being against all of this wireless transition (crazy), I would oppose to use it for any reason. Please consider a more plain method, keyboard, finger or iris identification or real time on camera identification.
I am not familiar with the security features of NFC. But I know one for sure: everything is crack able.	Not applicable, but one question: point1: "A 4 digit PIN code that doctor will enter (unique for each InHome box)". I hope that you do not mean that the doctor should keep a file with pins of all his/her patients...	If cloud database is up to date, no need for a point to point connection.	I cannot understand the actual system. Additionally, I need further data and time to suggest alternatives.
The most important part will be Open standards, quality, and scalability, low pricing and easy to use.	I think again that ease of use must be the first thing to think about. Doctors are not able to think about different PIN codes. Maybe you must identify the patient by social number or patient number from the hospital. I also think that just checking if the patient is taking his or her medicine could better be done by volunteers (low cost for insurance) or trained nurse. Doctor must only become into the cirkel when needed to diagnose the patient when ill.	No I do not believe in all those tools that save information.	I do miss the human factor how about the patient? Is this usable and patient friendly.
NFC only will be maybe not as secure as you want it i would also look for a security on top of NFC http://rfidsec2013.iaik.tugraz.at/RFIDSec06/Program/papers/002%20-%20Security%20in%20NFC.pdf	yes	For emergency or real-time information I think there needs to be a possibility to get direct access to the InHome box.	yes How will you check the that will refill the pillbox correctly
It is secure but extra testing would be needed, especially now that we are talking about patient's data	OTP is very good choice, already I have seen similar methods used un other devices	I would go with direct access to the box. If the information on the cloud are live, then you have the same information at stake.	Yes, I like the idea of using RFID

Question 13	Question 14	Question 15	Question 16
not applicable	Seems like a good idea, however I have little experience with actual functioning of this process. You could focus on GP´s or careers as well.	Fingerprint unlock	4
Please consider that a RFID tag can be stolen or misplaced, should be safer, and see above.	Consider the holder of the bottles to be smart, medicine A in a round bottle or Green Bottle, B square or red etc. The base can recognize which one is picked up and calculate the dose by measuring the weight. For pills released by button and special mechanism one pill at a time.	Fingerprint unlock	5
Do you know how many pills an old person consumes? How many different medication can this box manage? What happens when the patient is away from home (for a walk/vacation/in hospital)?	It will be difficult to check that a pill weighing 1g is out of a bottle weighing 150g. If you are considering such a device, you might consider a dosing mechanism, ie, to give one pill from the proper slot.	Retina identification	4
Looks nice. Still you do not know if it is really taken. For mental ill people this is good they cannot make mistakes.	I think this is complex and will be expensive to build and to use. Creative but still a bit out of scope	This is difficult to answer due to several users of the system. Older people might not be able to use fingerprints. For the caretaker this is fine. For mental care you might want to use a separated batch.	3
Yes	I think the way of suppling pills depends on the patient bottles with a weight sensor and motion sensor is maybe for some patient the best solution but a reminder sound or light can also be a solution for other patients So the solution must be flexible to give a patient a choice.	look question 9	5
The functionality seems efficient and secure	Really nice functionality	Fingerprint unlock	3

Question 17	Question 18	Question 19	Question 20
3	4	5	4
2	2	4	4
3	3	4	4
3	3	3	3
3	4	4	4
3	4	4	3

Question 21
This is a unified way of offering several services to patients, careers and their care institutions. It will help people to live independently longer and to allow careers to work more remote instead of doing a lot of repetitive work.
Simplicity! (if achieved!)
Automatic transfer of data to/from doctors. Will save some visits to doctors/ hospitals.
The idea is fine. Older people that are taking a lot of pills can be remembered about the pill they need to take. The nice thing is that you can check all the pills to make sure that they are not conflicting with each other.
less errors more medical information during treatment BI about patient with different medication
Mainly focuses on the patient!!!

Appendix E

Process Changes Survey Results Table

Question 1	Question 2	Question 3	Question 4
Statistician at a hospital	2	Improving the communication between patient and various players in the healthcare industry, Minimizing discomfort caused to patients with movement problems, Improving cooperation between Insurance companies, GP and Hospitals, Improving the medication ordering process	4
Programmer/database Manager at hospital	3	Minimizing waiting time for an appointment, Improving the communication between patient and various players in the healthcare industry, Minimizing discomfort caused to patients with movement problems, Improving the medication ordering process	5
Senior employee at a Dutch health insurance company	5	None of them	1
Healthcare equipment manufacturer, privacy officer	3	Minimizing waiting time for an appointment, Improving the communication between patient and various players in the healthcare industry, Minimizing discomfort caused to patients with movement problems, Improving the overall efficiency of the process and lead times between the various steps	4
Chronic disease patient	4	Minimizing waiting time for an appointment, Improving the communication between patient and various players in the healthcare industry, Minimizing discomfort caused to patients with movement problems, Decreasing percentage of deaths caused by bad/late communication with emergency services, Improving cooperation between Insurance companies, GP and Hospitals, Improving the medication ordering process	5
Cardiologist	4	Decreasing services costs, Improving the communication between patient and various players in the healthcare industry, Minimizing discomfort caused to patients with movement problems, improving and monitoring the medication taking process	5
Doctor Nephrologist/ CEO at a Clinic	4	Minimizing waiting time for an appointment, Improving the communication between patient and various players in the healthcare industry, Minimizing discomfort caused to patients with movement problems	5

Question 5	Question 6	Question 7	Question 8
Repetitive Steps (f.e. different departments checking the same type of documents), Time consuming medication ordering process	Not aware	-	4
Discomfort from the constant movement between various offices and departments, Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist)	Not aware	3	5
Discomfort from the constant movement between various offices and departments	Yes	3	1
Repetitive Steps (f.e. different departments checking the same type of documents), Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist)	No	-	4
Repetitive Steps (f.e. different departments checking the same type of documents), Discomfort from the constant movement between various offices and departments, Repeatedly providing personal information, Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist), Time consuming medication ordering process	Not aware	-	5
Discomfort from the constant movement between various offices and departments, Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist)	Not aware	2	4
Facing bottlenecks that delay the process (f.e. GP waiting for the letter from the specialist), Time consuming medication ordering process	Yes	5	3

Question 9	Question 10	Question 11	Question 12
Do not have any particular experience on this matter, cannot answer	Potentially facilitate data analysis	3	Quite useful for patients (facilitate everyday life of patients, particularly of older patients)
Not really	I think the platform would be very useful and it will increase the patients comfort a lot. However, please keep in mind that creating such a platform is very hard. Coupling all the necessary systems is a real technical challenge. And besides that, there is a huge privacy issue with your solution.	4	Very useful
No	No, see my answers	5	it is already very useful
- No additional changes, but there will be privacy concerns raised with the data. So it has to be ensured that the personal information including the health information of patients is flowing between the various systems in a secure manner (i.e. through secure interfaces, proper access management).	-Not applicable	2	- Very useful for the patients with chronic diseases.
No	It would be really useful, since it can make procedures faster and in more efficient way.	4	It would be really useful and would make chronic disease patients lives easier
What is very important is information about the situation, how the patient really feels. So find a way to also include this part of the diagnosis that can be coupled with the monitoring.	It is quite frustrating having a patient that you said to him/her you are ok now and then two weeks later the patient is back again, because he didn't recognize the symptoms a let the disease worsen. So, it would be wonderful to have a control system that would have warned the doctor and the patient of the situation earlier.	4	It very crucial the help of such a device as it provides extra control. Also it increases the confidence of the patient because it makes him/her feel secure, given the fact that there a constant monitoring and communication the doctor.
Every foundation that focuses on a specific disease are asking for the process to function based on their needs.	The platform will allow me to focus on things that really matter, instead on measure vital signs.	4	It will empower the patients. Also give the pride of doing things on their own

Question 13	Question 14	Question 15	Question 16
Personal Data Update Functionality	Personal Documents Functionality	Personal Documents Functionality	Personal Data Update Functionality
Personal Data Update Functionality	Personal Documents Functionality	Personal Data Update Functionality	Personal Data Update Functionality
Personal Data Update Functionality	Personal Data Update Functionality	Personal Data Update Functionality	Personal Data Update Functionality
Emergency Services Functionality	Personal Documents Functionality	Emergency Services Functionality	Personal Data Update Functionality
Emergency Services Functionality	Personal Data Update Functionality	Personal Data Update Functionality	Personal Data Update Functionality
Personal Data Update Functionality	Medication Ordering and Refill Functionality	Personal Documents Functionality	Medication Ordering and Refill Functionality
Medication Ordering and Refill Functionality	Personal Documents Functionality	Medication Ordering and Refill Functionality	Personal Documents Functionality

Question 17	Question 18
GPs	GP's updated on their patient's health status, follow up of patients becomes easier
Patients	It will save the patient a lot of trouble and frustration.
Patients	....
Patients	As the patients are already in suffering, anything to reduce their need to manually perform tasks will be greatly appreciated. They are the customers.
Patients	I chose patients since the suggested changes would affect them the most in to their daily lives, since it will probably increase their survival and quality of lives. The other parties wont, in my opinion, be in such degree affected if a patient die from a delayed procedure or a patient feel discomfort
Patients	The patient will be at the center of the process.
Patients	Patients will have control over their records and their treatment will be more adjusted to their needs.

Appendix F

Transcription 1st Interview

Interviewer: Thank you for having us here, it is a pleasure meeting you.
Interviewee: My pleasure
Interviewer: I will first give you a short description of the system and the proposed changes before starting the interview if that is ok with you?
Interviewee: Of course.

We skip the part where we described the architecture and its main functionalities. During the description a relevant point from interviewee experiences was mentioned.

Interviewee: I worked in den Haag hospital, I quit working there one and a half year ago. I work now to Surinam from time to time just for keep doing my job a little bit. I remember that in den Haag we were busy with a study investigating how useful a telemedicine system could be for patient with heart failure, together with the physicians' assistant. It might be useful that research for your work also.
Interviewer: It is a very interesting point and we will consider its connection with our study, or maybe there is an opportunity for future research in that aspect.
Interviewee: I think you already know but a lot of other studies who are doing similar things.
Interviewer: Actually there are similar studies but the combination of developing such a platform and applying it on the existing process is not yet done.
Interviewee: Don't you think that the quality of the platform has to do with the sensors? Which have to be very good?
Interviewer: The technology used is very reliable.
Interviewee: So it will become better and better.
Interviewer: Yes, that is the ultimate goal.
Interviewee: But you have to integrate that idea, find an algorithm to connect those parts.
Interviewer: The connectivity to be honest is not that hard.
Interviewee: So what is the difficult part?

Interviewer: All the needed technology are already in the market and tested. The biggest problem is on the side of the users and all the stakeholders. For example how willing will be an insurance company to pay for such a system.

Interviewee: They will pay if they see a benefit from it.

Interviewer: If the system saves them money from the accommodation of the patient in the hospital they will support it. On the other hand GP might lose part of their appointments by facilitating the process and decreasing the number of appointments for prescribing medication.

Interviewee: Insurance companies in my opinion will see the benefit first. Then they will go to the doctors and they will say "we want you to use the system because in that system there are financial and also health related benefits otherwise we are paying you any more".

A description of the identify problem and the proposed changes in the process followed.

Interviewer: So let's start with the question, shall we?

Interviewee: Yes, of course.

Interviewer: What is your profession and/or role to the Dutch healthcare process?

Interviewee: Cardiologist

Interviewer: How would you rate your knowledge over the healthcare process? With 1 being no knowledge at all and with 5 being expert knowledge.

Interviewee: Although I haven't been working as cardiologist in Holland for more than a year, I believe I can say I am still quite good, knowledgeable about the process. So I would say 4 or 5, give me 4.

Interviewer: Great, thank you!

Interviewee: I mentioned to you those four proposed changes, which are aiming in improving the existing problems in the process. So I will list you some benefits from implementing such a platform in the process and I would like you to choose up to four of them.

We listed the choices.

Interviewee: I would say decreasing service costs, minimizing discomfort caused to patients with movement problems, improving the communication. Those three are in my

point of view the most important things and the most easily grabbed benefits. Also the monitoring option of the patient.

Interviewer: So you also see as a benefit the improvement of the monitoring process.

Interviewee: The monitoring of how the patient is taking his/her medication will be very important.

Interviewer: Ok then I will also choose the other option and I will add "improving and monitoring the medication taking process".

Interviewee: Because in Netherlands there are investigations that show that only 60% of the patients take prescription as they should be.

Interviewer: Really that is very interesting.

Interviewee: Yes, stunning.

Interviewer: I wouldn't expect something like that in the Netherlands.

Interviewee: Actually when the doctor is not present patients tend to skip the doses or take their medication in the wrong time of the day. So if there was such a system in the "neighborhood" it would be very good.

Interviewer: Could such a platform improve the communication between chronic disease patients, that need constant monitoring, and various players like GPs, hospitals, insurances and pharmacies? And to what degree.

Interviewee: I would say that I will help the communication a lot, so yes, yes, yes!

Interviewer: In a scale of 1 to 5, with 1 being no improvement and 5 being great improvement you would rate it with?

Interviewee: I will put it a 5.

Interviewer: What are top problems/issues that chronic disease patients are facing during the Dutch healthcare process? You can choose up to two option from the given.

We listed the choices

Interviewee: I think that discomfort from the constant movement between various offices and departments is important. The repeatedly providing personal information is not very important, that is something occurring maybe when someone has to be sent to another specialist and has to give all the information again. Of course in chronic disease patient there are a lot of specialists that are taking care of the patient so it could be a point but I believe this is only in the begging. Facing bottlenecks that delay the process like (GP waiting for specialist letter) is also very important, because you get easier access to the information of the patient and they are up to date. Finally about the

medication ordering process it can make the process very easy as the current situation includes unnecessary steps, so if you can improve that part of the process with your system it will be a great thing. But I have to choose only two, so I will stick the first ones.

Interviewer: Do the systems used by hospitals and insurance companies for communicating with the patient function with a onetime registration?

Interviewee: I actually I am not aware.

Interviewer: To what degree you consider applicable the communication between the systems of the various stakeholders and the proposed system?

Interviewee: What do you mean with applicability?

Interviewer: How willing they will be to do it and how easy it is to actually connect them?

Interviewee: Well as I look at the history of IT in hospitals you can say that it will be very difficult. Because every hospital uses its own system and you already are aware of the APD problems, so I think that would be difficult. Maybe you can start on a local basis, on a smaller scale but having the same system in all hospitals is very difficult, already it is extremely challenging to have the same system just in one hospital. I believe that if you can show of providing advantages from the use of the proposed architecture to a lot of stakeholders you can have good chance.

Interviewer: That is what we are looking for, the opinion of people that have use and work with the existing system. So in a scale of 1 to 5, with 1 being very difficult and 5 being extremely easy you would rate it with….

Interviewee: Well, let's say two.

Interviewer: Based on existing researches we recognized the patients' frustration by having to providing their personal and physical information repeatedly and by not having very good communication with other healthcare industry players. Do you believe that the proposed system can decries that frustration with the proposed changes?

Interviewee: So if you could have a USB stick with all the information of the patient inside then that will make it easy for us and also simplify the process for the patient as well.

Interviewer: Thank you, and in a scale of 1 to 5, with 1 being not at all and 5 being very much.

Interviewee: I would give it a four. Because if this is possible I would even consider giving it a 5. Another thing I want to mention that if you have a very good IT system in your hospital you can really improve the process. For example in our hospital

everything was electronic, and as soon I was finished with the report of patient and I was saving directly that form was send also electronically to the GP, this might varies from hospital to hospital. The real difficulty is sending the information to another hospital.

Interviewer: Apart from what we have mention so far do you see a need for further changes in the healthcare process?

Interviewee: In the system you described there are a lot of important things, which are taken care of. What is very important is information about the situation, how the patient really feels. So find a way to also include this part of the diagnosis that can be coupled with the monitoring.

Interviewer: Based on your experience how useful could such a platform be for your work and process related tasks and why?

Interviewee: It is quite frustrating having a patient that you said to him/her you are ok now and then two weeks later the patient is back again, because he didn't recognize the symptoms a let the disease worsen. So, it would be wonderful to have a control system that would have warned the doctor and the patient of the situation earlier.

Interviewer: We previously mentioned the privacy issue of the data, in your case as a doctor if you were receiving a report with information from an electronic source like our system would you trust those data?

Interviewee: As a cardiologist I am used of balancing the information received by devices and the logical thinking like the look of the patient. Maybe at first I will be a little skeptical like in every new device but after a little I will get used to it.

Interviewer: In a scale of 1 to 5, with 1 being not trusting the data.

Interviewee: I would give it four.

Interviewer: In your opinion, how useful could such a platform be for the patient's everyday life?

Interviewee: I believe it will be a great improvement. It very crucial the help of such a device as it provides extra control. Also it increases the confidence of the patient because it makes him/her feel secure, given the fact that there a constant monitoring and communication the doctor.

Interviewer: In total, which of the proposed changes is the most important for the patient?

Interviewee: The personal data update.

Interviewer: In total, which of the proposed changes is the most important for the insurance companies?

Interviewee: The medication ordering and refill functionality, because it always comes to cost for insurance companies.

Interviewer: In total, which of the proposed changes is the most important for the hospital?

Interviewee: The Personal documents functionality.

Interviewer: In total, which of the proposed changes is the most important for the GP?

Interviewee: The medical ordering and refill functionality.

Interviewer: When a chronic disease patient, who is treated by you, wants to make a new appointment with you, does he/she have to arrange with you or your secretary, or dies the patient to have to book the appointment through the administration of the hospital?

Interviewee: If you are treated as chronic patient, on your last visit with the specialist, the doctor asks to meet again on specific date, which will be booked at the secretary of the specialist.

Interviewer: Overall, which player do you believe is the most benefited from the changes?

Interviewee: The patient, clearly!

Interviewer: Thank you very much for your time, it was a pleasure meeting and talking to you.

Interviewee: The pleasure was mine.

Appendix G

Transcription 2nd Interview

Interviewer: First of I would like to thank you for helping us, we really appreciate having someone with your experience participating in our research. I would like to start by going through our work quickly and then we can proceed with the questions, is that ok with you?
Interviewee: Yes, of course

We skip the part where we described the architecture and its main functionalities, as well as the process problems and the provided solutions. Before starting with the questions the interviewee provided some general information about issues with the process and attempts from various health organizations to provide IT solution for facilitating the patients.

Interviewee: Did you talk from people with "Zelfzorg Ondersteund"?
Interviewer: The organization about interconnecting you mean?
Interviewee: Yes
Interviewer: We tried to contact them couple of times but they didn't reply.
Interviewee: Because they should be the ones working on matching the regulation of the devices with the process.
Interviewer: We tried but we were unsuccessful.
Interviewee: I see and did you talked with the GPs in Leiden?
Interviewer: Yes we talked with one GP but he was a little bit sceptical as most of the changes has an impact on their work.
Interviewee: The things you are mentioning are happening and they are most of the times failing and some time they are success. So this is difficult. The thing is that I used to think that the health providers, hospitals, GPs, were the owners of the information concerning the patient. That was my opinion a few years ago. I was trained that way. I now am convinced that this doesn't work because the health providers are protecting those information, whether it is by mouth or by writing or by computer. They are protecting their information, because this is their business, their status, their emotion. So it very difficult to find someone that knows as much as you do. So those players are born to protect the information, GPs are not born to cooperate or raised to cooperate,

neither are hospitals. My point of view is that patient should own his own information that is the only way you can be successful.

Interviewer: That is what we are actually trying to achieve.

Interviewee: There is a beautiful example now in the US by a big pharmacy chain, which is called Walgreens and they offer to all their customers a healthcare record. And they offer it like getting a candy on the counter. You do you shopping in Albert Heijn and at the end you get a present, at the US you do your shopping in Walgreens and at the end you get health record. That is happening now. The second thing is that the technical opportunities at the moment are rapidly expanding. I have visited the HIM (Health Information Management) in Chicago, it was on April, and I was impressed by all the technical possibilities. I will give an example, we get patient in the emergency room that is feverish and they are analysing his vitals. The doctor says he is old, we are not taking him to the hospital let's send him home. The patient dies the same night at home or he is admitted to the hospital nobody takes care of him and he dies the same day in the hospital. Now what I have seen is what you can do but no one is doing here in the Netherlands is to give to the patient a small plastic bag with your Bluetooth measuring device and just tell him put this in your wrist, put the plug into the electric system at home and every half an hour we will get your information, if we don't get your information we will send a nurse to check on you. That way we have every half an hour respiratory rate, oxygen consumption, lung function, heart rate, pulse, temperature and blood pressure. You virtually informed of all the vital elements of the human body. We are not doing that…that is interesting isn't it? Because there will be people who would yes and who owns those information? Who is analysing it? And if you have something like an emergency system they will say who is responsible for the emergency? So you have to organize it. Still you are right you have to try moving in that direction.

Interviewer: That I very interesting do you have anything like that in the hospital?

Interviewee: We have here at this hospital a system, started on 2008, for patient records that is owned by the patient and delivered by the hospital. It is a success in a sense that we have 15.000 to 20.000 patients in the records and it shows me two things, one it is difficult for the patient because you cannot change anything because otherwise you will end up in troubles, but everything that is in hospital system goes unfiltered in the patient system. So if you as a doctor you have not discussed the outcome of certain tests with the patient then no matter what in two weeks it will appear on the screen of the patient. We also provide access to the GP for going into our system. Only one in twenty is doing

that. The rest are just not interested. The patients though really appreciate it, it is not the best but still is better than nothing at the moment.

Interviewer: I believe it is a really nice idea.

Interviewee: The system is maintained by the hospital, so the patient and the GP can only see the results not edit them. If GPs had privileges of editing the data then they can ruin them and make them rubbish. But it come to one thing that patient don't have to give their information over and over again. Which is a terror for them.

Interviewer: Shall we start with questions because I know that you have limited time?

Interviewee: Yes.

Interviewer: What is your profession/ role in the healthcare process?

Interviewee: Now I am retired. I used to be a doctor, nephrologist. And I specialized on dialysis which actually can be done at home. Also I used to be CEO of hospitals and the moment I took this role I took with me the interest in ICT and empowering the patient.

Interviewer: Quite a ride

Interviewee: Yes. I believe that in the Netherlands in that aspect we are not doing as successful, still better than most countries.

Interviewer: True

Interviewee: But we are very limited by the privacy problems. Everyone kept saying to me that if those data are more than a year ago you have to ask the patient again.

Interviewer: In a scale of 1 to 5, with one being no knowledge and five being expert, how you would rate your knowledge over the Dutch healthcare process?

Interviewee: Four.

Interviewer: Earlier I described to you four changes in the process, we concluded to some benefits that can emerge from their implementation. Can you please choose up to four of choices that I am about to list you?

We listed the choices.

Interviewee: The second, the third and the forth.

Interviewer: Thank you.

In your point of view could a platform like ours improve the communication between chronic disease patients and various players in the industry? Please rate it on a scale of one to five, with one being no improvement and five being great improvement.

Interviewee: I would give it a five it can improve greatly the communication. This kind of solutions are underestimated.

Interviewer: I will list some options and I want you to choose up to two of those as the top issues/problems that chronic disease patients are facing in the process.

We listed the choices.

Interviewee: The fourth and fifth, the delays and the time consuming.

Interviewer: Ok. Do the system that your hospital is using works with a one-time registration?

Interviewee: It tries to and I am not convinced that it works.

Interviewer: So I will consider it as a yes.

Interviewee: Yes, exactly.

Interviewer: Do you believe that the communication between the hospital system and the platform that we are proposing is possible?

Interviewee: Yes, of course.

Interviewer: Please rate how possible you consider it in a scale of one to five.

Interviewee: It is possible, it is a five. We can do it if we want it.

Interviewer: You believe that a like the proposed one could decrease the frustration level of a patient?

Interviewee: Yes

Interviewer: In a scale of one to five, with one being no improvement, you would rate it as…?

Interviewee: I will put it a three, because patients always find a reason to get frustrated.

Interviewer: Apart from the previously mentioned problems in the process, do you any other problem worth mentioning based on your experience?

Interviewee: If you cooperate with certain organizations on specific diseases and you are using the already existing platforms, which are working for the patients. So if you work with health providers like hospitals they always think of themselves.

Interviewer: For you as a doctor, how useful with such a platform and the proposed changes for you delay tasks?

Interviewee: That is very daring question. For me it would be fantastic because it would give me the opportunity to focus on the things I should do. Not do blood pressure measurement at the hospital that has no use at all. So this platform would allow me to do useful and important tasks in the hospital, no simple staff like measurements.

Interviewer: How much would you trust data originating from a platform like the proposed? Please rate your trust level in a scale of one to five, with 5 being trustful.

Interviewee: I will give it a four.

Interviewer: On your opinion how useful can the platform be for the patient's everyday life?

Interviewee: It is very helpful, the ability to things on his own would give him pride. So it very important.

Interviewer: Now I will ask the same question four times but in a different point of view. In total which one of the proposed four changes is the most important for the patient? I will list again the four options.

We listed the choices.

Interviewee: I believe the medication ordering is the most important.

Interviewer: Now the same question for the insurance companies

Interviewee: It is hard to tell because insurance companies are successful if health organizations are willing to cut down cost. So the personal documents functionality is the only one I can choose.

Interviewer: The same but for the hospitals this time?

Interviewee: Less work that is what is important for the hospitals, so maybe the best choice is the medication ordering functionality.

Interviewer: Ok last one, now on GPs' point of view.

Interviewee: GP is not that much involved in care service nowadays, so I would say the personal documents functionalities will help him the most.

Interviewer: Which one of the four players groups, patient, GP, hospital and insurance companies do you believe would be the most benefited?

Interviewee: Patients by far.

Interviewer: Can you elaborate on your answer?

Interviewee: Because patient combine all the material and immaterial benefits.

Interviewer: Great, that is all. Thank you very much for your time it was a pleasure discussing with you.

Interviewee: It was great meeting you.

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