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EIRA PROJECT: ADVANCING IN THE MANAGEMENT OF PERSONAL HEALTHCARE

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Tengo que confesar que, cuando me llegó el momento, hace ya 4 años, de escoger carrera universitaria, no tenía claro ni por dónde empezar. No he tenido la suerte de contarme entre los afortunados de vocación temprana, qué le vamos a hacer. Finalmente opté por estudiar Ingeniería Biomédica por los motivos de siempre: que si es una ingeniería y en inglés, que si tiene muchas salidas, que si es un campo con mucho potencial, que si la salud sigue siendo una prioridad aunque haya crisis, y un largo etcétera que ya os sonará familiar. Y aquí estamos, parece que no se dio mal. Las asignaturas fueron lo que esperaba, y los laboratorios, y las prácticas. En la línea de lo esperado, contenta con el resultado pero sin muchas sorpresas. Lo que no esperaba es que durante estos años sí que iba a encontrar mi vocación. Y eso sí que fue una sorpresa. Escogí esta carrera por los motivos de siempre, y ya os sonará familiar, pero, si tuviera que escoger de nuevo, volvería por la gente. Y es que eso sí que no lo da cualquier carrera.

Esa gente que me ha acompañado en mi día a día, aguantándome con todas mis peculiaridades incluidas, compartiendo entregas de prácticas y repasos de exámenes, siempre en el último minuto. Siempre hay tantas cosas por hacer. Esa gente que me ha dado la oportunidad de aprender y ponerme a prueba, que me animó a participar en Delegación de Estudiantes y a ir asumiendo cada vez más responsabilidad en ella. Esa gente que siempre ha estado a mi lado para enseñarme cosas nuevas, fueran de la carrera que fueran. Esa gente que me apoyó para ser Delegada de Escuela, y que me animó a dar el salto a la representación estudiantil nacional entrando en la Comisión Ejecutiva de CREUP. Pero, sobre todo, esa gente que ha confiado en mí y me ha seguido con todos los proyectos que hemos sacado adelante con nuestro pequeño, pero inmejorable, Consejo de Titulación, desde el día a día de nuestra carrera hasta la fundación de la asociación nacional de estudiantes de nuestro sector, el CEEIBIS.

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“You will have a whole eternity
to think inside the box”

ABSTRACT

This project arises with the purpose of shedding some light on a subject that is the order of the day in the world of medicine: the unification of the medical history.

The motivation of the project comes from getting to know the lack of coordination in the organization of the health system that currently exists. First, the health centers in different regions follow different systems, end even public and private health centers in the same region operate independently, so they can not share data between them. Second, in different centers they use different and incompatible applications to perform tasks that are similar or complementary. This means that, ultimately, patients are those who are harmed, since the problem of medical data accessibility implies a risk for them. Moreover, unifying or making compatible the various existing applications could improve clinical decision making helping tools, optimizing the efficiency, effectiveness and the use of resources. (Chapter 1)

The development of this project draws from a comprehensive analysis that allows finding out which is the current situation of our country on this issue, as well as the measures that have been developed to improve it, their advantages and disadvantages and the main problems that our society faces. It also includes the points of view of both patients and health professionals. For this purpose, it has been necessary to do interviews with professionals, to visit hospitals, to attend to forums and to try personally most of the systems currently in use. Also, both regulatory and socioeconomic framework have been studied, including business opportunities in the field. In parallel to this analysis, advances in new technologies and their possible applications in the implementation of our system have been studied, specially tools for the development of online mobile applications and its back-end structure. Learning how to use them has also been necessary. (Chapter 2, 4 and 7)

Based on the findings from the first phase of analysis and learning, objectives and functional and nonfunctional requirements to be met by the application are defined, as well as the platform on which it would be implemented, a mobile device with an Android Operating System. Then, the architecture of the system is structured, and it is modularized according to functional requirements. Finally, the graphic design and the implementation of a semi functional demo are performed, and a project development planning is developed step by step. (Chapters 3, 5 and 7)

The original idea of the design was intended to assume greater innovation in technology advances, even incorporating artificial intelligence and massive data processing applied to the healthcare field. However, from the analysis it was concluded that, before incorporating such technologies, a solid

groundwork should be laid, a system able to collect all the relevant data to work on them later. Thus, the design was finally oriented to a simplified, unified, bilateral, multifunctional accessible and secure system. The application of advanced technologies becomes part of the future lines of the project. (Chapter 8)

To conclude, this project was initiated with the aim of getting to know better the healthcare system and its tools, learning about new technologies already used or that could be applied in the field and designing an innovative system with business potential. Despite the difficulties encountered and the changes made in the project with respect to the original idea, the main objectives have been successfully met. (Chapter 9)

Keywords: data management, e-health, healthcare, health system, m-health, mobile applications

RESUMEN

Este proyecto surge con el propósito de arrojar algo de luz sobre un tema que está al orden del día en el mundo de la medicina: la unificación de la historia clínica.

La motivación del proyecto surge de conocer la gran descoordinación en la organización del sistema sanitario que existe actualmente. Primero, los centros sanitarios en comunidades autónomas distintas siguen sistemas diferentes, e incluso los centros públicos y privados de una misma región funcionan de forma independiente, por lo que no comparten datos entre ellos. Segundo, en los diferentes centros se emplean aplicaciones diversas e incompatibles entre sí para la realización de tareas o bien similares o que podrían ser complementarias. Esto hace que, en última instancia, sea el paciente el que sale perjudicado, ya que el problema de accesibilidad a los datos médicos supone un riesgo. Además, unificando o compatibilizando las diversas aplicaciones existentes podrían mejorarse las herramientas de ayuda en la toma de decisiones clínicas optimizando la eficiencia, la efectividad y los recursos del sistema (Capítulo 1).

El desarrollo de este proyecto parte de un amplio análisis que permite conocer la situación actual de nuestro país en este tema, así como las diferentes medidas que se han desarrollado para mejorarla, sus ventajas y desventajas y los principales problemas a los que se enfrenta nuestra sociedad. También incluye las opiniones tanto de pacientes como de profesionales sanitarios. Para ello se han realizado entrevistas a profesionales, se han visitado hospitales, se ha asistido a foros y se han probado personalmente muchos de los sistemas que están actualmente en uso. También se han estudiado tanto el marco regulador como el socioeconómico, incluyendo las oportunidades de negocio del sector. En paralelo a dicho análisis se estudian los avances en las nuevas tecnologías que podrían aplicarse en la implementación del sistema, entre las que se incluyen principalmente herramientas para el desarrollo de aplicaciones móviles online y su back-end, además de aprender a utilizarlas (Capítulos 2, 4 y 7).

En base a las conclusiones obtenidas de la primera fase de análisis y aprendizaje, se definen los objetivos y requisitos funcionales y no funcionales que deberá cumplir la aplicación, y se elige la plataforma sobre la que será implementada, un dispositivo móvil con sistema operativo Android. Posteriormente, se estructura el la arquitectura del sistema y se modulariza en función de su funcionalidad. Finalmente se trabaja en el diseño gráfico de la misma, se crea una demo semifuncional y se elabora una planificación de su desarrollo paso por paso. (Capítulos 3, 5 y 6)

La idea original del diseño pretendía suponer una mayor innovación en el ámbito tecnológico incorporando incluso avances de inteligencia artificial y tratamiento masivo de datos aplicados al campo sanitario. Sin embargo, a partir del análisis realizado se concluyó que, antes de incorporar dichas tecnologías, debía construirse una base sólida, un sistema capaz de recopilar todos los datos para, posteriormente, trabajar sobre ellos. Por eso, el diseño finalmente se orientó a un sistema simplificado, bilateral, unificado, multifuncional, accesible y seguro. La aplicación de tecnologías más avanzadas pasa a contarse entre las líneas futuras del proyecto. (Capítulo 8)

En conclusión, este proyecto se inició con el objetivo de conocer mejor el sistema sanitario actual y sus herramientas, aprender acerca de las nuevas tecnologías que se están utilizando o podrían aplicarse en el sector y diseñar un sistema innovador con posibilidades de comercialización. A pesar de las dificultades encontradas y los cambios hechos en el proyecto con respecto a la idea original, los objetivos principales han sido cumplidos. (Capítulo 9)

Palabras clave: aplicaciones móviles, e-health, gestión de datos, m-health, salud, sistema sanitario

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CHAPTER 1 INTRODUCTION

In this chapter the origin of the idea of this project is explained, followed by the main goals on which it is built and the approach chosen for its fulfillment. Finally, the project planning and the structure or the report are also included.

1.1 Motivation

In order to find out where the EIRA Project idea comes from and what it has become, let's go back a few years in the history of technology. Regarding technological eras it is said that during the late 1970s the *Digital Revolution*, based in the adoption and proliferation of digital computers, gave way to *Information Age* (mainly with the emergence of Internet) which turned information and data into our main capital and knowledge into our main product. This new stage has been characterized by an explosion of opportunities not only to access but also to create vast amounts of information. And, nowadays, although the *Information Age* is still in the process of evolving, the possibility of being living a new stage of transition in favor of creativity and innovation is on the table. Now it is all about the ability to use all the knowledge available for the creation and design of all kinds of solutions to an endless flow of problems, issues, challenges and needs. This wave of change could have begun some years ago, when technology in all its forms experienced a rate of development unprecedented in history. Needs which could not be addressed before, now can, and businesses readily jumped at the opportunity to make a profit from an ever-evolving set of demands which arose from a market that had now been empowered with access to limitless information putting it in a continual state of morphosis. This phenomenon presents the great challenge not only to businesses but to the whole society, learning how to adapt to the rapid changes in the market simply because what worked before may not work anymore. The message is clear: do not be afraid of challenge, invest in it [1].

Now think about a sanitary system in which daily work is still based on paper and patient data is stored in hospitals' local networks, being only accessible for other hospitals or centers in the same region through collaborative tools that do not go beyond static formats, without any help from specific searching or data analysis tools. The collaboration between private and public systems is minimum when centers are located in the same region, and non-existent in any kind at a national level. From my point of view, this implies a risk for the patients and a continuous wasting of resources, including public resources and taxpayers' money.

The first time I had the opportunity to learn about the organization system of a hospital was almost two years ago, when, as a part of the subject of Anatomy, I spent some days rotating through different areas of the Gregorio Marañón Hospital in Madrid. My first day was in Internal Medicine, also known as General Medicine, which is the medical speciality dedicated to the diagnosis and medical treatment of adults. I followed a doctor during the whole morning finding and carrying huge folders from one room to another, visiting a few patients to check their medical tests, treatments and evolution, and finally writing long reports to update the data stored in the internal system. I could see how those huge folders, which contained the only updated and complete patients' records, were passing around all health professionals, from administratives and technician to nurses and doctors. I remember thinking that optimizing those methods had to be possible. And so I thought when I saw the computer system. Information contained in the computer reports was summarized and incomplete, based mainly on conclusions and leaving aside plenty of monitored data. The patient ID was only used by that hospital, and the accessibility of the information was limited by *Horus*, the most advanced system to share data between public sanitary centers in the region of Madrid.

On the other hand, think about a growing market of web and mobile applications emerging dialy where anyone is able to store, manage and access their own data, no matter when or where, including from sleeping or nutritional habits to whole lifestyles, with information more objective or reliable than that obtained from any poll.

Overall, there were too many factors to take into account: the inaccessibility of the data turns out in a daily risk for any patient if any kind of emergency happens far from their main hospital (throughout unknown allergies, incompatible treatments, chronic diseases, past operations...etc.); the decentralization of the information leads to a huge inversion of time of doctors not only in organizing reports and updating the same data in several platforms, but also reading and understanding it; resources are invested over and over in medical tests that could be avoided by accessing previous results; and massive data niches are increased day by day without reporting any benefit to the collective intelligence. And, on the other side, new technologies and big data analysis techniques are continuously emerging and being improved and no one is being able to take full profit from them.

If health is a priority, why technology is evolving so fast and far in so many fields and it is still deficient in healthcare? With the technology available, it should be possible to develop an optimized system, betting on accessibility without compromising safety, responding to daily needs of different health professionals, avoiding risks and allowing the patients to be empowered in the care of their own health. Having lived for 40 years in the *Information Age* and being entering the *Innovation Age*, we should be able to do it better.

When I started to think about possible approaches to this bachelor thesis I had only one thing in mind: I wanted a project that defines me, able to reflect my desire to innovate and learn and my passion for business. Thus, the main **motivations** that drove me to develop the EIRA Project as my thesis were being able to design an innovative project on my own, getting to know the market of developing IT tools for the healthcare field, increasing the basic knowledge of programming and computer sciences learnt during the bachelor and learning about business and entrepreneurship.

1.2 Goals

The **main goals** initially established for the project were:

1. Get to know the types and performance of current IT tools used at different levels of the healthcare sector; analyze, classify and recognize the advantages and disadvantages of these tools and identify the problems and challenges for the technology in this field for the next years.

2. Design a system which responds to the identified necessities and which adapts to users' requirements in the field of healthcare data management.

3. Learn about IT tools development, specifically mobile applications, and develop a demo of the project.

In addition, some non-essential **secondary goals** were also established:

4. Explore the impact of recent big data techniques and tools in healthcare.

5. Learn about the business performance in the field and design a sustainable business model for the project.

1.3 Resolution method

The problem posed is broad and ambiguous, so for its resolution a **synthetic method** has been followed. The project has started from scratch by analyzing and schematizing a huge and diverse amount of information in order to determine the main lines, advances and problems, and, depending on them, define the specific objectives of the project, design an improved system and develop a simplified technical solution.

In order to achieve these goals the project has been organized in three main **phases**:

1. *Analysis and learning*. Get to know the sanitary system through visits to hospitals, interviewing doctors, attending forums and researching. Start an online course for application development.

2. *Synthesis, design and development*. Summarize and organize all information collected and start designing and developing the project.

3. *Conclusions, future progress and reporting*. Make conclusions, determine the possibilities for the future and report the process.

In parallel, the last secondary goal would be faced through the participation in the university program *TFG Emprende* for entrepreneurship.

1.4 Project planning

With the purpose of explaining the planning of the project development properly, it has been divided into phases according to the **WBS (Work Breakdown Structure)** approach and in accordance to the main blocks of the resolution method established in the previous section 1.3. A WBS is a chart in which the critical work elements, called tasks, of a project are illustrated to portray their relationships to each other and to the project as a whole. The graphical nature of the WBS can help to predict outcomes based on various scenarios, which can ensure the optimum decisions are made about whether or not to adopt suggested procedures or changes [2].

In order to create a WBS, first key objectives are identified and then tasks required to reach those goals are listed. This structure takes the form of a tree diagram, where the primary requirements or objectives are shown at the top within the “trunk”, and the tasks are listed in the “branches” below. When completed, a WBS resembles a flowchart in which all elements are logically connected, redundancy is avoided and no critical elements are left out. The WBS created for EIRA Project is shown in *Figure 1*.

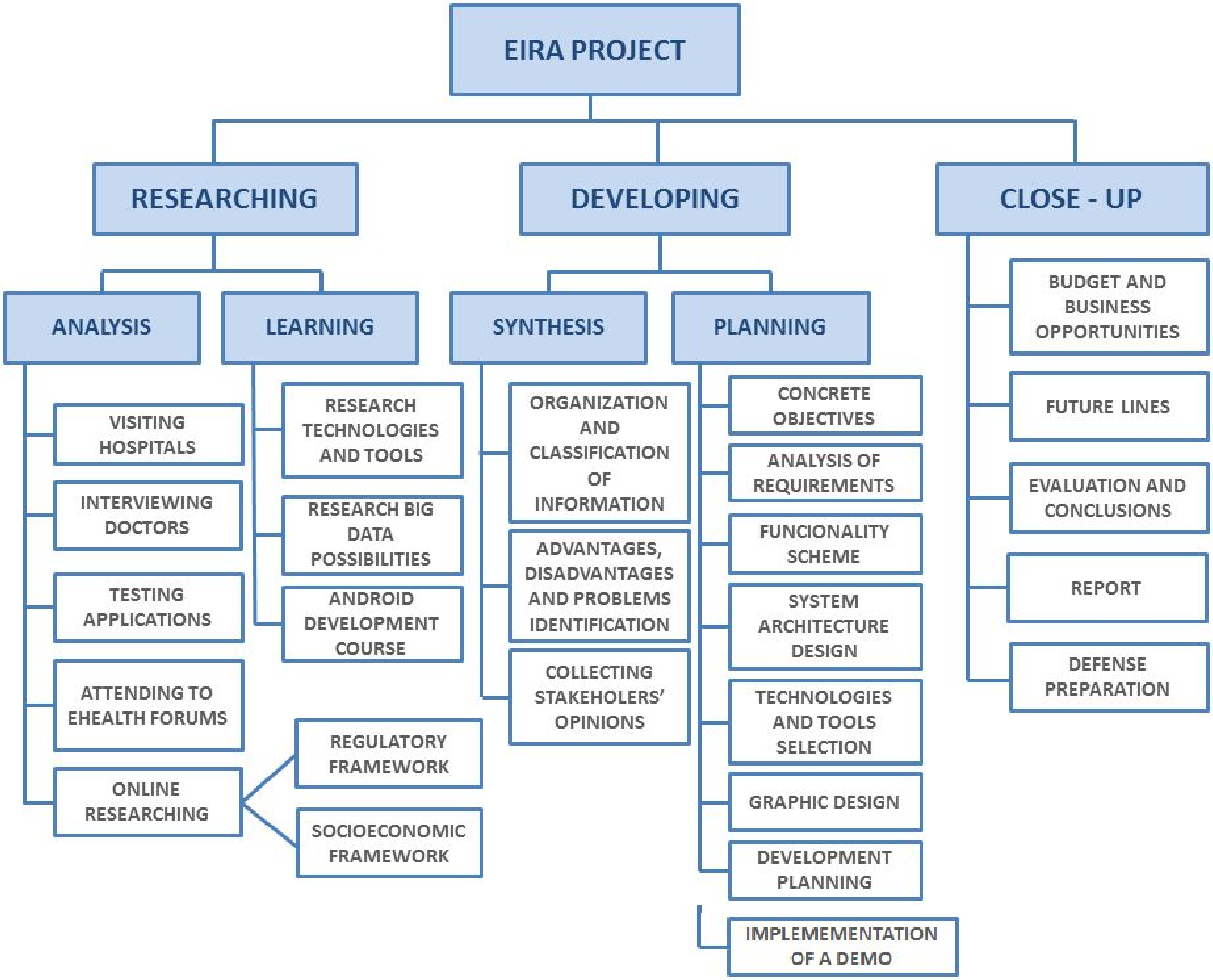

Figure 1. Work Breakdown Structure

1.5 Structure of the report

This report has been organized in 9 chapters, a glossary and a bibliography. In addition, there is also one appendix. The **content of each chapter** is described next:

- Chapter 1*: Introduction*. It includes the explanation of the origin and motivation of the idea of this project, followed by the main goals on which it is built and the approach chosen for its fulfillment. Finally, the project planning and this structure of the report are also included.

- Chapter 2: *State of art*. It introduces the *eHealth* concept firstly by the analysis and classification of the currently used IT tools, not only for mobile platforms but also for computers; and secondly including opinions of patients and professionals in the sector. As the result of the analysis, advantages, disadvantages and main problems of current systems are exposed. Finally, in a section more focused on applications for mobile platforms (which will ultimately be used for this project), a brief of the restrictions due to the regulatory framework is included. This chapter focuses on the first and the fourth goals.

- Chapter 3: *Analysis*. In this chapter, the objectives of the project are concretized, and several statements and restrictions to which the application must adjust are declared and functional requirements are collected and classified. Finally, the measures taken for the protection of users' data are also included. All this analysis is done to lay the groundwork for the design and development of the project. This chapter derive from the second goal.

- Chapter 4: *Technologies and tools*. It includes a description of technologies, tools and hardware resources used throughout the project. The most important characteristics, as well as their role in the project development, are explained. This chapter focuses on the third goal.

- Chapter 5: *Architecture and design*. It includes the design of the system architecture, the identification of the main user actions in the application and the separation of the system functionality in modules.

- Chapter 6: *Implementation*. In this chapter the process of developing the application for an Android platform is explained step by step, and those steps that had not been previously presented in previous chapters are completed, such as the gathering of the basic information, the graphic design and the development of the demo. In addition, an introduction to quality assurance and testing is included.

- Chapter 7: *Socio-economic framework*. In this chapter the business models that exist in the field of mobile applications are discussed, including the possibilities for monetizing the EIRA Project. In addition, the costs of the project, the estimated budget for its full development and the factors to take into account for its maintenance and scalability in its growing process are presented. This chapter arises from the fifth goal.

- Chapter 8: *Future work*. It lists and explains briefly both the remaining steps for the developing of the application on an Android platform and possible future improvements for the EIRA system. Next steps towards its commercialization are also included.

- Chapter 9: *Evaluation and conclusions*. In this chapter a global review of the project is given, the fulfillment of the goals is analyzed and the main difficulties encountered during its development are presented. Furthermore, final reflections on the evolution of the project from the original idea until today, advances that its implementation would involve in the field and the work that remains to be done are included.

To complement the main structure, a list of main terms alongside their definition is included in the *glossary*, and a list of references consulted throughout the development of the thesis is presented in the *bibliography*. Finally, the *Appendix A* includes the main interviews with doctors, from where ideas for both analysis and design phases have been taken.

CHAPTER 2 STATE OF ART

In this chapter the *eHealth* concept is introduced firstly by the analysis and classification of the IT tools that currently exist in the health field, not only for mobile platforms but also for computers, and secondly including opinions of patients and professionals in the sector. General current problems and challenges are also presented. Finally, in a section more focused on applications for mobile platforms (which will ultimately be used for this project), a brief of the restrictions due to the regulatory framework is included.

2.1 How technology is transforming healthcare

This chapter could be infinite. Advances in technology in the healthcare field have enabled us to explore ways that a few years ago sounded like science fiction, from printing organs to the creation of brain-controlled prosthesis , going through stem cell therapies or development of imaging up to 4 dimensions.

But, focusing on what concerns directly to the EIRA Project, IT technology is the main matter that has to be brought up for discussion.

In the mid-20th century, Joseph Schumpeter, an Austrian economist, popularized the term *creative destruction* to denote transformation that accompanies radical innovation. By the virtue of the intensive infiltration of digital devices into our daily lives, the way people communicate with each other or with their entire social network, the way they take and share pictures and videos at any time and, last but not least, the way information has been made accessible no matter when or where have changed our lives. Radically transformed. Creatively destroyed.

But, sadly, even though health is for everyone a priority, it has thus far been largely unaffected, insulated and almost compartmentalized from this digital revolution. Medicine is remarkably conservative. Maybe it is due to the reluctance of physicians, the difficulty of the health community or even society to accept and adapt to change, or maybe because of the complexity and bureaucracy of the system that raises against any kind of potentially revolutionary innovation. But that is about to change. Medicine is about to go through its biggest shakeup in history [3].

For the first time humans can be digitized: life signals can be monitored, any part of the body can be imaged and 3D reconstructed, and even full genomes can be sequenced. **IT tools are designed, developed and improved daily to serve both patients and doctors**, waiting for the time when the digital revolution make its great impact on the field, changing it radically. Possibilities grow exponentially day by day. Regardless of how and for whom, or even for which platform (computer or mobile devices) are these digital applications created, all pursue a common set of **objectives**:

- *Increase the productivity* of the health professionals and reduce the cost for healthcare providers.
- *Improve the quality* of ongoing care with faster and safer diagnostics and treatments.
- *Empower the patient* to manage their own health, paving the way for more personalized medicine.

- *Promote a healthier lifestyle*, improving life quality, reducing the impact of chronic diseases and avoiding acute crisis for patients.

Those are the objectives, the changes that would lead us to a **new model** for our sanitary system. Healthcare has historically been a response-based industry, with the vast majority of patient care administered after something goes wrong. With the help of technology, clinical teams and their patients have an opportunity to be more proactive, working together to try to avoid – or at least delay – crises in chronic diseases and medical events [4]. The healthcare industry has to move from reactive care to proactive prevention, from a doctor-centered to a patient-centered system, in which the patient is empowered, reliable information is accessible and the medicine is adapted and personalized to respond to the most specific requirements. Health must stop being an occasional need to become a lifestyle.

Although this new model is still far from reality, technologies keep evolving to approach it. In order to lay the ground for EIRA Project, some examples developed in the past years have been analyzed and classified to study their impact, coming up with the conclusion that there are **6 main ways** through which IT industry is enhancing healthcare [5].

1. *Organizing massive data*

Everyday, an unmeasurable amount of data is being generated, from health centers and laboratories to the daily lives of people, each diagnosis and each treatment, each monitored signal from every patient no matter how simple it is, each research group, each website or mobile application in the field and even other not directly related tools, such as social network or blogs. In recent years media has coined the term *Big Data* to refer not only this large volume of data, both structured and unstructured, but also the data processing techniques that are being developed in order to have sufficient power to analyse, curate, search, share, store, transfer and, in short, to exploit its potential.

In the field of healthcare advances in this technology are crucial. Maybe all the data available is trying to tell us something, such as the relationship between certain diseases and lifestyle or what are the most effective treatments for them, no matter how recent or far have they been discovered, and we are not able to understand it yet due to a lack of organization. Through predictive analytics, user behavior analytics and other advanced data analytics methods the value from the data can be extracted. Accuracy in *Big Data* may lead to more confident decision making, and better clinical decisions can result in greater efficiency, better use of resources, cost reduction and reduced risk and impact for patients, which is more important for this sector than for any other.

An example of an IT tool that is already being used and that proves the importance of the organization and accessibility of the data is *UpToDate* [6], an evidence-based clinical decision support resource used worldwide by healthcare practitioners to help them make the right decisions at the point of care, both for diagnosis or treatment.

Other important tools are the administrative platforms for medical histories. Although they are still very limited and confined to static data formats that do not allow to take full profit of their content, they have had a great impact on local medicine by improving data accessibility. In Madrid, the most important one is *Horus* [7], a platform that allows the exchange of medical histories between all the public health centers and hospitals (and even some associated private centers) in the region. Other examples are *AP Madrid*, a platform made only for primary care health centers, and *Selene*, a new improved system that is being implemented in new public hospitals.

2. *Linking doctors*

Facilitating communication, coordination and support among doctors, a more effective, efficient and accurate system is achieved.

One promising example, although it is still in pilot phase, is *Telederma* [8]. This application will allow a group of primary care physicians to consult directly and instantly dermatology specialists through teledermatology to either give a diagnosis or referral to a specialist with priority if necessary. This will avoid long waiting lists for specialists while improving diagnostics provided by non-specialist doctors.

This project is being developed in the *Hospital Ramón y Cajal* of Madrid. This initiative could set a precedent and spread to other medical specialities.

3. *Connecting doctors and patients*

It has been found that, even for patients who follow the usual way through the health system by visiting their doctor and receiving diagnosis and treatment until recovery, searching on the Internet is a common resource. The 75% of the patients search online before consulting a doctor, 70% do it also after the diagnosis and 78% turn to Internet again while they are being treated or even after recovery to share their experience [9]. The demand of information from patients is clear, it is the task of physicians to ensure its reliability. Information available on the Internet is wide and complete, but also ambiguous and sometimes even contradictory. The best way to ensure that patients reach the information they aim for is providing the health professionals with the necessary tools to share it.

An example of this current is *Consultorio Médico* [10], a simple website that allows patients to make inquiries directly to medical professionals, but also warns them that searching online should not replace their doctor visits.

Another approach to this category are the tools that facilitate in-person and direct communication between doctors and patients, as *UniversalDoctor Speakers* [11], which is an application that guides multilingual communication between patients and health professionals through a translator that includes expressions from general symptoms to more specific or emergency situations.

4. *Helping patients to prevent, endure or overcome an illness*

One of the most important factors for the patient both in the prevention and overcoming of diseases is the emotional support. Feeling backed up and motivated to take care of their health, and accompanied and advised in their recovery gives the patient the strength, optimism and confidence needed to overcome the disease sooner and better. Moreover, providing tools to the patients to update daily data about their health gives the doctor the possibility of following their evolution constantly and precisely in a way that otherwise would be impossible.

An example of this category, focused on prevention, is *Fotoskin* [12], an application developed by specialists in dermatology and skin cancer diagnosis. Through the photographic self-control, it allows the patient to track and study their own skin, as well as to get advice and personalized recommendations for correct photoprotection.

Another example, more focused on enduring and overcoming the illness, is *Contigo* [13], an inspiring application developed for women who have been diagnosed with breast cancer, with the support of professionals and other women that have already overcome the cancer.

5. *Helping patients to stay healthy*

There is a large and growing market for mobile applications and gadgets with the aim of helping people to stay active, sleep well and eat healthy. This is due not only to the high demand for them, but also the increasing number of compatible devices and integrated functions. One clear example of this tendency are the *wearables*. Measuring activity levels, heart beat rate and sleep times and stages from a single bracelet, synchronized with a mobile device, is already possible.
One example of an active lifestyle promoter wearable compatible application is *Enmondo* [14], which allows people to track all their workouts by using GPS, to check their statistics and reach their fitness goals.

Another example that could be classified in this category, but focused on a more specific audience, is *Más que dos* [15], an application designed to accompany the future parents throughout the process of pregnancy with information, suggestions and other useful resources organized in a timeline.

6. Education

Among the many technological innovations of our time, collaborative work platforms and virtual learning environments are arising to help, through the gamification of content, to train of new health professionals. Playing is innate and funny, but can be also educative. Educative games should be balanced between challenges and abilities to enhance learning without falling into boredness or frustration. But the best part of it is that games are a safe place for experimentation, where it is possible to mistake and rectify without consequences.

An example of educative game is *Speed Anatomy* [16], an application based on images that challenges the player to identify quickly and accurately anatomical structures.

According to the INE (National Statistics Institute), 78.7 % of Spanish households have Internet access, 75.9% of households with at least one member aged between 16 and 74 has a computer, and 96.7% of those has a mobile phone. Moreover, 64.3% of the population between 16 and 74 years old uses Internet daily [17].

These data, which at first glance are not surprising, are a real eye-opener. If the main purpose of the evolution of health system is to be accessible, getting the patient involved in their own health and improving their quality of life, the best way to do it is through the tools that they are using everyday. The beginning of this path has already been traveled, but we are just scratching the surface of what can yet be done.

2.2 What do patients want?

In the evolution of the health system only one thing is certain, patients are the priority. We have all been, are or will be patients at some point of our lives. So it is important not only to know the point of view of the health or technical professionals, but also to listen what patients have to say.

The term *empowerment* is being increasingly used in healthcare. In the past, when acute episodes were the main cause of disease, patients were often inexperienced and passive recipients of medical knowledge. Nowadays, scientific advances have led us to have more resources, to win life quality and lifetime expectancy. But, on the other hand, chronic diseases have replaced acute diseases as the main health problem. A passive patient is no longer enough, the patient must be an active agent, they must contribute to the process and take a leading role in it, the patient should be empowered.

And what is needed to empower the patient, what the patient wants, can be summed up in three concepts: *information*, *formation* and *emotional support*.

Not only professionals must be trained to adapt and take full advantages of new technologies, but also patients. From this new approach, more oriented to self-management by the patient, myriad of projects such as patient associations, and even schools of patients, arise.

According to a survey made by the School of Patients in Andalusia, more than 70% of patients use the Internet as their main source of information, consulting before and after visiting the doctor and throughout the treatment. In addition, 1 out of 4 goes to social networks to learn about other people's experiences. Learning and sharing their experiences is part of the therapy. However, only 17% of them said that they always understand the information they read, not to mention the number of sources whose veracity and reliability have not been proved. *Figures 2 and 3* clearly illustrate this problem.

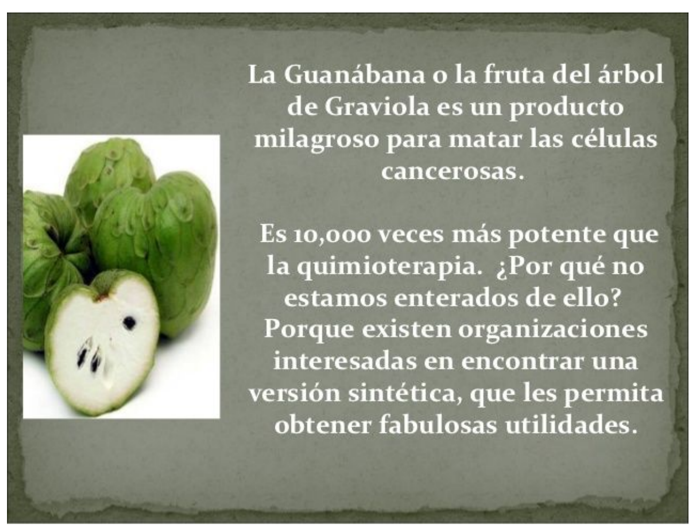

Figure 2 and 3. Problem of veracity and scientific rigor of information on the internet

Therefore, in the development of IT technologies for the health field, we must take into account the use that patients will make of them and prioritize their needs. In short, health should be always provided by, for and with patients.

2.3 The health professional's perspective

In May 2016, a forum around eHealth was held in Madrid. During the meeting, patients and professionals such as doctors, pharmacists and even application developers could present and share their different points of view. Different issues were raised.

What are the main barriers for developing applications?

One of the main barriers to the proliferation of patient-oriented applications in this field is the lack of *constancy* of the users. It may be due to the constant appearance and evolution of these applications, which make the process of adaptation more difficult, or perhaps more training is required. We have the technology but, are we ready for it?

Moreover, in the case of tools designed for doctors, it can be seen that often we fall into a design very focused on the technical point of view and not so much on the doctor's. Currently is the doctor who has to respond and adapt to the system, which is time consuming and reduces its efficiency, when it should be the other way around. Also, some of the existing features of the tools in use are not being exploited due to the lack of training of health professionals for it.

Where are we going?

Nowadays there are more than 150,000 health applications in the stores, and the number is increasing daily. In 2015, more than 3,000 million of downloads of these applications were registered. It is hard to keep updated as technology evolves faster than society. It is time to move from *quantity to quality*. [18]

And it is precisely the pursuit of quality which brings us to the second major concern regarding the future of e-health: *quality assurance*. Or, in other words, the regulation of health applications as a healthcare product. Some doctors have even begun prescribing applications as if they were medicines, as can be seen in the *Figure 4*. Thus, applications whose usefulness and reliability of their content can be evaluated and verified are needed.

Figure 4. Prescription of the App Fotoskin

Which other factors should be taken into account?

It is important not to let us get curried away by the currents of innovation to the point of forgetting the main issue, the respect for the patient. Therefore, when developing better tools, we have to always keep in mind security and *data confidentiality*.

What does the future hold?

The answer is clear: the power of data.

2.4 Advantages, disadvantages and problems

From the analysis of different applications in the categories previously defined in section *2.1*, and gathering information from forums and interviews with health professionals, the following conclusions presented in the *Table 1* were drawn.

Category	Advantages	Disadvantages
Data organization	Better accessibility	Insufficient accessibility Disjointed data Difficulty of use and lack of training Takes a long time to be updated Incomplete information
Linking doctors	Accelerates processes and optimizes results	Very specific functionality
Communication between doctors and patients	Time optimization Reliable information	Visiting the doctor should not be replaced
Prevent, endure or overcome an illness	Very specific functionality	Lack of regulation Disjointed data Lack of constancy Constant evolution and difficult adaptation
Stay healthy	Usability Compatibility and integration Personalization	Disjointed data Lack of constancy Oversupply

Table 1. Advantages and disadvantages of current IT tools.

So, to summarize, the main **problems** of current tools are:

- *Reliability*. In the absence of an existing regulatory process, we must ensure and guarantee that applications are useful, and their content complete and reliable.

- *Usability*. Applications must be as simplified as possible in order to create a better user experience, to encourage its use and to avoid the lack of constancy. Time and resources must to be also optimized. The functionality of these tools has to be designed and custom for both patients and professionals.

- *Integration* and *compatibility*. We have an incomplete and desynchronized oversupply in the health applications market. The integration of different functions in the same application favors quality over quantity. Moreover, increasing the compatibility between both IT tools and medical devices encourage data collection and exploitation. We are moving towards a more unified future.

- *Accessibility*. In addition to making information more accessible, it is necessary to also disclose the applications to make them reach their target, and train users to take full advantage of them.

2.5 Where is the challenge?

Once, I had the opportunity to attend a talk by Dr. Ignacio H. Medrano about the future of eHealth:

"*The evolution of health technologies is now going through what already happened several decades ago in the history of the development of autonomous cars*", he said. The first time that the idea of an autonomous car arose was during the 1920s. It was called the "*ghost engine car*" during its first show in 1926. A real revelation. And, nevertheless, it took more than a decade until it was heard of them again. In 1939, in the exhibition Futurama, the idea of creating adapted roads capable of charging the batteries of autonomous cars arose, and during decades several projects explore the possibility, waiting for the perfect environment of idyllic roads, a situation that never happened. It was already on the 90s when the approach took an unexpected twist, they should not wait more for the perfect moment, or try to change the whole environment for a project, the autonomous car had to adapt to the real current environment. And so it was that in 1994, thanks to multiple sensors, probabilistic calculations and parallel computing, an autonomous vehicle traveled around the Paris ring road, surrounded by normal roads and normal drivers [19]. He conclude the story with a reflection: "*Do not expect perfection to begin, let's start being imperfect*".

And there it is the challenge for the developers and health professionals. It is not possible to erase everything and start from scratch. Environmental conditions are out there, and the challenge is not to change them radically, but to adapt and learn how to take full advantage of them. We must work in an off-road system, able to adapt to the current tools and instruments, to integrate and to merge their functions, and to leave room for those which are yet to come; a system capable of improving others and improve itself.

2.6 Regulatory framework

Spain is one of the European countries with the highest rate of smartphones penetration. The proliferation of applications and its consequent increase in their use by the population leads us to the necessity of establishing a control system in order to evaluate their applicability, functionality and quality to ensure their usefulness, safety and appropriate treatment of personal data. Moreover, some of them share synergies with medical devices, which brings us the main issue: can a mobile application be considered a medical device? [20]

So far, some studies indicate that there are deficits in the quality of these applications, either due to a lack of experience or a poor collaboration with medical professionals, so that they do not cover the needs of the population and may even be a potential risk for the patient. Therefore, the European Union proposed to set a minimum quality criteria for these applications, and launched the "*Guidelines on the qualification and classification of stand alone software used in healthcare within the regulatory framework of medical devices*" [21]. *Figure 5* shows a decision diagram for determining when an application should be considered or not as a medical device.

According to this guide, applications considered as medical devices must be computer programs that perform a particular function, such as could be to manage medical records. Moreover, they must imply actions on the data with a medical purpose, and not just be limited to the storage, archiving, presentation or sharing of them. In the case of EIRA project, it matches the first two conditions, being a computer program and perform a function in the health field, but, so far, it is limited to storing, organizing and displaying data, so this first version should not be considered or regulated as a medical device. If eventually, in the following versions, the functionality is increased and it is concluded that the application is a medical device, it should follow the Royal Decree 1591/2009.

However, despite of not being a medical device, any mobile application must follow the Organic Law 15/1999 about Personal Data Protection [22]. In short, an application must:

- Stipulate the essential aspects for the protection of privacy.
- Explain the purpose for which the information is collected.
- Properly inform final users about their rights or retention periods of data.

All this information must be provided to the user before downloading the application [23].

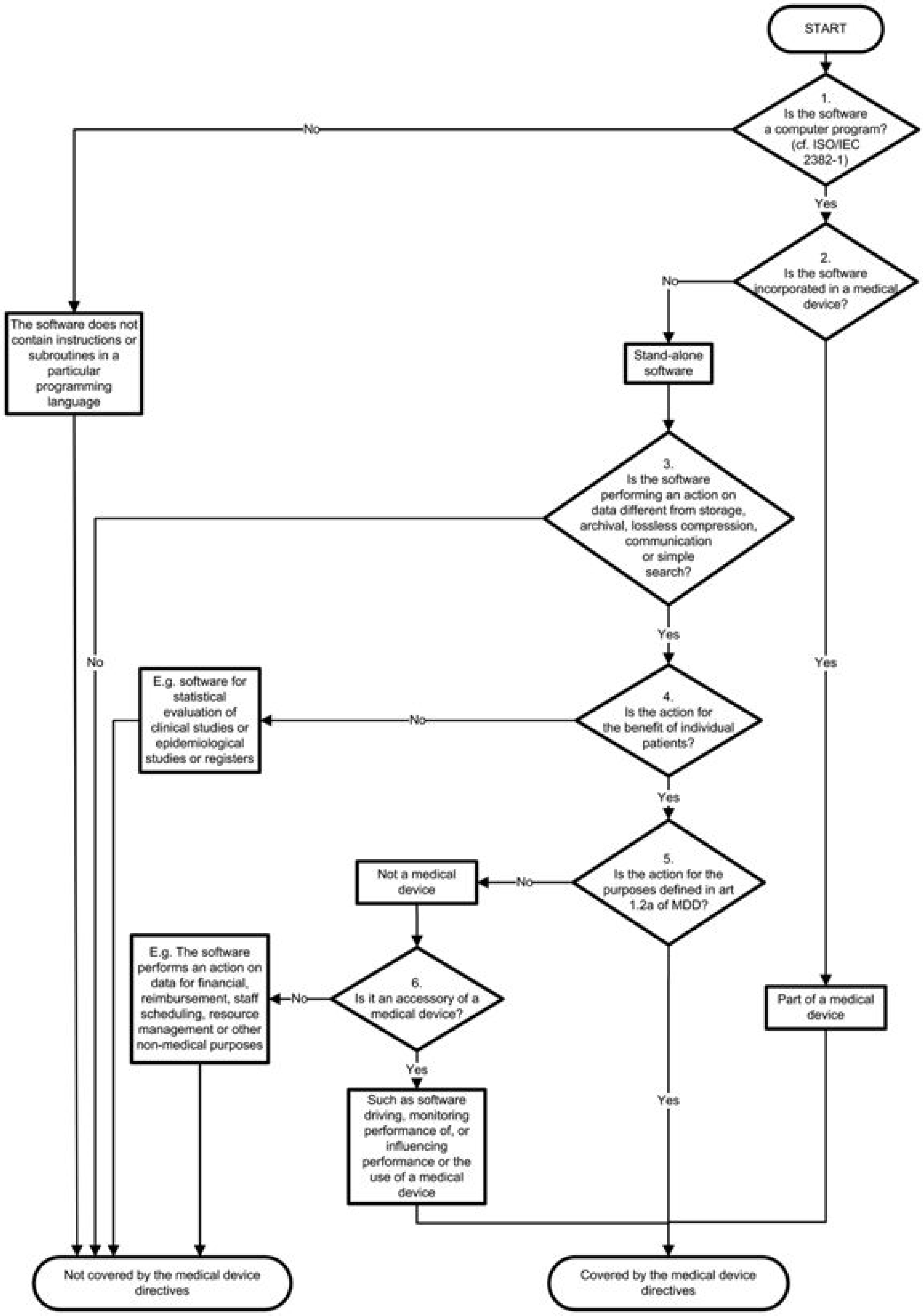

Figure 5. Decision diagram to assist qualification of software as medical devices [21]

CHAPTER 3 ANALYSIS

In this chapter the objectives of the project are concretized, and several statements and restrictions to which the application must adjust are declared and functional requirements are collected and classified. Finally, the measures taken for the protection of users' data are also included. All this analysis is done to lay the groundwork for the design and development of the project.

3.1 Objectives

The **aim** of the project is to create a unified, accessible, bilateral (patient-doctor) platform that collects all the clinical information from the patient, being compatible with other applications and devices, and which allows the use of these data for statistical analysis in order to draw useful conclusions for clinical decisions making.

For the pilot stage we will focus on the following **statements**:

- *Simplicity*. Through simple, intuitive and adapted to the demand interfaces the user experience will be simplified.
- *Reliability*. The system will be focused to guarantee the veracity of its content.
- *Accessibility*. Using simple and common online platforms the information will be accessible for the users at any place and time.
- *Data privacy*. By users identification system and data encryption privacy will be guaranteed.
- *Utility*. The system should be useful for both doctors and patients so as to encourage its use.
- *Scalability*. Given the large number of potential users, the system should be based in technologies that allow scalability.

3.2 System requirements

3.2.1 Stakeholders

As the system has to follow the statements of *utility*, *accessibility* and *reliability*, it could distinguish between two different type of users: patients and doctors. This bilateralism would allow the establishment of different functional requirements for each type of user, depending on their demand. Moreover, doctor users would be able to access and verify information of the patients, always respecting their privacy.

Information needed to fulfill a patient or doctor profile is displayed here. It has to be taken into account that this project has been thought initially for residents in Spain.

Patients

Registration data of the user profile for patients are:

- Name and surname
- ID number
- Email
- Password

Subsequently, the **profile data** that will be requested include:

- Profile picture (optional)
- Postal code
- Phone number (optional)
- Social security number and/or private health insurance number
- Physical constitution: gender, date of birth, height, weight.
- Habits: smoker/non-smoker, frequency of physical activity (sedentary/moderate/active)

The patient will also have the option to add **emergency contact information**, up to 5 people, including:

- Name and surname
- Contact numbers
- Email (optional)

Moreover, the patient should add at least one doctor profile, identified as their family doctor, to their **list of doctors**. If the doctor is already registered in the application, he will receive a notification through it; if not, the confirmation request will be pending. Once the doctor confirms the request, the patient will be included in his/her patient profiles. Then, the patient can subsequently add more specialists to his/her profiles to allow these to add reports to their history, prescribe medicines or add appointment reminders. These physicians may or may not have access to patient information fields according to his privacy configuration. Thus, the patient will include from the doctor:

- Name and surname
- Speciality
- Center
- Privacy settings

Anyway, in case of emergency, privacy settings can be omitted.

Finally, the patient can add their **basic clinical information**, taking into account that these data will be displayed as non-verified until their family doctor approves them. The fields to fill include:

- *Blood type*
- *Allergies*
- *Chronic or current acute diseases*
- *Current medical prescriptions*
- *Past surgery*
- *Vaccine calendar*
- *Specific warnings.* Both doctor and patient can add warnings for emergency states. An example of warning would be that the patient does not accept blood transfusions.

These fields of medical information have been selected as the most important for emergency cases according to the answers obtained from the interviews [Appendix A].

Doctors

Registration data of the user profile for doctors are:

- Name and surname
- Medical board number
- Email
- Password

Subsequently, the **profile data** that will be requested include:

- Health center (1 or more)
- Speciality

Finally, doctors can also access their corresponding **list of patients**. Doctors can only add patient profiles to their lists by verifying those who had already added them to their list of doctors or sending a request to those who not. Thus, in any way, the authorization of the patient is required unless emergency state is declared.

3.2.2 Functionality

The functionality specified in this first draft, according to the identified needs in Chapter 2, should be sufficient to meet the *utility* statement for both user types, thereby avoiding the lack of constancy in its use.

Patients

In order to distinguish between the various functions that the application offers to patients, they are going to be classified into static functions, those that are only occasionally edited and whose main objective is to display information; and dynamic functions, those that are constantly updated to facilitate the patient's health management. Finally, some additional features, oriented to the configuration and technical aspects of the system, are included.

The **static functions** are:

- *Profile and contact information*. It includes patient information and emergency contacts.Only the patient can edit their profile information.
- *Basic clinical information*. Patient can edit their information, but it would be displayed as pending verification until their family doctor approves the changes.
- *List of doctors*. Their family doctor and, if necessary, other specialists, will be displayed here. Patients can add, edit (only if the doctor has not their own user account, in which case data would be taken from their profile) or remove doctor profiles.

The **dynamic functions** are:

- *Reminders*. Including categories of medical appointments and prescriptions, vaccines or medical tests. Patients can add, edit or remove their reminders, but again those added by the patient and those added or edited by the doctor would be differentiated. Reminders added by the patients can be for a specific doctor o for a speciality, which would be useful, for example, in the case of regular medical check-ups.
- *Medical history*. The patient's medical history, ordered chronologically, will be collected through the addition of chapters labeled with different categories such as diagnosis, medical check-up or follow-up, vaccine, surgery, hospitalisation, etc. Each chapter will contain the date, doctor, speciality, health center, brief, category and some additional fields based on it (diagnosed disease, medical prescription, etc). Usually, doctors add the information to the medical history of their patients. If not, the patient would be able to add their own chapters but they would be displayed as pending verification by the doctor.

And, finally, the **system features** are:

- *Sign up*, *sign in* and *logout*.
- *Notifications*. Every change in the patient's information would be notified: changes verified by a doctor, new chapters added to the medical history, proximity of the date of a reminder, etc. Moreover, the first time in a day a doctor consults a patient's profile included in their list of patients, he/she will be notified. In case of emergency, any doctor could consult the information of the patient's profile, but that would be not only notified through the application, but also by mail and, if appropriate, SMS. The aim of these notifications is to avoid the improper use of the emergency state function of the application.
- *Settings*. Reminder or privacy settings, among others, would be included in this function.
- *Incidence report*. For some time the option to report errors must be available for the user in order to improve the functionality of the application.

Doctors

In the case of the doctors the classification can also be applied, and some functions have similar aims, but different approaches.

The **static functions** are:

- *Profile information*. Only the doctor can edit their profile information.

The **dynamic functions** are:

- *List of patients*. In this case, this function is the most important for the user, so it is considered dynamic instead of static as the list of doctors for the patient user. All the doctor's patients (those who had added them as a doctor and have been verified by the doctor user) would be listed alphabetically here. A searching tool by patient's name will also be included, so in a state of emergency declared, any patient's profile could be accessed.
- *Reminders*. A calendar with their appointments will also be available.

And, finally, the **system features** are:

- *Sign up*, *sign in* and *logout*.
- *Notifications*. In doctors' case, notifications will be received for verification requests of changes made by patient users in their medical information or histories.

- *Settings*. Related to the custom operation of the application.
- *Incidence report*. As in the case of the patient users, for some time the option to report errors must be available for the user in order to improve the functionality of the application.

As an additional but essential function, in case of emergency, doctors will be able to declare a **state of emergency** in the application through a simple button. The system will request the doctor user to introduce their password as a confirmation in order to avoid that this state is declared unintentionally. Once the state has been confirmed, the application allows the doctor to access any patient profile without privacy restrictions under his own responsibility, since this state should only be activated if the patient is unable to give access themselves and their physical or mental integrity is at risk. The patient will be notified of this access immediately through the application, via email and SMS. As said before, the aim of these notifications is to avoid the improper use of the emergency state function of the application. Emergency contacts would also receive a notification from the application in their own user accounts.

In order to illustrate this matter, an outline of the functions and users' permissions has been made:

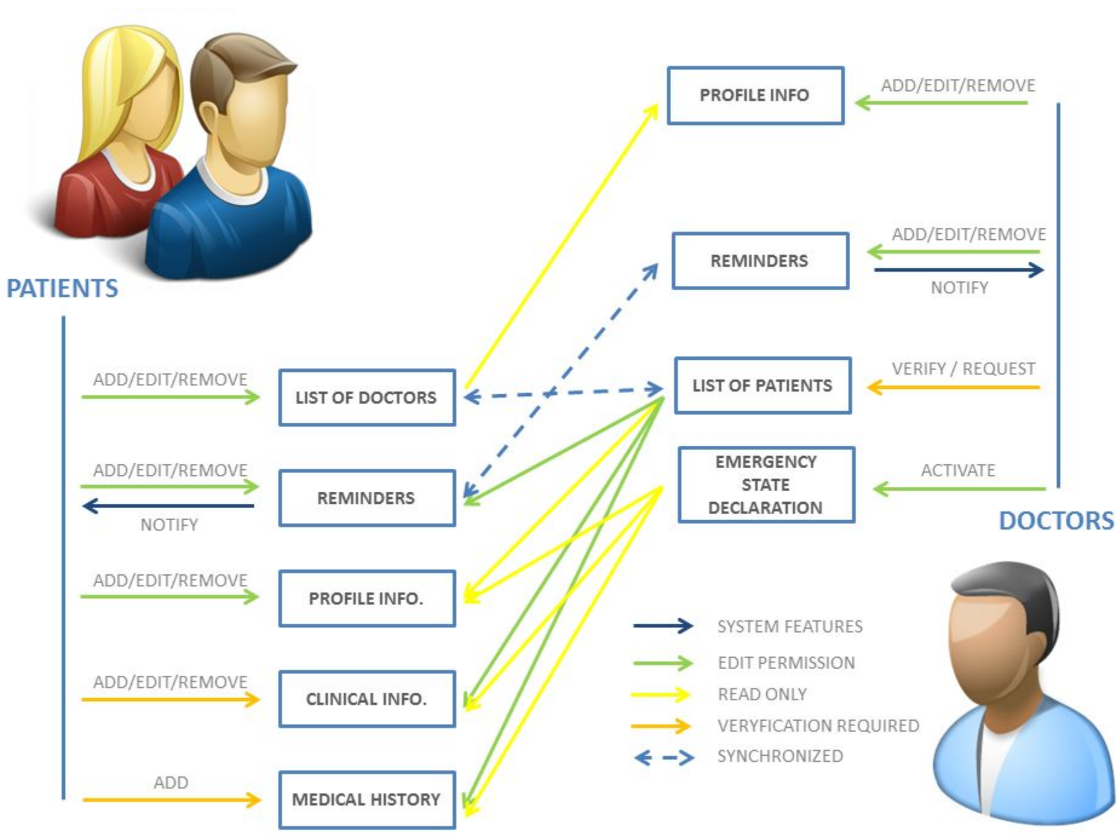

Figure 6. Functionality scheme.

3.3 Restrictions

The choice of the proper technologies in order to meet the statements of *accessibility* and *scalability* are explained in Chapter 4. However, a brief summary of the **restrictions** that these involve for the application development are included here:

- The application should be *compatible* with smartphones whose Android version is equal or superior to 4.1.
- The *user interface* should follow the Material Design guidelines.
- The *programming language* used to develop the application should be Java.
- The response time of the back-end services to the client must be less than 1 second.
- The database scheme must follow a non relational model.

3.4 Data protection policy

Aiming to not only follow the Personal Data Protection law, but also to gain user confidence through transparency, several measures to ensure patient privacy have been established.

3.4.1 User identity verification

The proper functioning and use of the application depends largely on the veracity of the user accounts, both doctors and patients. Therefore, during the registration process, the user will have to attach a picture of his/her identity card and another of himself/herself, taken instantly. In the case of patients, the match between the photo and the identity card will be checked. Furthermore, in the case of doctors, their medical board number will be also corroborated. At first, in the demo, this process would be done manually by the administration. Subsequently, an automatic facial recognition system would be included.

3.4.2 Doctor - patient access request and confirmation

In order to protect their privacy, it will be the patient who choose and authorize the doctor or doctors that can access to their data. Moreover, privacy settings can be specified for each doctor. Thus, if the patient wants to share only some information with a specialist, or maybe restrict editing permissions, it is all up to the patient. Once the doctor user confirms the patient, it will be added to their list of patients. Further on, a doctor user could request adding a patient to their list, but it will remain pending verification by the patient. A doctor could access the data of a patient which is not in their patient list only by declaring a state of emergency.

3.4.3 Access record

Each day, the patient will receive notifications of all the visits, if there have been any, of doctors to their profile. Furthermore, in case of declared state of emergency, as explained before, the patient will also receive an email and, optionally, a SMS.

3.3.4 Data anonymisation

In order to use data contained in the application for statistics generation and conclusions drawing for improving clinical decisions making, they will be anonymized. In no case will be shared or used any information that allows to identify the patient.

3.4.5 Restricted number of access attempts

The number of times a user can enter their password to access their account will be restricted to 5. To be able to try it again, a timeout will be set and an email will be sent notifying the activity and how can the access be blocked, thereby preventing unwanted access to the account.

3.4.6 Terms and conditions

In the terms and conditions of the installation of the application it is specified that the only use that will be given to the patient data, always anonymized, will be statistical with the aim of developing tools to aid clinical decision making and improve the quality of health care.

In addition, the acceptance of these terms implies a commitment by the doctor to only request unauthorized patient profiles in a declared emergency state, in which a number of conditions are met, such as patients are incapacitated to access by themselves and their physical or mental integrity is on risk. Those violating professional secrecy and disclosing medical information for their own benefit, harming the patient or outside the professional area may be denounced, as required by Article 199 of the penal code [24].

CHAPTER 4 TECHNOLOGIES AND TOOLS

In this chapter a description of technologies, tools and hardware resources used throughout the project is presented. The most important characteristics, as well as their role in the project development, are explained.

In order to meet the requirements and established functions, the perfect solution would be to develop the system for several platforms (computer, mobile, tablet, etc). As the objective for this project is to make a first approach to the development of the system, the broader platform and OS are chosen.

A **mobile platform** is chosen due to its:

- *Accessibility* requirement is met. The portability and connectivity of the device facilitates access to the information. Moreover, as the 89% of the Spanish population older than 13 years old has a mobile device, the regular use of the application is also facilitated [25].
- *Simplicity*. The reminders and notifications system is simplified.

Among the options available of **Operating System** Android is chosen because:

- *Number of users*. 76.6% of the smartphone users in Spain use Android as their OS [25].
- *Economic price*. Both for the user and the developer, as having a developer account for the Google Play only costs a 25$ payed once, while for example a licence for Apple costs 99€.
- *Developer resources*. Behind Android there is a large community of developers, so many resources are available and it facilitates both learning and development.

The biggest disadvantage of the mobile platform versus a computer system is that it is much easier to write and enter information in the second case, what difficulties the user experience, so developing a web platform would be one of the priorities for the future.

Once the bases of the system are clear, it is the time to analyze what tools and technologies should be used.

4.1 Technologies

4.1.1 Android

Android is an Operating System originally designed by Google for mobile phones. What makes it different from other systems such as iOS is that it is based on Linux, a core of an open source, free and cross-platform Operating System [26]. It is the OS with more applications available, probably because there are plenty of free developer tools and its main programming language for developers is Java, simple and well-known. It is also the OS with more users.

Java is the most widespread programming language worldwide, with more than 9 million of developers [27]. It is a *high-level programming language*, which implies that it is abstracted from the details of the computer but, in comparison to low-level programming languages, as it uses natural language elements and automatize significant areas of computing systems, it makes the process of developing simpler and more understandable for programmers. It is an *object oriented* and *multiplatform* language. Android allows the creation of applications developed in Java by using their own virtual machine, known as Dalvik. With java, programmers develop the *functionality* of their applications.

On the other hand, the **eXtensible Markup Language (XML)** is used to develop the *view*. It is a *markup language*, which means that it is a system for annotating documents in a way that they are syntactically distinguishable from the text, developed by W3C (World Wide Web Consortium) [28]. Android application development involves XML in the design of the so-called layouts, which define the graphical interface with which the user interacts. Layouts are used to separate the functionality (implemented in Java) and the view (implemented with layouts). XML files are stored with the .xml extension.

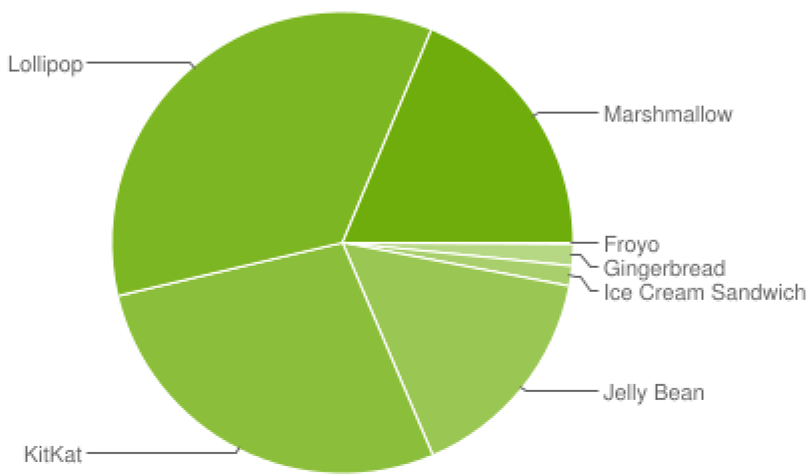

Figure 7. Percentage of users of different Android versions

Before starting to develop an application, it is important to define which Android versions are going to be covered by the application compatibility. It is necessary to find a middle point between incorporate the oldest versions, compromising the functionality, and choosing only the latest versions, making the application inaccessible for a high percentage of users. In *Figure 7* the percentage of active users for each version are shown, being *Froyo* the oldest version and *Marshmallow* the latest. For the EIRA

Project, versions from *Jelly Bean* to *Marshmallow* will be included in the compatibility, so the 97% of the active users will be reached [29].

4.1.2 REST

The **REpresentational State Transfer** (REST) is an architectural style, and a approach to communications that is often used in the development of web services [30]. When web services employs the REST architecture, they are called RESTful APIs (Application Programming Interfaces).

REST typically runs over **HyperText Transfer Protocol** (HTTP), which establishes a global system for information exchange in the World Wide Web, no matter whether the resource to be exchanged is an HTML file, an image or anything else. Those resources can be identified by their URL (Uniform Resource Locator) [31].

REST is often used in mobile applications. Its style emphasizes that interactions between clients and services is enhanced by having a limited number of operations (verbs) with specific meaning, avoiding ambiguity.

- *GET* (read). Used to request information to the server, such as introducing a URL in the web browser.
- *POST* (create). Used to send information to the server, such as data collected in a form.
- *PUT* (update). Used to update information in the server, such as editing a post on a blog.
- *DELETE* (destroy). Used to delete information in the server, such as deleting a post on social media.

4.1.3 JSON

The **JavaScript Object Notation** (JSON) is a lightweight data - interchange format. It is easy for humans to read and write, and for machines to parse and generate. Although it is in a text format that is completely language independent, it uses conventions that are familiar to programmers of many other programming languages such as Java or C++ [32].

JSON is built on two structures:

- *Object*. A collection of name/value pairs.
- *Array*. An ordered list of values.

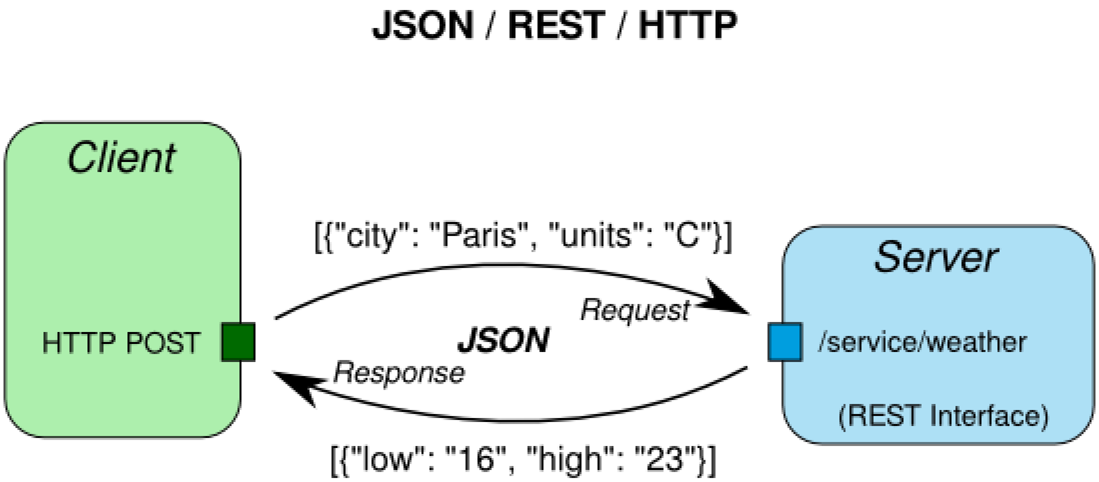

Figure 8. JSON Scheme

4.1.4 Node.js

Node.js is an open-source, server-side JavaScript interpreter. Its goal is to allow programmers to build highly scalable network applications and write code that handles tens of thousands of simultaneous connections in just a physical machine [33].

4.1.5 MongoDB

MongoDB is an open-source NoSQL (non relational) document database built in C++. Instead of storing data in tables and rows as it would be stored in a relational database, MongoDB stores JSON-like documents with dynamic schemas. The goal of MongoDB is to bridge the gap between key-values stores (which are fast and scalable) and relational databases (which have rich functionality) [34].

It has been chosen because while its schema-less design gives flexibility to the storage, enables fast access of data and makes it easy to scale; it is optimized with a deep query-ability by using a document-based query language nearly as powerful as relational databases. Moreover, it is recommended for mobile applications, content management and delivery and big data, which meets the requirements of the project [35].

4.1.6 NGINX

NGINX is a web server, free and open source software, which can act as a *reverse proxy server* (a type of proxy server, an intermediary for requests from clients seeking resources from other servers, that retrieves resources on behalf of a client from one or more servers) and an *HTTP cache* (information technology for the temporary storage).

It is one of the two most common open source web servers in the world. It has been chosen among others because it accelerates the content and application delivery, improves security, and facilitates availability and scalability on minimal hardware [36].

In *Figure 9* a graphic summary of the technologies is shown.

Figure 9. Technologies Scheme

4.2 Tools

4.2.1 Justinmind

Justinmind is a prototyping platform for web and mobile applications design. It facilitates the creation of highly interactive wireframes. It offers capabilities typically found in diagramming tools like drag and drop placement, resizing, formatting and export/import of widgets. In addition, it has features for annotating widgets and defining interactions such as linking, animations, conditional linking, calculations, simulating tab controls, show/hide elements and database simulation with real data.

It has been chosen for the graphic design of the project because, apart from its many predetermined graphic elements and its adaptation to the latest designing trends, it offers the possibility of applying functionality to the design, what is useful to see what the outcome of the application development will be [37].

Figure 10. Justinmind user interface.

4.2.2 Webstorm

Webstorm is a lightweight yet powerful IDE (Integrated Development Environment) from JetBrains, perfectly equipped for complex client-side development and server-side development. Its main advantage is the integration of Node.js, which makes it perfectly compatible with other technologies chosen for the *back-end development* [38].

4.2.3 Android Studio

Android Studio is an IDE for the Android platform. It is based in the IntelliJ IDEA software from JetBrains. It provides the fastest tools for creating applications on all type of Android devices. It includes code editing, debugging, performance tools and a flexible and instant compilation and implementation system, which allows to push code and resource changes to the application running on a device or emulator and experience them in real time. It is a custom designed tool, which translates in more productivity since the developer can write better code faster, and thus it is the perfect choice for application developing in Android. Moreover, it is built in coordination with the Android platform and supports all the latest and greatest APIs [39].

4.3 Hardware resources

For the development of the application, only a computer is needed. In this case, a laptop model HP 15-r213ns has been used. For its execution, the same laptop will be used as the server. A mobile terminal with an Android version equal or superior to version 4.1 is also needed, so a BQ Aquaris E5 HD will be used.

Moreover, one of the most controversial issue in the project approach has been to find the best option for accessing the user's information in an emergency without compromising the privacy of their data. Several options were considered, most of them involving hardware resources.

- *QR (Quick Response) Code*. It is a type of 2D bar code used to provide easy access to information through a smartphone. The information could be a unique code to identify the user and access their basic medical data. The advantages of this method is that it is economical, fast and its scanner is available for any smartphone, although it would not be easily adapted to computers. Also, it is not necessary to know the name of the patient to access the data. On the other hand it is easily replicable and, in an emergency state, the QR could be misplaced or not found. Finally, if no user registration is necessary to read a QR code from the application, it is not possible to keep record of the accesses.
- *Fingerprint recognition*. The fingerprint could identify the user and give access to their basic information, so it would not be necessary to have identified the patient either. It would be safer than a QR because it is much more difficult to replicate and it is not possible to misplace it, but the fingerprint scanners are not that common.

- *NFC (Near Field Communication) tags*. Smart little chips that allow the user to store digital information that can be read by a smartphone at short range. Once again, they are safer than QR because it is not easy to replicate them and they allow fast access too, but they are also more expensive and, again, can be easily misplaced. Although some smartphones include NFC readers, not all of them do, and it would be difficult to use the same method on computers.

	Advantages	Disadvantages
QR Code	- Economic - Available for any smartphone - Fast access - No previous identification of the patient needed	- Easy to misplace - Replicable - Not easy to read from a computer - No record of accesses
Fingerprint recognition	- Difficult to replicate - No previous identification of the patient needed	- Special scanner required for both configuration and access, not available in computers nor in most smartphones. - No record of accesses
NFC tags	- Difficult to replicate - Reader available in some smartphones - Fast access	- More expensive - Easy to misplace - Special reader required for computers and some smartphones - No record of accesses

Table 2. Advantages and disadvantages of several user access methods.

Due to all the exposed reasons, access options involving hardware were initially discarded. The option of verifying the identity of those allowed to access the information by creating the doctor user profile was finally chosen. When users register, they commit to make good use of the available information. Moreover, the record and notification of accesses allows the patient to know any consultation made to their profile. The biggest problem of this method is that it requires identifying the patient before accessing to their data, which is not always possible, so it is not discarded to improve and combine some of the presented methods in the future.

CHAPTER 5 ARCHITECTURE AND DESIGN

In this chapter the design of the system architecture, the identification of the main user actions in the application and the separation of the system functionality in modules are included.

5.1 System architecture

A system architecture is the conceptual model that defines the structure and behaviour of a system. Our system consists of three main **components**:

- *Android Client*. The user performs all interaction through a mobile application on an Android device.
- *Back-end*. It implements the necessary services for the collection, processing and synchronization of the information.
- *Database*. Stores all the information of the application.

Figure 11 represents the relationship between these components.

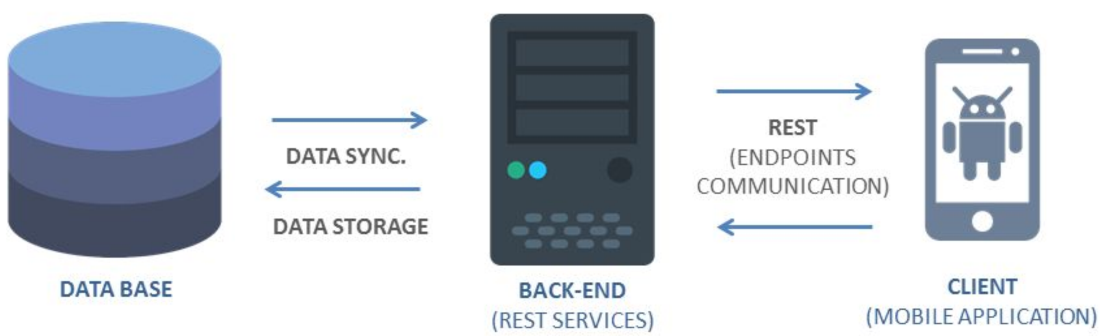

Figure 11. System architecture

5.2 System modularization

Based on the analysis of the requirements made in Chapter 3, and once a mobile device with Android Operating System has been chosen as the platform, the next step is to do a detailed design of the application capabilities.

To begin with, a compilation and classification of the possible **user actions** has been made, and it is shown in *Table 3*. They have been classified according to their performer and frequency (unique, occasional and regular).

	Unique	Occasional	Regular
Both	Registration Delete account	Log in Log out Change settings Account recovery Report an incidence Edit profile	Add, edit or remove a reminder Check timeline Check notifications in detail
Patients		Read doctor's profile Add a doctor profile to the list Edit basic clinical info Add an element to the medical history	
Doctors		Verify clinical info added by a patient Verify element added to the medical history by a patient	Read patient's profile Read patient's clinical info Edit basic clinical info of a patient Add, edit or remove an element to the medical history of a patient Verify/request to add patient profile to the list

Table 3. User actions.

All these actions that can be performed by the application are now grouped in different **modules**, taking into account that, although they have been summarized, the user action may vary depending on the performer (patient or doctor), as it has been presented in Chapter 3.

REGISTER / LOG	NOTIFICATIONS	PROFILE INFO
Registration Log in Account recovery	Check timeline Check notifications in detail	Edit profile Read profile
CLINICAL INFO.	**MEDICAL HISTORY**	**LISTS**
Edit basic clinical info Read basic clinical info	Add an element Edit an element Remove an element Verify an element (added by a patient)	Add a doctor profile Verify/request to add a patient profile

REMINDERS	SETTINGS	INCIDENCE REPORT
Add a reminder Edit a reminder Remove a reminder Verify a reminder (added by a patient)	Change settings Delete account	Report an incidence

Table 4. Modules

It has to be taken into account that this modular separation is based on the functionality of the application, not on the system architecture described in the preceding paragraph, as each module covers an requires execution on the three main components of the same one.

CHAPTER 6 IMPLEMENTATION

6.1 Developing an Android Application step by step
6.2 Basic information: definition of concrete targets
6.3 Design and layout of the user interface
6.4 Development
6.5 Quality assurance and testing
6.6 Publishing the application

In this chapter the process of developing the application for an Android platform is explained step by step, and those steps that had not been previously presented are completed, such as the gathering of the basic information, the graphic design and the development of the demo. It has to be taken into account that, since in the approach of the project both analysis and design have had priority over the development, this has not been included in the goals. Only a demo, which is not completely functional, has been developed. Thus, the sections are included as additional information to complete the development process structure, but neither testing nor the publication of the application have been carried out.

6.1 Developing an Android application step by step

Throughout the project a need has been identified, an analysis of the advantages and disadvantages of the current solutions has been made and finally the idea of an improved system has been concluded. But an idea, no matter how good it is, does not solve anything by itself. To turn the idea into a reality a series of **steps** must be followed [40].

1. *Clarify the basic information and define specific objectives of the application*

As part of the creative process, the original idea must be questioned. Both conceptual and technical questions should be posed, such as which is its target market or which technologies are going to be used. In this case, most of the technical questions have been already answered in Chapter 4.

2. *Market analysis*

It is necessary to analyze the market to check if there are already similar applications, which problems do they present and if they can be improved; or if, on the other side, the application is completely new. This analysis provides information about whether the application has already a potential market or not, if similar applications have already failed and why or whether we should raise awareness of the need or problem solved by our application in order to create a market for it.

This analysis has already been done in Chapter 2, concluding that many application exist already and are currently used in the field and the market already exists, but there are still a lot of features to improve and problems to solve.

3. *Analysis of the objectives, functional and nonfunctional requirements and restrictions*

The analysis of the features that the application should include in order to achieve the objectives, as so the restrictions it should be adjusted to, have already been done in detail in Chapter 3.

4. *Back-end design*

It includes the design of the system architecture of the project presented in Chapter 5 and the selection of the proper technologies and tools for its implementation, presented in Chapter 4.

5. *Design and layout*

All designing steps are included in this point, from the first sketch on paper to the exact replica of the application screens using digital graphic design tools, going through the choice of colors and elements that should meet the design guidelines of the selected Operating System.

6. *Development*

Once the design has been completed, next step is to plan its development and implement it. There are specific methodologies designed for software project management that can be used. Testing should also be included as a part of the development.

Once all these steps have been successfully followed, the application will be ready for its publication.

6.2 Basic information: definition of concrete targets

Clarify and model as much as possible the original idea of the application will not only help to make easier its design and the development, but also to reduce the time and costs. It is essential to stop and think about the details [41].

Some **conceptual questions** would be:

- *Which specific problem will be solved? Which need will be covered?* The main problem to solve is the accessibility of medical information in case of emergency, which implies taking care of its reliability and privacy. Additionally, other non-essential users' needs such as medical reminders should be covered in order to enhance the regular use and update of the application.

- *In which field?* The application is designed in the field of healthcare.

- *What functionality should our application have?* Its main functions should be organize and store medical information of the patients, making it accessible for their doctors. All the functionality has been analyzed in detail in the section of the functional requirements of Chapter 3.

- *What is our target audience?* The users of the application must be resident in Spain. Besides, although the ultimate goal is to cover the widest age range possible, in its first version the application will be focused on people between 18 and 55, since the 87% of them are used to using mobile applications in their daily lives, according to statistical studies [25].

And some **technical questions** would be:

- *What kind of application is?* It is a native application, which implies that it will be developed specifically for one Operating System. This type of application allows complete access to the hardware of the device and improves user experience [42].

- *On which platform is it going to be developed?* The first version will be developed for mobile platforms with Android Operating System version equal or superior to 4.1.

- *Which technologies are going to be used?* The choice of technologies is explained in detail in Chapter 4.

Once all the questions have been answered it can be determined, for example, that, regarding graphic design, the application will not need any specific adaptation because of the average age of its target market. However, the designing guidelines associated to the Operating System chosen have to be taken into account, as so it has that the application is developed for the healthcare field. On the other side, the answers also guide the design of the architecture of the system.

6.3 Design and layout of the user interface

6.3.1 Introduction to Material Design

Material Design is a design language developed by Google in 2014 with the aim of synthesizing the classic principles of good design with the innovation and possibility of technology and science, unifying experience across all kind of platforms and devices sizes. "*Unlike real paper, our digital material can expand and reform intelligently*", they said. "*Material has physical surfaces and edges. Seams and shadows provide meaning about what you can touch*". This guidelines are constantly updated as new elements and features are developed [43].

Material design is built on three **principles**:

- *Material is the metaphor*. It is the unifying theory of a rationalized space and a system of motion. The fundamentals of light, surface, edges and movement are key to conveying how objects move, interact, and exist in space and in relation to each other.
- *Bold, graphic, intentional*. The foundational elements of print-based design (such as typography, grids, space, scale, color and use of imagery) guide visual treatments.
- *Motion provides meaning*. Motion respects and reinforces the user as the prime mover. Primary user actions are inflection points that initiate motion, transforming the whole design.

As the EIRA Project is going to be developed on an Android platform, it must meet the Material Design guidelines. For that, there are some online resources that help developers. For example, in order to choose properly the principal colors, *Material Palette* [44] will be used. The **palette of colors** is generated from two main colors: light blue has been chosen as the primary color, and lime as the *accent color*. The selection of colors has been done according to the common colors used in the healthcare field. The resulting palette can be observed in *Figure 12.*

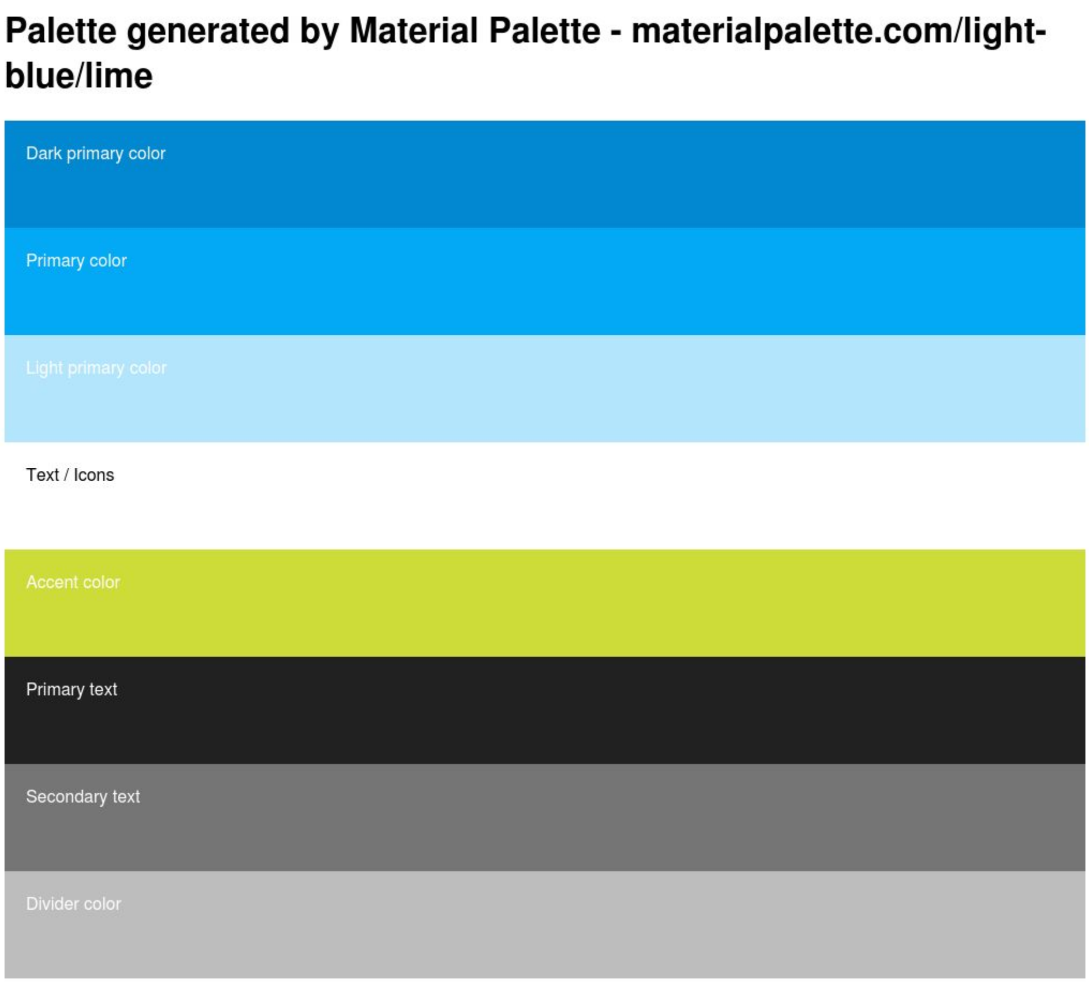

Figure 12. Material Palette

Finally, by using *Justinmind* designer tool for the next section, the correct choice of elements and structures is ensured.

6.3.2 Wireframes

A **wireframe**, also known as a page schematic or screen blueprint, is a visual guide that represents the skeletal framework of a website or application. *Justinmind*, the tool chosen for the design of the wireframes, includes color guides and default font and items that guarantee that the Material Design guidelines are followed. In this section some examples have been included in order to illustrate the style chosen for the layout of the application.

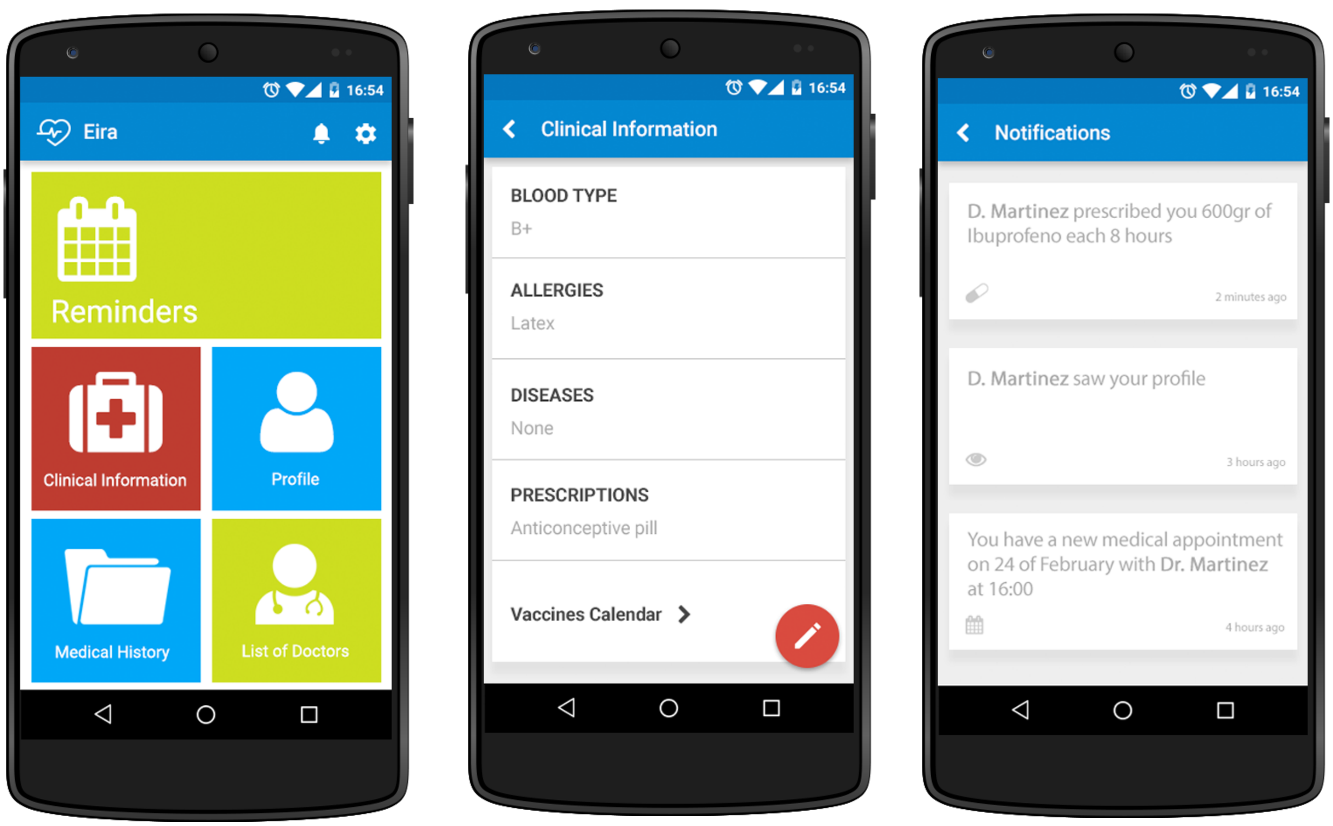

Figure 13. Wireframes

6.3.3 Storyboard

In parallel to the designing of the wireframes, the relationship between the different modules defined in Chapter 5 must be established. To this end, a **storyboard** is built. In the field of mobile applications, storyboard is a graphic organizer in form of images displayed in sequence for the purpose of pre-visualizing an interactive media sequence. In this case, a simplified graph showing the relationship and interaction between the different modules where the possible user actions of our system are grouped has been created. Since the system distinguish between two type of users, both have been represented. Storyboard for patients is shown in *Figure 14*.

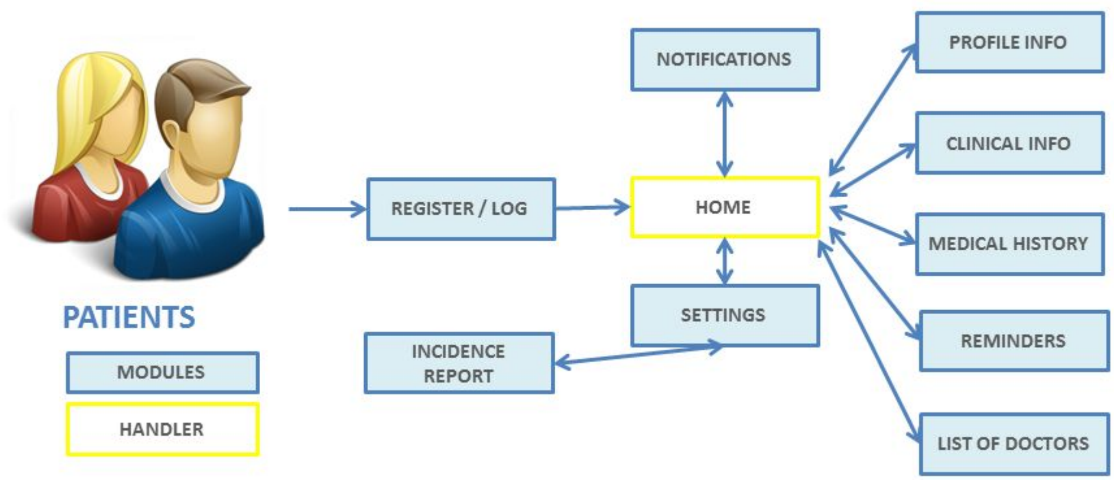

Figure 14. Storyboard for patients

Storyboard for doctors is shown in *Figure 15*.

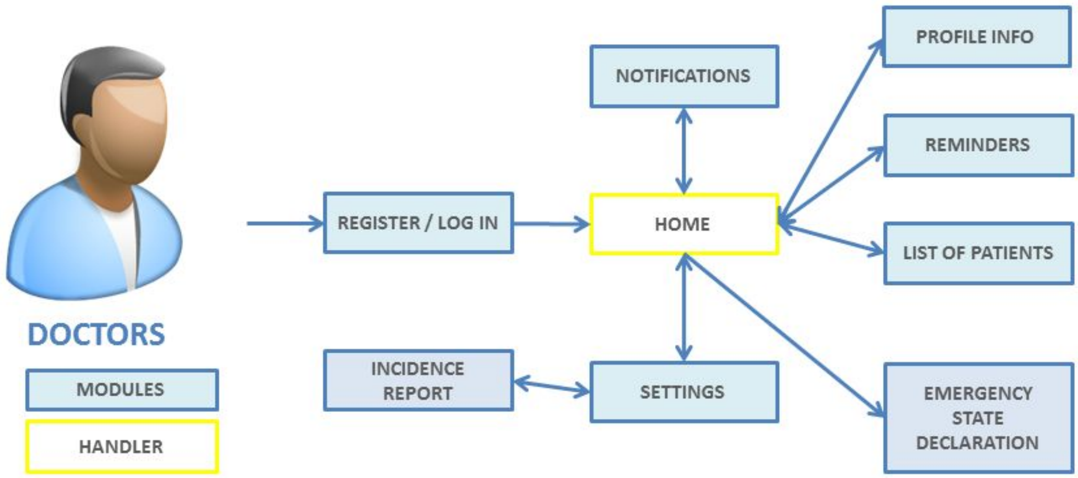

Figure 15. Storyboard for doctors.

6.4 Development

The development of the system is not contemplated in the goals of this project. Thus, the implementation has been reduced to a semi-functional demo. Regardless, in this section the following steps to perform the full implementation of the design are listed in order to complete the project planning.

Since it is a modular and multifunctional application, its development should be divided into different stages, for example by applying the **SCRUM methodology**. It is a project management system that relies on incremental development. That means that, whereas other project managements methods emphasize building an entire product in one iteration from start to finish, scrum methodology focuses on delivering several iterations of a product to provide stakeholders with the highest business value in the least amount of time possible, developing functionalities in order of priority. Each iteration consists of two to four week sprints [45].

This methodology has several **advantages** for our project. First, it encourages products to be built *faster*, since each set of goals must be completed within each sprint's timeframe. However, its greatest benefit is its *flexibility*, as dividing the project into sprints allows receiving feedback from stakeholders every two to four weeks, so the development of the application can be easily and quickly adjusted to patients' and doctors' opinion and necessities.

First of all, a product backlog has to be established. The **product backlog** is a list of features or technical tasks which are known to be necessary and sufficient to complete the project. In the scrum methodology, it is comprised of **user stories**. A user story is a tool used to capture a description of a software feature from and end-user perspective. It helps to create a simplified description of a requirement. Large user stories are known as *epics*, which may be decomposed into user stories as they near implementation. Then, tasks in the backlog should be prioritized and the most important one should be chosen as the target backlog of the current sprint. [46]

Applying this to our project, separation into modules could be considered as our epics listed in our product backlog. Thus, our target backlog for the first sprint could be the epic *Register/Log*, which functional requirement would be that the user has to be able to register and access to his/her account. Within this epic, several user stories can be found: *register for patients, register for doctors*, *identity verification*, *login* and *account recovery*.

Each user story is in turn divided into **tasks**. For example, tasks for *register for patients* would be:

1. *Design and implement the interface*. For this user story, only one activity has to be implemented. An activity is an android application component that provides a screen with which users can interact in order to perform some action. It consists of a java class, where functionality is programmed, and an XML file, where its graphic interface is modeled.
2. *Add a document to the database for user data*. As specified in Chapter 3, user data for patients include name and surname, ID number, email and password.
3. *Develop a service for the register in the back-end*. A REST service will be implemented using Node.js technology, so the application can make the corresponding requests. In this case, a POST request would be required to create the user by adding his/her user data to the database. The service will receive the data sent from the application and prepare it for its insertion into the database.

This first sprint would include all the tasks disaggregated from the user stories contained in the epic. The timeframe for its implementation should be established between two and four weeks. After fulfilling the goals and receiving feedback from the stakeholders, the product backlog would be updated and the target backlog and timeframe for the next sprint would be established.

6.5 Quality assurance and testing

Quality Assurance (QA) is the set of activities designed to ensure that the development and the maintenance process are adequate to guarantee that the system will meet its objectives. These activities include **software testing**, the process of implementing a system with the intention of finding defects; and **usability testing**, a technique used in user-centered interaction design to evaluate a product by testing it on users [47].

These processes are part of developing an application. In this project they have not been executed because the demo does not have full functionality implemented and cannot be tested, but they are included as part of the planning of the system development.

6.5.1 Mobile application testing

Mobile application testing, a specific type of software testing for mobile applications, is the process by which application software developed for handheld mobile devices is tested for its functionality, usability and consistency. It can be automated or manual type.

According to a recent survey, only 16% of users try out a failing app more than twice and around 80% of downloaded apps are eventually deleted due to poor performance. In this digital, 'always-on' world, the quality and performance of mobile apps have become critical, like never before. As consumers expect developers to provide responsive and seamless experiences anywhere, anytime, and on any device, the focus on mobile testing is rising. There are several factors that can contribute to our application failure, and these are what must be identified and solved, they are the **key challenges** of mobile application testing [48].

- *Multiple devices, platforms and versions*. It is not only about choosing the Operating System. With new launches and upgrades come various versions, different screen sizes and umpteen compatibility issues, and developers and testers strug to keep up this.

- *Real-time, anytime and offline*. Apart from the hardware and software issues, the performance of carrier's network can have a huge impact on the functionality of the app. Be it 3G, 4G or 5G, Wi-Fi users expect apps to work flawlessly. Some apps are expected to work the same in no-network condition, too. The connection APIs are designed after considering these factors, but the real world environment can have its own daunting set of issues. In an application whose main objective is to provide access to health data anytime and anywhere, especially in emergencies in which life runs against time, ensuring connectivity is essential.

- *Securing the data*. With a huge amount of personal and critical data being stored and shared, data security has become an inevitable part of mobile testing. Apps are prone to several security trespasses and hence require continuous monitoring and severe security testing.

The challenges of mobile testing are unique and so is the solution which is an amalgam of tools, platforms, frameworks and people; striking the right balance between cost, quality and time-to-market.

6.5.2 Usability testing

Usability testing refers to evaluating a product or service by testing it with representative users. Typically, during a test, participants will try to complete typical tasks while observers watch, listen and takes notes. The goal is to identify any usability problems, collect qualitative and quantitative data and determine the participant's satisfaction with the product [49]. **Benefits** of usability testing include find out how satisfied participants are with the application, identify changes required to improve user performance and identify how easily and how long it takes for users to complete specified tasks.

In order to develop and implement the application successfully, and optimize the time invested in the process, user tests should be part of the development process from the beginning. In this project, an interactive demo with basic functionality has been developed so, before proceeding with the code, both the design of the user interface and the basic features chosen should be tested.

To run an effective usability test, the first step is to develop a solid **test plan**. An example of a test plan for patient users of this project is shown in *Figure 16*.

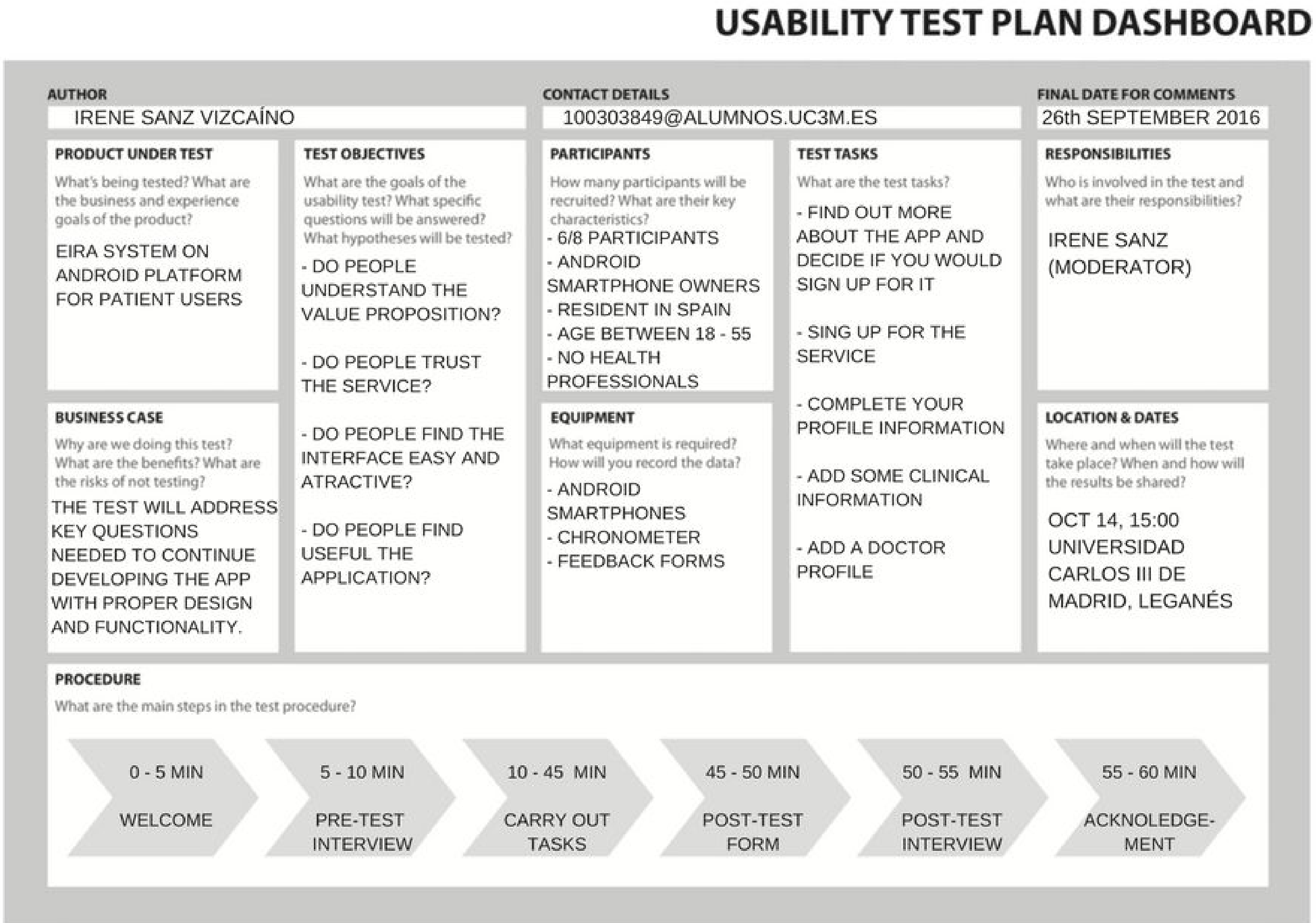

Figure 16. Usability Test Plan Dashboard for EIRA Project following David Travis' method

It has to be taken into account that as important as a good previous planning is the subsequent reporting and analysis of the results.

6.6 Publishing the application

This section includes a brief summary of the factors to consider when publishing an application as additional information in order to complete the step by step planning, taking into account that it is not part of this project goals, although it could be in the future.

6.6.1 Creating an Android Developer account

To be able to publish applications on Google Play, the main application store for Android, it is necessary to have a developer account. The first step to do it is creating a Google account in Gmail and access the Google Play Developer Console. Then, a 25$ (22.41 €, as of 18 September 2016) registration fee has to be paid. Once it has been paid, the full functionality of the Google Play Developer Console, the management and information center for developers, can be accessed. Here, different sections such as list of applications, report of benefits, configuration or advertisements, are displayed, and new applications can be added.

6.6.2 ASO (Application Store Optimization)

According to a study made by the consulting and visual communication agency Neo Labels, only in Spain 3.8 millions of applications are downloaded daily [50]. In addition, there are 2 millions of applications currently offered in the stores, and more than 2,000 new applications are uploaded every day. These applications are found by users through the searching tools in the applications stores, so optimize this system has become a critical point for developers [51].

That is the purpose of the Application Store Optimization, optimizing a mobile application to enhance its visibility and increase its downloads. Like any other Search Engine Optimization (SEO) process, ASO includes selection and use of keywords. Thus, the keywords that a user introduces when searching to find an app are identified, aiming to appear above the competition in search results.

In order to optimize an application at the time of publishing it what are known as **ASO on metadata factors** must be considered. These include: *title*, *icon*, *description*, *screenshots*, *keywords* and *category*.

How the EIRA App would look like in Google Play is shown in *Figure 17*.

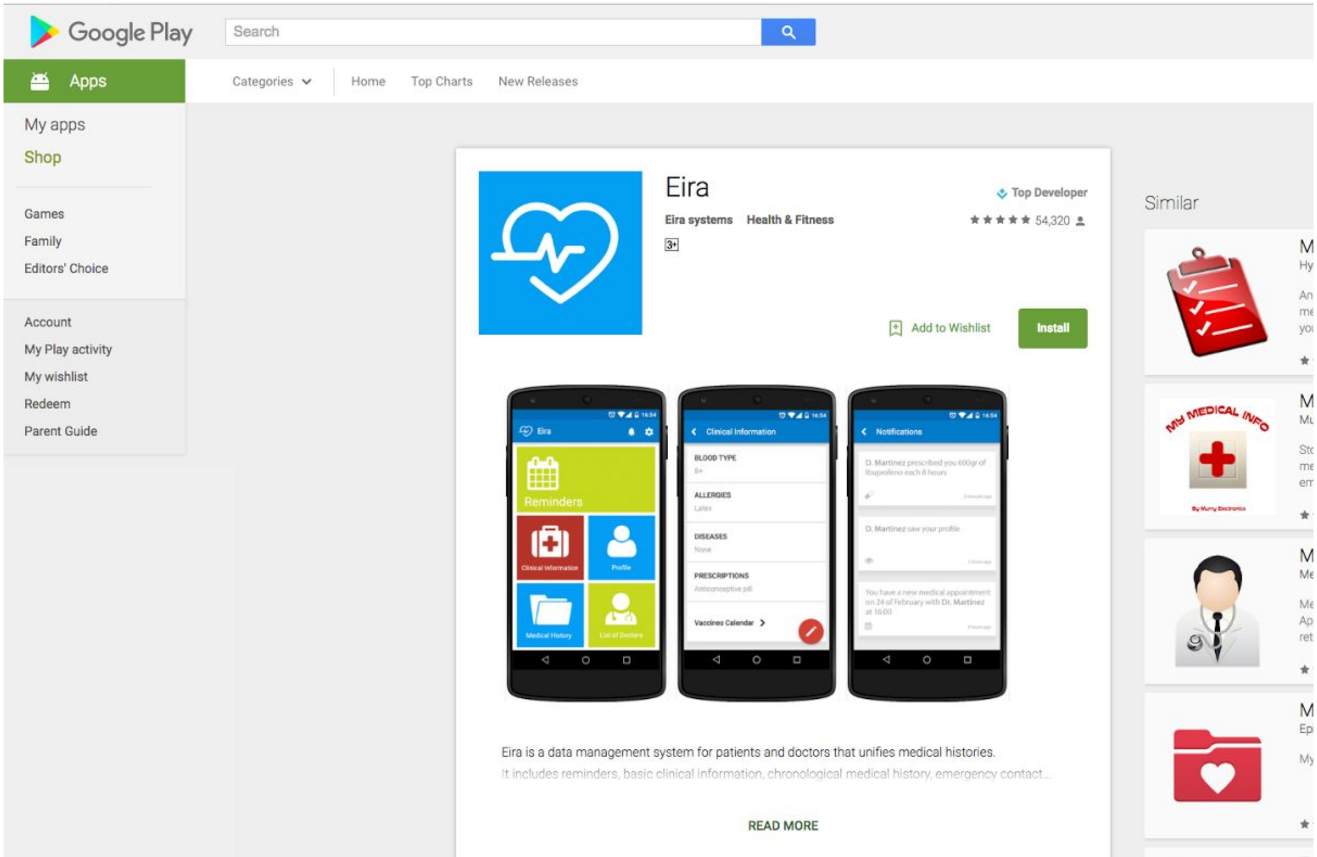

Figure 17: Screenshot EIRA in Google Play

Once the application has been already published, **ASO off metadata factors** can be also considered. Most of this factors are applied when promoting the application through different online channels, such as social media or websites. For example, creating a *landing application,* which means linking the downloading page of the application from other websites, or *link building*, sharing in different platforms links to our website or directly to the application downloading page. Other influencing factors are *reviews*, *number of downloads* and *comments* in the app store [52].

6.6.3 APK (Android Application Package)

The Android Application Package file is the package file format used to distribute and install application software onto Google's Android operating system, with the filename extension *.apk*. This file can be obtained from *Android Studio* by compiling the already developed code of the application. Then, all of its parts are packaged into one file. An APK file contains all of that program's code, resources, assets, certificates and manifest file. When users download and install an application from Google Play, they are downloading and running the APK file.

CHAPTER 7 SOCIO-ECONOMIC FRAMEWORK

In this chapter the business models that exist in the field of mobile applications are discussed, including the possibilities for monetizing the EIRA Project. In addition, the costs of the project, the estimated budget for its full development and the factors to take into account for its maintenance and scalability in its growing process are presented.

7.1 An introduction to the market

The mobile applications market is booming. The number and variety of mobile devices, as well as their affordability, are growing daily, meeting thousands of needs that people did not even know they had. That is why more and more developers decide to join this trend. However, it is not enough to know how to develop an idea, no matter how good it is, if it does not reach the users. Effective promotion and choosing the proper business models are also essential.

Currently, there are several possibilities when it comes to **monetizing** mobile applications:

- *Pricing the application*. Selling the application is the simplest way to make money, but it could not be the most effective. Given the amount of supply of free applications, users are often reluctant to pay for them, especially if there is no trial version to try it before buying.
- *Freemium*. The term freemium is coined using the words free and premium. It is a business model in which the core of the product is given for free to a large group of users and the premium products are sold to a smaller fraction of this user base.
- *Purchases within the application*. Offering intangible products is a very common for games, since it is based more on the addiction than on the usefulness of the content.
- *Advertising*. In this model the application is free for users but it contains advertising. The developer's earnings depend on the fee per click established and the times users click on the advertisement.
- *Installation cost*. Similar to the advertising model, as other applications are promoted, but this time the fee established is per installation.
- *Sponsorship*. Making a sponsorship agreement with company could be a win to win method if, apart from making money from promoting the company, it is possible to benefit from its brand name to increase the popularity of the application [53].

It is not easy to develop an application and make money from it, but it is entirely possible. The secret is to choose the right business model for the type of application offered and ensure that it will have visibility.

7.2 How to monetize the EIRA Project

The EIRA Project application meets a basic need and aims to reach the largest possible number of users. Therefore, no funding model in which the user has to pay for basic services could be valid, so pricing the application is completely discarded. Moreover, there is no way in which introducing in-app purchases can meet the project requirements, so the option is also discarded.

In any case, there are still a few ways in which the application could be monetized, also helping to fulfill the project objectives.

- *Advertising* and *installation cost*. Currently, on the market, there are many health applications oriented to specific communities, such as patients diagnosticated with a concrete disease. Since the data of the diagnosis and treatments of the users is updated on the EIRA platform, these applications could be recommended through it to specific groups of interest with a high probability of success, making them more accessible to those who may need them. Moreover, only applications that meet regulations and standards of utility and quality would be accepted in the platform, so it would be another measure to guarantee the quality of the applications in the field.

- *Freemium*. Although the basic functionality of the application, such as medical data storage, must be free for all users, a modular design would allow to create non-essential premium functionalities too.

- *Sponsorship*. A partnership could be interesting for some companies in the field.

There are some non conventional methods that could be sources of funding for the project:

- *Public funding*. Applying for public funding could be a possibility to financiate the development.
- *Big Data*. The enormous amount of medical data that the application could collect, properly anonymized, could be statistically analyzed, sold or used to develop other tools for aiding in the clinic decisions making process.

7.3 Budget of the project

The total budget of the project comprises the direct cost of human resources and hardware and software resources, as well as indirect costs.

7.3.1 Personnel costs

In order to estimate the personnel costs it is assumed that the project is carried out as a full-time job. Thus, following data are taken into account:

- Total duration: 18 ECTS · 30 hours = 360 hours
- Current salary: 1500 per month
- Working time: 40 hours per week

Thus, rounding to 4 weeks per month:

$$Personnel\ costs = \frac{Total\ hours}{Hours\ per\ week} \cdot \frac{Salary\ per\ month}{Weeks\ per\ month} =$$

$$\frac{360}{40} \cdot \frac{1500}{4} = 3.375\ €$$

The final result is **3,375 €** for personnel costs.

7.3.2 Equipment costs

The costs of the **hardware resources** are estimated based on its amortization, according to the following formula:

$$Equipment\ amortization = \frac{A}{B} \cdot\ C \cdot D$$

Where:

- A = number of months since the billing date in which the equipment is used.
- B = depreciation period (in months)
- C = cost of the equipment (without VAT)
- D = percentage of use dedicated to the project

Resulting costs can be observed in *Table 5*:

Resource	A (months)	B (months)	C (€)	D (%)	Cost
Laptop	12	48	867	20	43.35 €
Smartphone	12	18	205	10	13.67 €
Total	-	-	-	-	**57.02 €**

Table 5. Amortization costs.

Moreover, although most of the **software resources** used are free, the developer license fee has to be included. It costs 25$, **22.41 €** (as of 18 September 2016).

7.3.3 Total costs

Total costs of the project are computed in *Table 6*:

Category	Costs
Personnel costs	3,375 €
Hardware resources	57.02 €
Software resources	22.41 €
Total	**3,454.43 €**

Table 6. Total costs.

7.4 Development and scalability

7.4.1 Development costs

Since during the project most of the time has been spent meeting the goals of analysis, learning and design and, on the other side, only a demo of the application has been created and the development itself has not been concluded, the budget of the project does not include it. Thus, an online calculator is used to estimate the costs of the development [54].

Defining the application as an Android application already in development, with a simple interface design, monolingual, with users' profile and login functions and good quality-to-price ratio, the given estimation price for its development has been: **6,800 €**

7.4.2 Scalability and maintenance

Before concluding this chapter, it has to be taken into account that costs of an application go further than its developing. It is difficult to do an accurate estimation because all the following **maintenance duties** should be considered [55]:

- *Correct problems and errors reported by users*. Although the developing process of an application includes testing, it is usual that some errors still happen.
- *Increase functionality depending on users' demand*. Improving and increasing functionality are keys to success.
- *User support*. Being an application oriented to the healthcare field, customer service is essential.
- *Hosting and administration*. Being an online application, the project needs hosting and administration services to ensure its accessibility and store the data.
- *Expansion*. If the project grows, in addition to all the duties, additional servers or optimization of the code could be required.

Most of these duties depend directly on the popularity and, thus, the volume of users of the application. Although costs can not be estimated, all of them must be included in the process of growth and expansion.

CHAPTER 8 FUTURE WORK

In this chapter both the remaining steps for the developing of the application on an Android platform and possible future improvements for the EIRA system are listed and briefly explained. Next steps towards its commercialization are also included.

8.1 Full development of the project

Since the project has focused on analyzing the current situation and designing a unified system able to solve the identified problems, as well as in the selection of the most appropriate technologies for its implementation, there is still work to do in terms of development. This would include the *development* of the first fully functional version of the application for the Android platform, based on the design and on the planning, presented step by step in Chapter 6. *Quality assurance and testing* procedures are also included in this section.

8.2 Future lines of technical development

There is still a long way to go in the design and development of the perfect healthcare data management system. **Future lines** are presented around three main objectives:

1. *Enhance accessibility*

Although the designed system has implied a great improvement over the currently in use systems, it is not enough. Accessibility is the pillar on which this project has been developed. First, to ensure the availability of the information in any situation or context, and second, to make the application reach and be usable for the largest number of potential users are the main priorities. Some measures that could be taken are:

- Develop the application on more *platforms*. For example, in addition to Android, a website or an iOS application could be implemented.
- Increase the number of *forms of access* to the user account or information. As discussed in section 4.3, other forms of access apart from the name could be implemented, such as fingerprint recognition or NFC tags.
- Translate the application into *several languages*. This would be the first step to explore the possibilities of internationalization of the service.
- *Increase the age range of the target audience*. Initially it has been established between 18 and 55 years old, but designing adapted interfaces for elderly people or implementing a family account management system this range could be expanded.

2. *Improve and increase functionality*

The features and capabilities chosen in the designing process of the first version of the system have only include basic functionality. The set basis offers many more possibilities, such as:

- *Speed the information searching process* within the application. For example, implementing thematic filters and searching boxes, or using voice recognition system.
- *Increase the amount of collected data*. There are still many types of data that have not been covered by the application and that could be useful, such as family relationships between the users, which could lead us to find genetic patterns in the diagnosis of diseases.
- *Add service modules to the application*. For example, it would be useful for doctor users that the application could detect incompatibilities between specific medicines and the patient's profile to which it is prescribed (allergies, other already prescribed medicines, etc). On the other hand, it would be useful for patients including automatically generated reminders for vaccines or for scheduling medical reviews if their profile indicates that they may be at risk.

3. *Become compatible with other applications in the field*

Both oversupply and incompatibility of IT tools in the field of healthcare were among the reasons that prompted the development of this project. However, this problem has not been solved yet. The signing of cooperation agreements with other applications in the field and being able to import and process their data is a fundamental step in the unification of healthcare services, and it would represent significant savings of time and resources for health providers.

8.3 Promotion and commercialization

Once the development of the first version of the application has been completed, and in parallel to the implementation of the technical advances, **promoting** the application must gain prominence. Users are the key to success of this system. In order to grow, *agreements with health centers* must be signed and the advantages of the application must be directly presented to the doctors, becoming word of mouth doctor-patient the most important spreading channel. Moreover, other *online and offline marketing*, such as social media or media advertisements, resources should be also used as a complement.

Once a representative number of users is reached, it becomes possible to make the leap to *big data* analysis, processing and profitability. As explained in Chapter 7, the use of collected data for the development of tools to aid clinical decision making is one of the ways of business with more long-term potential. Other possibilities for **commercialization** of the application are the inclusion of *premium services* or *advertising*.

CHAPTER 9 EVALUATION AND CONCLUSIONS

In this chapter a global review of the project is given, the fulfillment of the goals is analyzed and the main difficulties encountered during its development are presented. Furthermore, final reflections on the evolution of the project from the original idea until today, advances that its implementation would involve in the field and the work that remains to be done are included.

For the development of this project 3 **main goals**, presented in section 1.2, were established. First of all, a wide analysis and test of the current situation in the field of IT tools for healthcare has been performed, including classification, advantages, disadvantages and main problems to be faced. Thus, the *first goal*, getting to know the types and performance of currently used IT tools for healthcare management, has been successfully fulfilled. Then, according to the conclusions drawn, statements, requirements and restrictions for the system were defined, and its architecture, modular structure, graphic design and development planning were performed, fulfilling the *second goal*, designing a system that responds to the identified necessities. Finally, a selection of tools and technologies for the development was carried out, defining their role in the project. Also, in parallel, an Android Development course was attended. In order to develop the demo for the application, an external tool was used. Therefore, the *third goal*, learn about IT tools developments and implement a demo of the project has been fulfilled too.

In addition, 2 **secondary goals** were also established. While developing the socio economic framework, business models in the field and business opportunities for the projects, so the *fifth goal* was met, learning about the business performance in the field and design a sustainable business model for the project. However, when it comes to the *fourth goal*, explore the impact and the possibilities of big data techniques in healthcare, results have not lived up expectations. The original idea of the design was intended to assume greater innovation in technology advances, even incorporating artificial intelligence and massive data processing applied to the healthcare field. However, from the analysis it was concluded that, before incorporating such technologies, a solid groundwork should be laid, a system able to collect all the relevant data to work on them later. Thus, the design was finally oriented to a simplified, unified, bilateral, multifunctional accessible and secure system. Although big data techniques have not been finally incorporated to this first design of the project, they are still a key elements in its future lines and business opportunities.

I am globally satisfied with the performance and the results of the project. However, I believe that the work done should not end here. The positive impact on the society and the possibilities that could imply bringing this projects to success make it worthwhile.

Since the beginning of times, human being has improved technologies that allow communication between individuals and information sharing, as the main way of perpetuating the knowledge of the specie. In our era, a simple in concept but sophisticated in implementation, first communication between two computers supposed a landmark. Nowadays, where millions of connections are done with the only purpose of obtain and create information, the named as Information Technologies has democratize access to knowledge. Constantly we are exploring new ways of make use of Information Technologies as a factor that carry out to stand out our daily activities. In the field of healthcare, without hesitation, information systems that organize in a useful way healthcare data and perform a proper analysis, will conduce us progressively to a deep knowledge in the health discipline. Only we must keep in mind that magic does not reside in computers, by themselves doesn't know how to serve us in the most proper way: we must work in improve our abilities and techniques with the objective of shape systems to our most ancient and primary necessities as specie. This is just the beginning.

"Computers ares useless,
they can only give you answers."
- Pablo Picasso

GLOSSARY

- **ACTIVITY:** component of an Android application that reflects an activity carried out by the application and which typically has an associated user interface.
- **API (APPLICATION PROGRAMMING INTERFACE)**: set if calls that give access to functions and procedures, representing an abstraction layer for the developer.
- **ASO (APPLICATION SEARCH OPTIMIZATION)**: is the process of improving the visibility of a mobile application in an application store.
- **E - HEALTH**: healthcare practice supported by electronic processes and communication.
- **HTTP (HYPERTEXT TRANSFER PROTOCOL)**: web application level protocol designed by W3C that follows a request-response pattern between a client and a server.
- **IDE (INTEGRATED DEVELOPMENT ENVIRONMENT)**: is a software application that provides comprehensive facilities to computer programmers for software development.
- **JSON**: lightweight data interchange format.
- **LAYOUT**: XML files that define the visual structure of the user interface of an Android activity.
- **M-HEALTH**: sub-segment of e-health that consists of the practice of medicine and public health supported by mobile devices.
- **OS (OPERATING SYSTEM)**: is a system software that manages computers or mobile devices hardware and software resources and provides common services for applications.
- **REST (REPRESENTATIONAL STATE TRANSFER)**: architecture for designing communications among web applications based on the HTTP protocol.
- **RESTFUL**: term used on an API that follows REST architecture.
- **SDK (SOFTWARE DEVELOPER KIT)**: set of tools that allow a developer to create applications for a specific platform or language.
- **SEO (SEARCH ENGINE OPTIMIZATION)**: Area of website development that seeks to improve the way content is ranked by search engines in organic search results.
- **SMARTPHONE**: mobile device that represents the evolution of mobile phones by integrating a computer and other features.
- **STAKEHOLDER**: an accountant, group or system that affects of can be affected by the project.
- **STORYBOARD**: is a graphic organizer in the form of illustrations or images displayed in sequence for the purpose of pre-visualizing a motion picture, animation, motion graphic or interactive media sequence.

- **W3C (WORLD WIDE WEB CONSORTIUM)**: international association that work to develop web standards.
- **WBS (WORK BREAKDOWN STRUCTURE)**: in project management and system engineering, it is a deliverable-oriented decomposition of a project into smaller components that organizes the teamwork into manageable sections.
- **WEB SERVICE**: facilitate the interoperability among systems independently of the language or platform they are develop in.
- **WI-FI (WIRELESS FIDELITY)**: standard for sending data that uses radio waves instead of wires.
- **WIREFRAME**: A sketch or graphical representation of the layout or structure of a website or app.
- **XML (EXTENSIBLE MARKUP LANGUAGE)**: standard language that, by means of tags and attributes, allows to express and easily transmit data structures.

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APPENDIX A INTERVIEWS

The aim of the project is to get to know and improve IT systems created for doctors and patients, find their advantages and disadvantages and create an improved system based on the conclusions of the analysis. Thus, an essential part of analysis of the current situation is to interview stakeholders.

In interviews with doctors the following issues have been raised:

1. **Information of the interviewed**: speciality, health center, years in the profession.
2. **Daily data management**. Currently used data management methods.
3. **IT tools**. Applications currently in use in the center.
4. **Evolution**. Opinion on the application of new technologies in the health system, improvements they have led and things still to improve.
5. **Information about the patient**. Data that would be useful to know of the day by day of the patient, important data in case of emergency, interesting data for identifying patterns and generating statistics.
6. **Medicines**. Criteria used to prescribe medicines.
7. **Further comments.**

Interview #01

1. A doctor specialized in Family and Community Medicine from Centro de Salud Fuentelarreina, Madrid. He has been in the profession for 25 years. Interviewed on the 17th March 2016.
2. He manages his daily data through the local health center computer system, called AP-Madrid.
3. Applications currently in use in the health center are:
    - AP-Madrid. Management tool for medical records in primary care.
    - UpToDate. Medical database for aiding in the process of clinical decision making. This resource is included in the Virtual Library of the Ministry of Health of Madrid, a digital knowledge space that facilitates library services and scientific resources for public health professionals in Madrid.

- Horus. Medical information from local center networks is shared through Horus in PDF format. One interesting point about Horus is that it has a digital print of accesses to the system to ensure patient privacy.

Other interesting tools used in new public hospitals in Madrid:

- Selene. Unification of medical histories of the public hospitals in the region.

4. When he started working as a physician, all the information was handled in paper. Patients had to take their own information if they wanted to go to a different center. In 2005, computers started to be used. In 2010, AP Madrid was implemented, so health centers (not hospitals) from madrid could share information. In 2012, they started to use UpToDate. In 2013, Horus was implemented. Although the platform is based on static format (PDF) and data can not be manipulated, making it accessible for all the public health centers and hospitals in the region was a great advance.
5. Daily information from the patient that can be useful include smoking and physical activity habits, weight, height and familiar relationships. In case of emergency, interesting medical data would include: blood type, allergies, chronic or current acute diseases and treatments, past surgery (specially implants), and vaccines. In addition, it could be interesting to know their advance directives.
6. He prescribes medicines by active ingredient, not by brand.
7. Some ideas to include in the project could be emergency contact data and alerts. The application could be used also to monitor that the patient follows medical prescriptions. Regarding medicine prescriptions, it would be useful to detect contraindications contrasting patient information (allergies, other treatments, current diseases..).

Interview #02

1. A doctor specialized in allergology from Hospital Henares of Madrid. She has been in the profession for 26 years. Interviewed on 12th April 2016.
2. She manages her daily data through the local hospital computer system, Selene.
3. Applications currently in use in the hospital are:
    - UpToDate and Finisterra (similar platforms but the first is American and the second one is Spanish). Both are included in the Virtual Library of the Ministry of Health of Madrid.
    - Selene. Its aim is to unify the information of medical histories of the public hospitals in the region. However, the system is not optimized. Its interface is not intuitive enough,

and it takes more time that it should to perform regular tasks. Moreover, the system has functionality that she still does not know how to use. Doctors should be trained regularly to make the most of the possibilities of the system.

- Horus. It is a visual system, easy to use.
- Institutional email. Updates and news of the hospital.

4. Medical information was handled on paper until Selene was implemented in 2008. One thing to note from the interview: People are not always favorable to the integration of new technologies, especially those who have been in the profession for a long time. Therefore, although an update in medical technology resources is needed, doctors have to be taken into account in the design of simple, useful and intuitive tools, and they should be trained in their use too. Technology must not be an additional complication, and it must not take additional time either.
5. As in the previous interview, in case of emergency, interesting data would include: blood type, allergies (to medicines, food or materials that could be included in medical devices), chronic or current acute diseases and treatments (including prescribed medicines and intake times), past surgery (specially implants), and vaccines. In addition, it would be interesting to have a customizable space to add specific observations for the patient.
6. The criteria for prescribing medicines follows: effectivity, intake system and price. No brand influences.
7. An idea to include in the project would be the concept of familiar accounts, so that the information of children or elderly people can be managed by their relatives.