ISR Institute for Software Research
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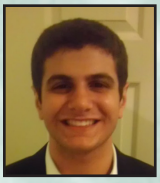
Project Cognatio: Developing a System for Medication Adherence (Evaluation of Requirements Engineering for Sustainability)



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Abstract

Sustainable development means that the present generation can meet its own needs without jeopardizing the ability of future generations to do the same. This concept applies to many subjects including software engineering. Developing sustainable software must begin with the first stage of the software engineering process, requirements engineering (RE). RE is the elicitation and specification of a software system's requirements that are agreed upon by all stakeholders. These requirements must be addressed and adhered to throughout the entire software engineering process. RE answers the general question, "What should this software system do?" RE for sustainability outlines the process of RE while taking steps to make the system more sustainable. This process answers the question, "What should this software system do, and how will it contribute to overall sustainability?" The goal of this report is to present and analyze how the consideration of sustainability impacts the entire requirements engineering process for a software system. The examined system is known as Project Cognatio and is targeted toward outpatient medical practices with the goal to improve medication adherence among patients. In this project, we found that a number of artifacts must be adjusted in order to consider the dimensions of sustainability. In the future, this analysis will also prove useful for the consideration of sustainability for future steps in the software engineering process for Project Cognatio.

1. Introduction

Over the past century, human innovations have sadly started to erode certain aspects of our planet. But for the past few decades, industries, corporations, and governments have taken steps to be more sustainable and maintain resources for future

generations. One way they have been doing so is through the sustainable development of technology. Sustainable development highlights the ability for the present generation to meet its own needs without jeopardizing the ability for future generations to do the same. Technology has the ability to enhance all five dimensions of sustainability. They are defined as:

- *Human sustainability:* the maintenance of human capital. Health, happiness, education, etc.
- *Social sustainability:* the maintenance of social capital and services.
- *Economic sustainability:* the maintenance or improvement of economic status
- *Environmental sustainability:* the preservation and protection of the environment when utilizing its resources.
- *Technical sustainability:* the improvement and maintenance of the longevity of systems in a rapidly changing technological environment (Raturi *et al.,* 2014).

Technology is only as good as its software, and both can make huge contributions to each dimension of sustainability. To develop software, one would need to follow the software engineering process. It consists of four iterative and integrated steps to develop a stable system. They are (1) requirements engineering (RE), (2) design and implementation, (3) testing for fulfillment of requirements, and (4) deployment, maintenance, and enhancement. By developing what is known as sustainable software, certain alterations may need to be made in the software engineering process.

The purpose of this study is to analyze how the RE process would be altered by the consideration of all five types of sustainability. This is known as RE for sustainability. Ordinary RE is defined as the elicitation and specification of a software system's requirements that are agreed upon by all stakeholders. The specified requirements must be addressed and adhered to throughout the entire software engineering process. RE answers the general question, "What should this software system do?" When performing RE for sustainability, this question is altered, asking "What should this software system do, and how will it contribute to overall sustainability?"

The model of RE that will be followed is the RE4S (Penzenstadler, 2014) using the Artifact Model for Domain-independent RE (AMDiRE) (Fernandez *et al., 2014*). It utilizes the creation of multiple diagrams and documents to thoroughly specify and analyze the requirements of a software system. Presented in this report are the methods utilized when analyzing the requirements of the software system, a description of the software system itself, and the full requirements specification that follows the AMDiRE model.

2. Background

2.1 Materials and Methods

The elicitation of requirements was done by exclusively interviewing a doctor and other members of his medical practice. Dr. Don Mehrabi M.D. was available for interview to give feedback on a potential software system that would be used to improve medication adherence for his patients. Meeting with him biweekly proved to be easiest and beneficial to develop and review requirements for the system.

Each modeled artifact was developed using Cacoo, a web-based diagramming tool, and Microsoft Office for other documentation. Each artifact was reviewed by requirements engineering experts, Dr. Debra Richardson and Dr. Birgit Penzenstadler, a sustainability expert, Dr. William Tomlinson, and Dr. Don Mehrabi to verify if the requirements were coherent and consistent with the desired system. They were then altered and amplified to fit the desired requirements and specific software engineering standards.

2.2 Project Cognatio

2.2.1 Description and Purpose. Project Cognatio is a two-tier system that relies on a mobile application to be used by medical patients and every day consumers and a desktop application to be used by medical practices. The overall goal of this system is to improve medication adherence among patients.

Medication adherence is known to be a common problem among medical patients who do not feel it is entirely necessary or forget to take their medication as it is prescribed. There are many factors that cause this, but the aim of Project Cognatio is to eliminate those factors and to encourage patients to better adhere to the directions of their prescriptions. The system depends on collaboration between employees of the medical practice and the patients themselves in order to achieve the desired goal.

2.2.2 Features. The most fundamental feature of this system is its ability to exchange information between the mobile application and the desktop application via the Internet. The mobile application relays patient activity to the desktop application that will be viewable by members of the medical practice. The desktop application keeps the

prescriptions on the mobile application updated so the patient understands which medications to take and when to take them.

On the side of the mobile application, the user will have the abilities to send usage reports of medications to his or her doctor to confirm that he or she has consumed the medication at a certain time. The patient also has the ability to send user-typed reports of possible side effects that would be caused by the medication. Because this is an Internet-enabled function, if there is no Internet connection, the data will be stored until a solid Internet connection is established, and then it will be deleted once it is successfully sent. The graphic user interface of the application will be designed so that reporting of medication usage will be easy.

All members of the medical practice will have access to specific functions on the desktop application. The desktop application will be proprietary for each individual practice that adopts the system, so it will be custom and accommodate for any special characteristics of the practice. With this application, verified and medically licensed individuals like doctors and physician assistants will be able to view, assign, and update prescriptions for patients in the system. Secretaries and other unlicensed individuals will only have the ability to view patient activity send reminders to the patients who have not taken their medication as directed or if their activity on the application has been idle. All of these functions and the participation of both parties will encourage a higher level of medication adherence among patients.

3. Requirements Specification

Project Cognatio

A software system to improve medication adherence

Joe Mehrabi

Preface

I was given the opportunity to participate in the Summer Undergraduate Research Fellowship in Information Technology (SURF-IT) at UC Irvine in 2015. Dr. Debra Richardson and Dr. Birgit Penzenstadler contacted me to conduct a case study on how the consideration of sustainability impacts the requirements engineering process. With my focus on premedical sciences and my ambitions to attend medical school, I spoke with an outpatient dermatologist, Dr. Don Mehrabi, and we came up with the idea for a system aimed to improve medication adherence among his patients.

I met with him regularly to elicit and specify the requirements of the system. I presented to him the artifacts laid out in this document to earn his approval on the goals and vision of the system. In addition to regular meetings with Dr. Mehrabi as the client, I also regularly met with Dr. Penzenstadler and Dr. Richardson to discuss the progress of the project and for feedback on the artifacts.

As part of the fellowship, the consideration of sustainability for this requirements specification will be analyzed and documented. My findings will be reported and hopefully published to conclude my participation in the program.

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Project Flowchart

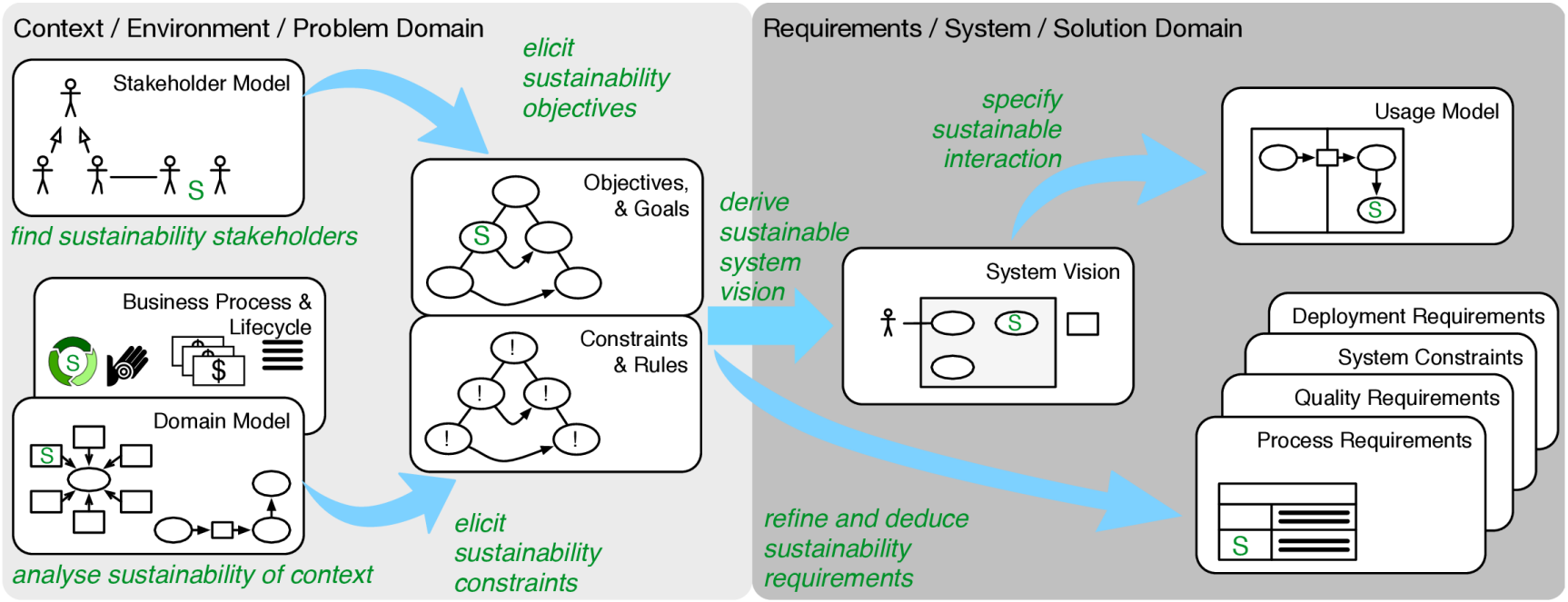


Figure 1 INSERT CAPTION HERE

Business Case Analysis for Project Cognatio

Problem

There remains a real discord between doctors and their treatments of patients. Doctors do not have control or follow up with patient treatments on a regular basis to the extent where patients will certainly follow their treatment. For example, when a dermatologist prescribes topical cream for eczema on a patient's arm, the patient may not follow the doctor's orders every day or may simply quit the treatment. This problem can stem from a number of issues: harmful side effects from the medication, forgetfulness of the patient, or simply laziness. Due to a patient's regular lack of time, the cost of seeing a doctor, and his laziness, he neither feels the urgency to contact his doctors about problems with the medication, nor does he follow up with them every day on the treatment (Hoffman, 2014). To some degree, the relationship between the doctor and the patient is a brief, impersonal one that only exists during a regular, scheduled appointment. At other times, the doctor moves on to treating other patients, and the patient may or may not follow the doctor's exact orders to treat his condition. In conclusion, patients may not be compelled follow what is called "medication adherence," the regular use of medication as prescribed by a medical professional to treat a patient. This can lead to worse conditions and higher costs for healthcare.

Analysis

Currently there is evidence that patients do not necessarily follow the doctor's orders all the time. According to **Figure 1,** when the daily dosage of a patient's medication is higher, the patient becomes less likely to follow through with the treatment (Brown *et al.,* 2011).

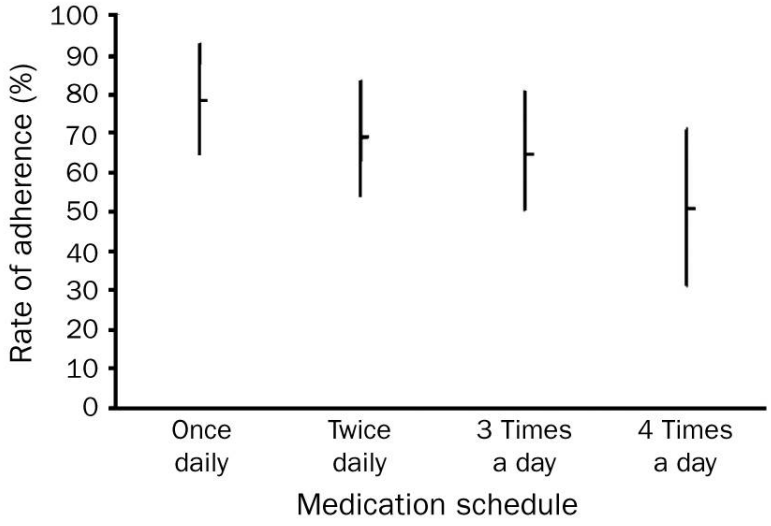


Figure 2: Adherence to medication according to frequency of doses. Vertical lines represent 1 SD on either side of the mean rate of adherence (2).

This becomes the case when patients did not receive any sort of reminder or reinforcement to take their medication.

Patients also have many reasons for not wanting to adhere to their treatments. According to **Figure 2**, reasons for medication non-adherence include forgetfulness, lack of doctor concern, poor physician relationship, and side effects from the drugs (Motheral, 2011).

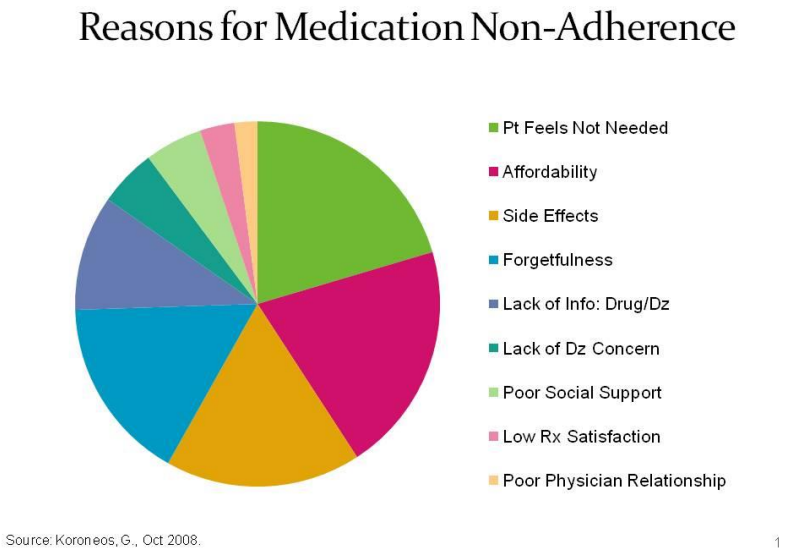


Figure 3: A distribution of the most common reasons for medical non-adherence.

Solution Options

A solution would improve medication adherence among patients. The most effective tool would be an improvement to the relationship between the patient and the doctor. This can be done in multiple ways.

One of which would be via a connected mobile app that ties together a patient and his doctor through the patient's treatment. Another would be to have manual contact between the doctor's office and patients to enforce the treatment of a condition. This can be done by any medium including phone calls, emails, text messages, visits with patient on a regular basis. The final solution option would be simply do nothing in response to the medication non-adherence problem.

Project Description

The most effective tool to influence medication adherence and a closer relationship with a patient's physician would be through a mobile app. This app would automate the communication process between the physician and the doctor while still maintaining the personal relationship. A patient would document when and if he followed is treatment regimen that day, and the physician, or his assistants, would monitor the patient and his treatment. If any irregularities in the regimen erupt, the patient would receive a notification from the doctor's office via the application to remind the patient to regularly apply the treatment as needed. A patient would also be able to report any side

effects that would impede the application of the treatment. The doctor then would be able to respond to these conditions in his own ways.

A system described as the one above would eliminate the patient's forgetfulness as a factor of medication non-adherence and hopefully improve the patient's relationship with his doctor. The doctor will also show more concern for his patients and will work more closely with the patient in dealing with side effects.

Cost-benefit Analysis

Mobile Application: From a business standpoint, building the mobile app would involve an outside developer contributing to its creation, which could cost a considerable amount of money. However, the application could be adapted and commercialized to operate for many doctors' practices and their patients. From a functional standpoint, the application would improve the communication between the doctor's practice and the patients. Patients may take their treatments more seriously, and as a result, and will avoid higher health costs from worsening conditions in the future. Medical non-adherence would be less of a problem. A mobile application would be considered a wasted investment if the patients of the doctor tend to be of the older generation who are not all too familiar with the functionality of a mobile phone and its applications,

Manual Contact: A doctor would not appreciate contact from patients via telecommunications because of a lack of time on the part of the doctor and his assistants as well as the patients. If the manual contact is a result of constant appointments, patients will incur high costs to directly visit the doctor. While this may be a benefit to the doctor, a practice generally focuses on treating as many patients as possible, and may hinder this goal of the practice. The doctor and his staff would need to work harder to maintain a relationship via email, telephone, and text-message, which takes time and effort that could be utilized in other segments of the practice. However, manual contact would eliminate the need for the creation and maintenance of a mobile application.

Do Nothing: Medication non-adherence will still grow to be a problem. If a patient wants questions answered about side effects or any other parts of the treatment, he will need to drive to the doctor's office, using gas and increasing carbon emissions. The creation and maintenance of a mobile application would not be needed. The staff in the office would focus all of their attention on treating the patients that attend the office each day.

Recommendations

After assessing the three options, it would be best to develop a mobile application that will more closely connect a doctor's practice with patients. Developing the system will require the creation and publication of the mobile application on a major application store. It will also require specifying and developing the software that will run on the end of the doctor's practice.

It should be determined who will be interacting with patients via the application. It would be recommended that physician assistants and secretaries interact directly with patients via the app, while the doctor should only be utilized for cases that are extreme or cannot be handled by such personnel.

The high level view of the strategy of how the application should function is laid out in the Project Description. Requirements and the design for the functions of the application should be developed in collaboration with the physician and his staff. Designing the user interface of the application should be done in collaboration with the staff so that they will understand how to function the system and provide any overall feedback. A few test subjects and the developers along with the doctor's staff should test the mobile application and the back end segment to confirm verify and validate functionality and provide any feedback. The process of developing the application should be iterative and any feedback should be considered at each stage of the application engineering process.

Hopefully, when the core functionality is present, a beta version of the system can be implemented and used by the staff of the practice and a few select patients. It will first be available to and compatible with a dermatology practice. The mobile application would be available on Android 4.0 and iOS 7 devices. In the office, the system should be compatible with 32 and 64-bit machines running Windows 7. When the project is finalized, it can be published for the use of all patients of the practice and further enhanced and commercialized for other practices.

Tentative Project Timeline

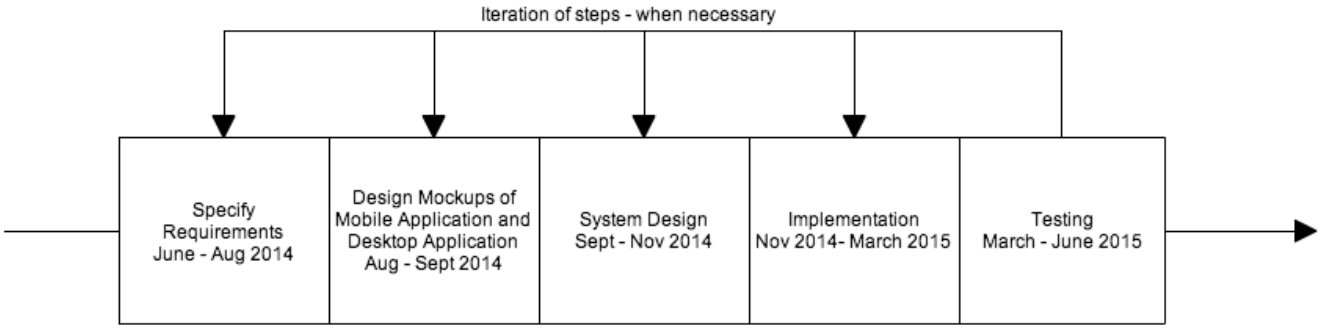


Figure 4: A tentative timeline for the development of Project Cognatio.

The development of Project Cognatio is under way. It is expected that the requirements specification should be finished at the end of August. The presentation of software mockups would be a step forward toward knowing what the mobile and desktop applications should look like on the sides of the medical professionals and the patient. One month to develop the mockups should be plenty of time to draft them and have them reviewed by the testing dermatology practice. The design of the system could be finished at the end of November. A generous amount of time was given for this step because a more elaborate design makes the implementation much easier.

For the implementation, a unique idea would be to formulate a development team at UC Irvine's Med App Jam competition (http://goo.gl/aGCGG4). This would simply be one option, but it would definitely help with kick starting the implementation process and

developing a prototype application most likely for only one platform. The system could first be developed into a mobile application for the patient and web application for the medical users. It should be noted that this is a two-week competition and further development will be required. Most of the time was allotted to the implementation because we expect a number of prototypes of this system to be developed. Aside from the Xtreme programming approach from the Med App Jam competition, another option would be to develop the system in a more professional and iterative manner with a formalized software engineering process.

And finally, the beta version of the application should be available to a test dermatology practice in order to assure that the system works the way it should. By the summer of 2015, the application will be fully developed and available to more medical practices for its use.

The development of the system will be iterative. When challenges and changes arise in one step of the development, previous steps will be consulted and altered in order to account for any difficulties or changes.

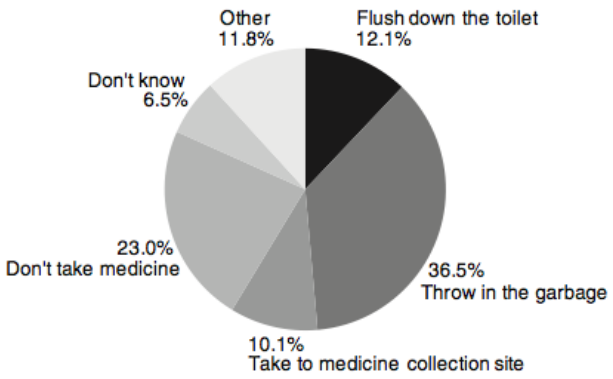
Sustainability

This system contributes to all five dimensions of sustainability:

Human Sustainability: The system is designed to promote the health of those who receive treatments from their doctors. The mobile application will help patients adhere to the use of their medications in order to improve their health.

Economic Sustainability: (Second Order) The system encourages the proper use of medications and the adherence to medical treatments. Doing so will prevent patients from encountering even worse health problems, following up with their doctors, or attending hospitals. Each of these situations would raise the healthcare costs of the patient and others in the United States.

Environmental Sustainability: (Second Order) Project Cognatio provides patients with instant communication towards his doctor and the staff. The mobile application is designed to have the patient adhere more closely to his treatments in order to prevent follow-ups to his doctor if his conditions get worse. Follow-ups entail transportation to the doctor's office possibly in the form of driving. With this application, the patient's health should be improved and he should not need to drive to his doctor's office as often for a follow up, reducing carbon emissions and gasoline consumption.



Source: 2009 Behavioral Risk Factor Surveillance System (BRFSS), Health Statistics Section, Colorado Department of Public Health and Environment.

Figure 5: Common methods of disposing unused medication in Colorado, 2009

According to **Figure 4**, the disposal of medication frequently occurs incorrectly, and this can hurt other organisms in the environment (Boxall, 2004). By promoting the

correct and complete use of medication, consumers will not need to dispose of medication as often.

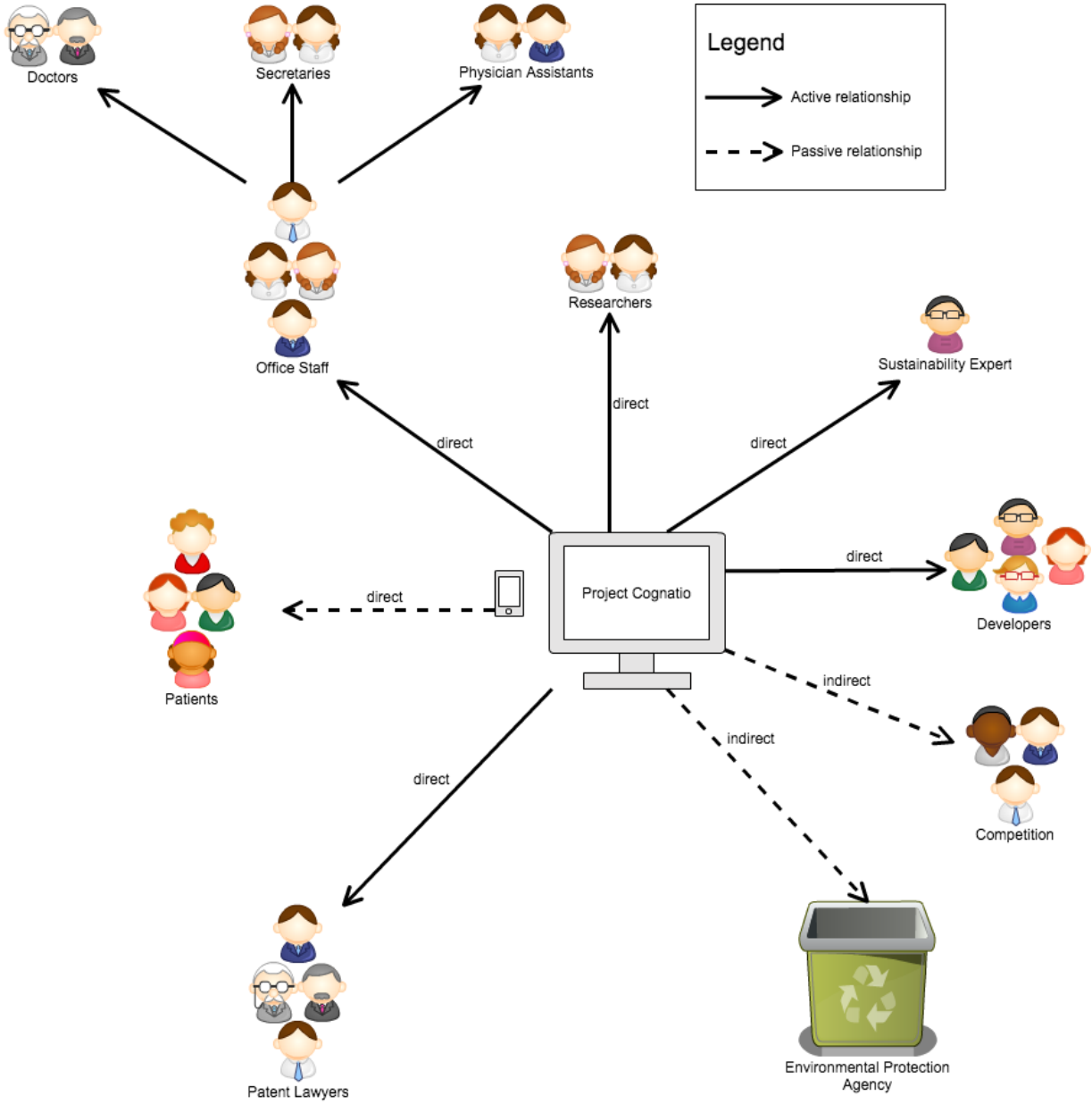
Technical Stability: The system should be available on a wide variety of platforms, making it compatible with many mobile and desktop devices. This would reduce the need for users of the application to dispose of their technologies to utilize this application, hopefully increasing the lifespan of such devices.

Social Sustainability: Project Cognatio relieves the need to for unnecessary follow-ups to see the doctor. Therefore, patients will not need to drive to their doctor's offices as often. While this proves to be environmentally sustainable, it also lessens the amount of traffic on the roads, allowing other drivers to get to their destinations more quickly.

Stakeholder Model

The purpose of the stakeholder model is to depict the stakeholders involved in the development and operation of the system and how they are related to the system. In this model, there are ten stakeholders. Each stakeholder either has a direct or an indirect relationship with the development of the system. A direct relationship includes having a primary interaction with the development or usage of the system. An indirect relationship is applied to those stakeholders who are not primary actors in the development or usage of the system. The stakeholder matrix contains a more exhaustive description of each stakeholder involved in the development of the system.

The Stakeholder Model provides a basis for the **System Vision.**



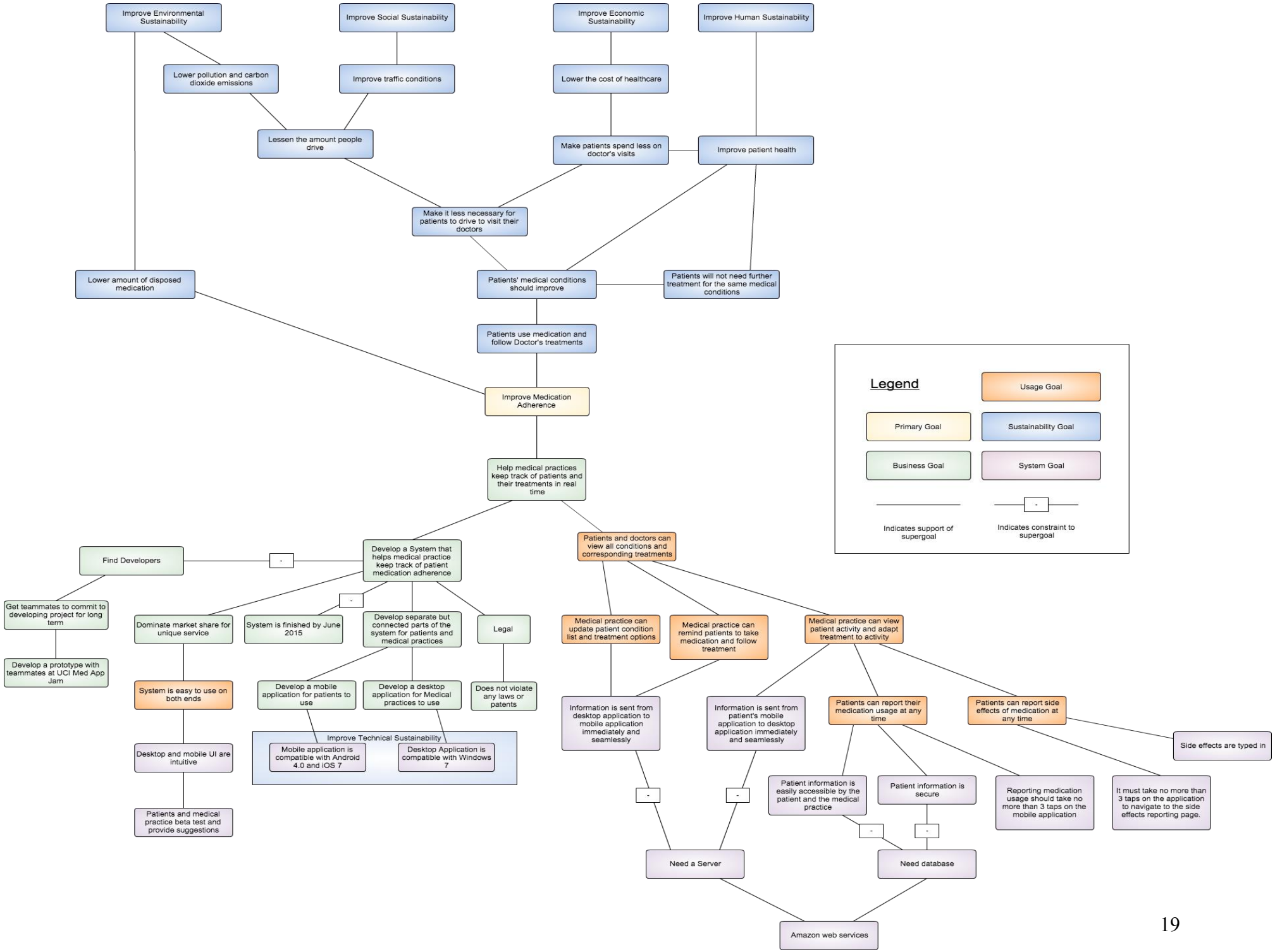
Click here to view the full stakeholder matrix.

Goal Model

The purpose of the goal model is to outline the goals and subgoals that the system will achieve and the goals to achieve proper development of the system. The main goal of this system is to improve the five the five domains of sustainability: economic, environmental, human, technical, and social. All five domains can be achieved through the development, implementation, deployment, and successful usage of this system. *Human sustainability* is achieved because this system is directed toward improving the health of its constituents. *Social sustainability* can be achieved through third order effects on reducing traffic in large cities if the system is widely adopted and used because fewer people would need to drive to visit their doctors as often. *Environmental sustainability* would be built off of the idea behind social sustainability. Since traffic would be reduced through a third order effect, carbon emissions and pollution would be reduced. Since the system will be compatible with older devices, *technical sustainability* will be achieved. And because the application aims to have patients adhere more closely to their medical treatments, economic sustainability will be achieved by lowering the consumer's cost of health care.

These sustainability goals will be accomplished by improving medication adherence among patients. To help patients adhere more closely to their medical treatments, the system would connect patients with their doctors via a mobile application and connect doctors with their patients via a desktop program. Most of the subgoals of implementing this system deal with how the system will be used and how it will be programmed. It should have a user friendly interface on both ends, and the communication between both the desktop and mobile applications should be quick and seamless. The collection of all of these goals would make for a functional system that will encourage patients to consume their medication as directed and provide medical practices with valuable information concerning their patients and their corresponding treatments. Doctors would then be able to alter medical treatments more precisely based on the results of their patients' medication usage and their reports of side effects.

The content of the Goal Model is linked to the **Business Case Analysis.**

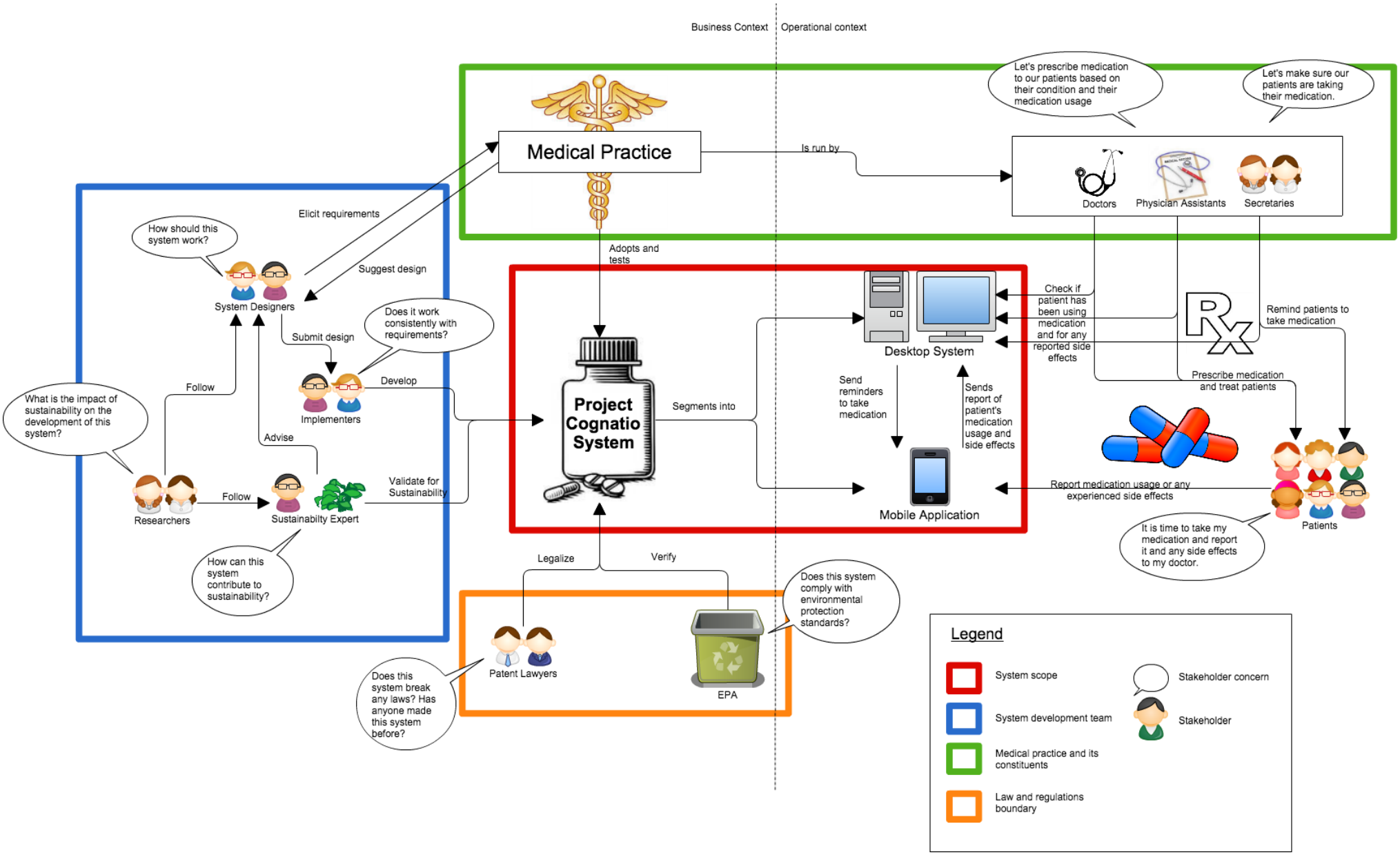

Improve Environmental Sustainability
Improve Social Sustainability
Improve Economic Sustainability
Improve Human Sustainability
Lower pollution and carbon dioxide emissions
Improve traffic conditions
Lower the cost of healthcare
Lessen the amount people drive
Make patients spend less on doctor's visits
Improve patient health
Make it less necessary for patients to drive to visit their doctors
Lower amount of disposed medication
Patients' medical conditions should improve
Patients will not need further treatment for the same medical conditions
Patients use medication and follow Doctor's treatments
Improve Medication Adherence
Help medical practices keep track of patients and their treatments in real time
Legend
Usage Goal
Primary Goal
Sustainability Goal
Business Goal
System Goal
Indicates support of supergoal
Indicates constraint to supergoal
Find Developers
Develop a System that helps medical practice keep track of patient medication adherence
Patients and doctors can view all conditions and corresponding treatments
Get teammates to commit to developing project for long term
Develop a prototype with teammates at UCI Med App Jam
Dominate market share for unique service
System is finished by June 2015
Develop separate but connected parts of the system for patients and medical practices
Legal
Medical practice can update patient condition list and treatment options
Medical practice can remind patients to take medication and follow treatment
Medical practice can view patient activity and adapt treatment to activity
System is easy to use on both ends
Develop a mobile application for patients to use
Develop a desktop application for Medical practices to use
Does not violate any laws or patents
Information is sent from desktop application to mobile application immediately and seamlessly
Information is sent from patient's mobile application to desktop application immediately and seamlessly
Patients can report their medication usage at any time
Patients can report side effects of medication at any time
Side effects are typed in
Improve Technical Sustainability
Mobile application is compatible with Android 4.0 and iOS 7
Desktop Application is compatible with Windows 7
Desktop and mobile UI are intuitive
Patient information is easily accessible by the patient and the medical practice
Patient information is secure
Reporting medication usage should take no more than 3 taps on the mobile application
It must take no more than 3 taps on the application to navigate to the side effects reporting page.
Patients and medical practice beta test and provide suggestions
Need a Server
Need database
Amazon web services

System Vision

The purpose of the system vision is to give an overall view of the function of the system and how the stakeholders interact with the system. The business context of the system depicts the overall process of and the stakeholders involved with the development of the system. In this context, the development team interacts among each other and the medical practice to produce the product. Each stakeholder interacts with other stakeholders in a specific way and also has their own concerns. Legal bodies include the EPA and patent lawyers to make sure the system does not violate any environmental regulations or any existing patents.

In the operational context, the function and purpose of the system is outlined by the interactions between the members of the medical practice, their patients and the two components of the system: the desktop system and the mobile application. The purpose of the system is to have doctors, physician assistants, and secretaries of a medical practice track their patients' usage of medication and encourage patients to adhere to the usage of medication as it is directed. This is done by having secretaries remind their patients to take their medication when irregular activity is reported and by having doctors and physician assistants use the data produced by patients to adapt treatments for their patients based on their medication usage.

The System Vision provides a basis for the **Domain Model** and is derived from the **Stakeholder Model.**

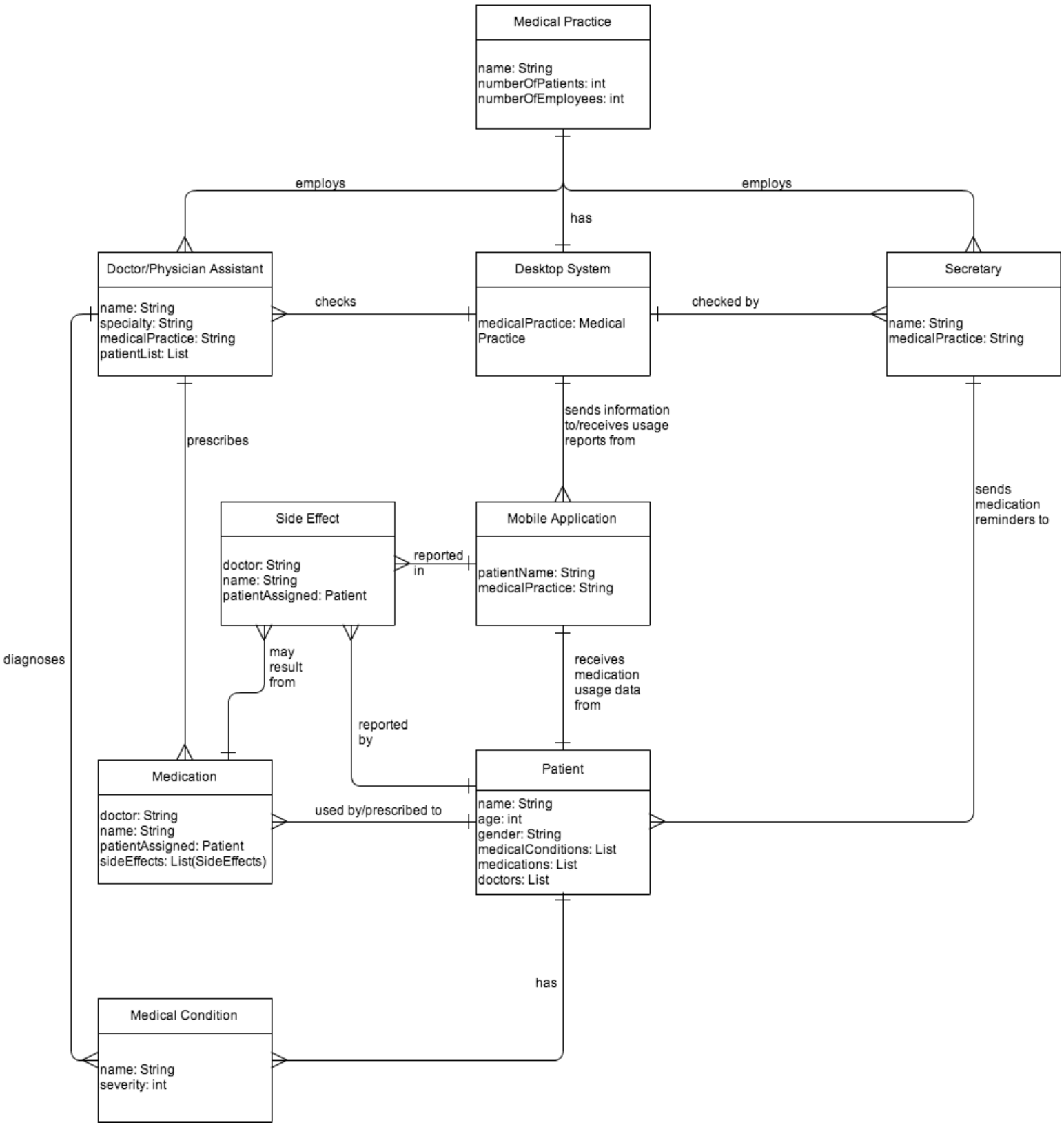

Business Context
Operational context
Medical Practice
Is run by
Let's prescribe medication to our patients based on their condition and their medication usage
Let's make sure our patients are taking their medication.
Doctors
Physician Assistants
Secretaries
Adopts and tests
Elicit requirements
Suggest design
How should this system work?
System Designers
Submit design
Does it work consistently with requirements?
Develop
Implementers
Follow
What is the impact of sustainability on the development of this system?
Advise
Researchers
Follow
Sustainabilty Expert
Validate for Sustainability
How can this system contribute to sustainability?
Project Cognatio System
Segments into
Desktop System
Mobile Application
Send reminders to take medication
Sends report of patient's medication usage and side effects
Check if patient has been using medication and for any reported side effects
Remind patients to take medication
Prescribe medication and treat patients
Report medication usage or any experienced side effects
Patients
It is time to take my medication and report it and any side effects to my doctor.
Legalize
Verify
Patent Lawyers
EPA
Does this system comply with environmental protection standards?
Does this system break any laws? Has anyone made this system before?
Legend
System scope
System development team
Medical practice and its constituents
Law and regulations boundary
Stakeholder concern
Stakeholder

Domain Model

The purpose of a domain model is to map out the various entities, their corresponding attributes, and their relationships to other entities. The medical practice has three types of employees that interact with the desktop system: the secretary, the physician assistants (PAs), and the doctors themselves. Doctors and PAs have the same capabilities when interacting with the system. According to this model, they prescribe medications and alter the treatments of the patients. The secretaries, since they do not contain the legal capability of diagnosing patients and prescribing treatments, are given the capability of reminding patients to consume their medications when irregular adherence to the treatment is observed.

The Desktop system gathers and organizes information supplied by the patient concerning their habits with medication consumption and any side effects. The information is transmitted from the mobile application that contains the data about the patient's medication adherence and reported side effects. Each desktop system is proprietary to the medical practice, and the mobile application is a publicly available program that can be downloaded on the consumer's mobile phone.

The content of the Domain Model is linked to the **System Vision.**

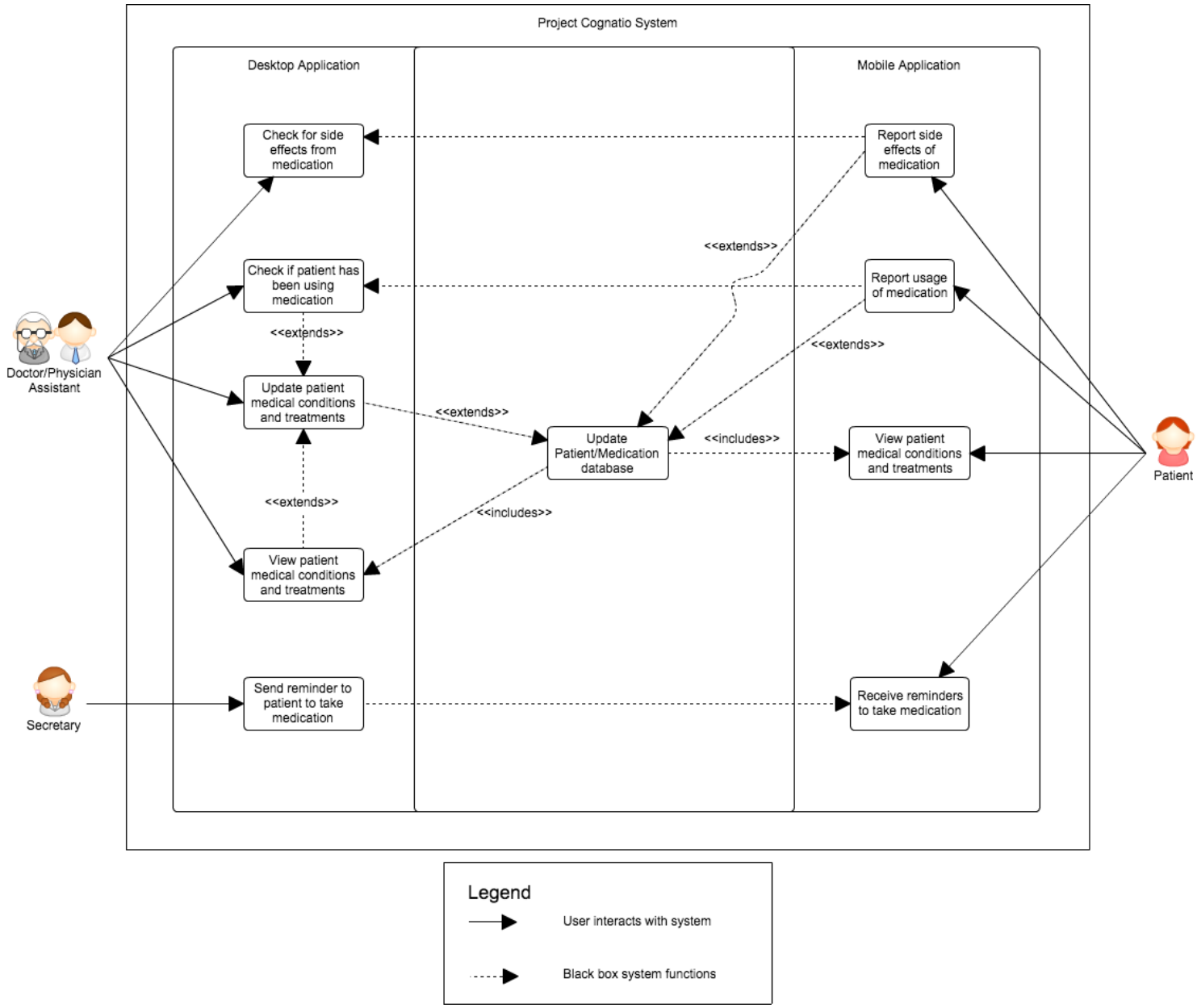

Medical Practice
name: String
numberOfPatients: int
numberOfEmployees: int
employs
has
employs
Doctor/Physician Assistant
name: String
specialty: String
medicalPractice: String
patientList: List
checks
Desktop System
medicalPractice: Medical Practice
checked by
Secretary
name: String
medicalPractice: String
prescribes
sends information to/receives usage reports from
sends medication reminders to
Side Effect
doctor: String
name: String
patientAssigned: Patient
reported in
Mobile Application
patientName: String
medicalPractice: String
diagnoses
may result from
receives medication usage data from
reported by
Medication
doctor: String
name: String
patientAssigned: Patient
sideEffects: List(SideEffects)
used by/prescribed to
Patient
name: String
age: int
gender: String
medicalConditions: List
medications: List
doctors: List
has
Medical Condition
name: String
severity: int

Usage Model

The purpose of the usage model is to give a black box depiction of how users will interact with the system and how the system responds to those interactions.

Usage Overview

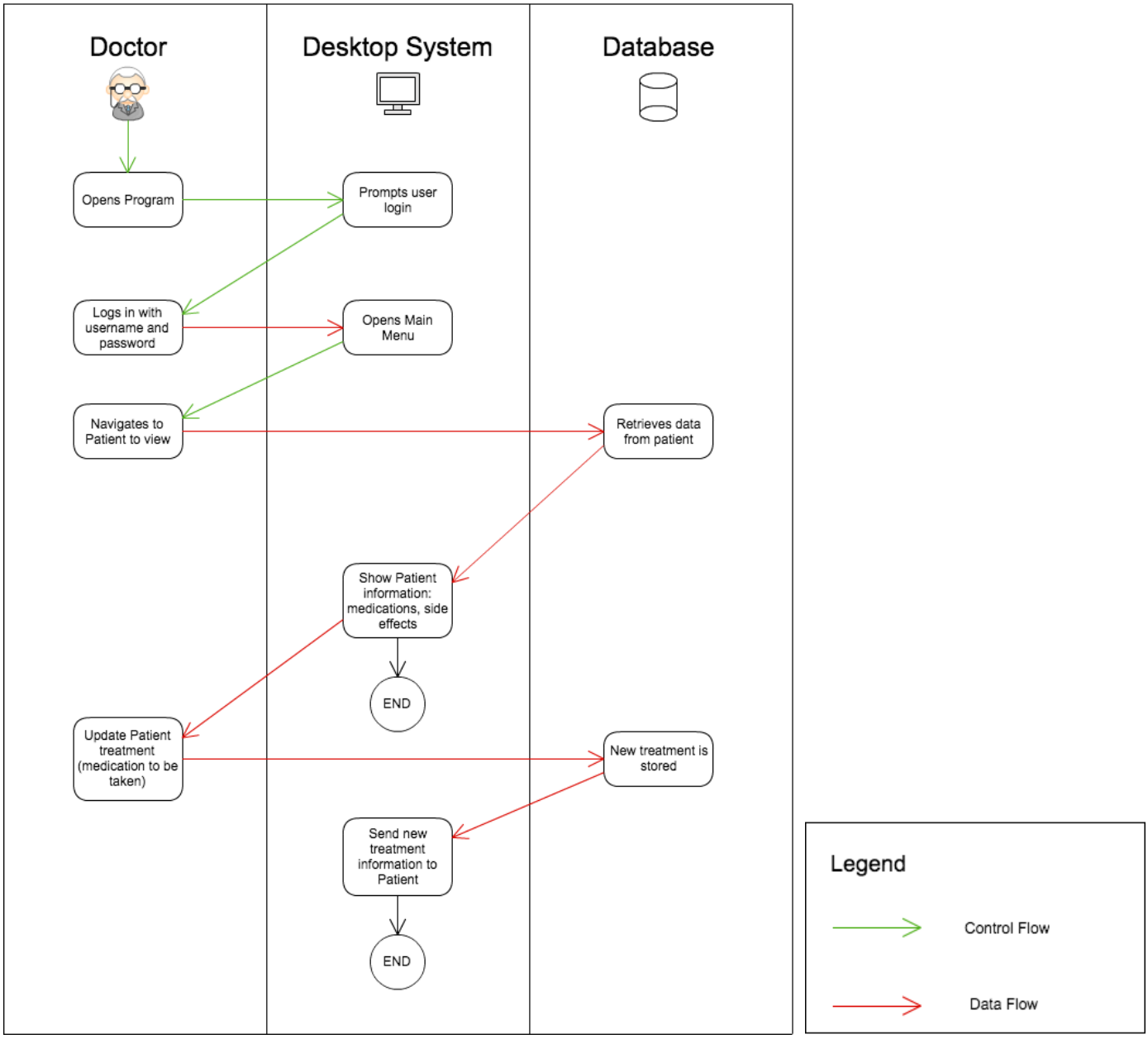
This is a birds-eye view of the overall functions of the system and the users who interact with the system. Also included are the three key components of the system: the desktop sub-system, the mobile application, and the patient database. Each function on both ends of the Project Cognatio system interacts with with either the database or the other side of the system. Solid lines depict an interaction between a user and the system, and the dashed lines depict the actions that the system itself performs to manipulate and transmit any reported or updated data.



Scenario 1: Doctor views and updates a patient's treatment

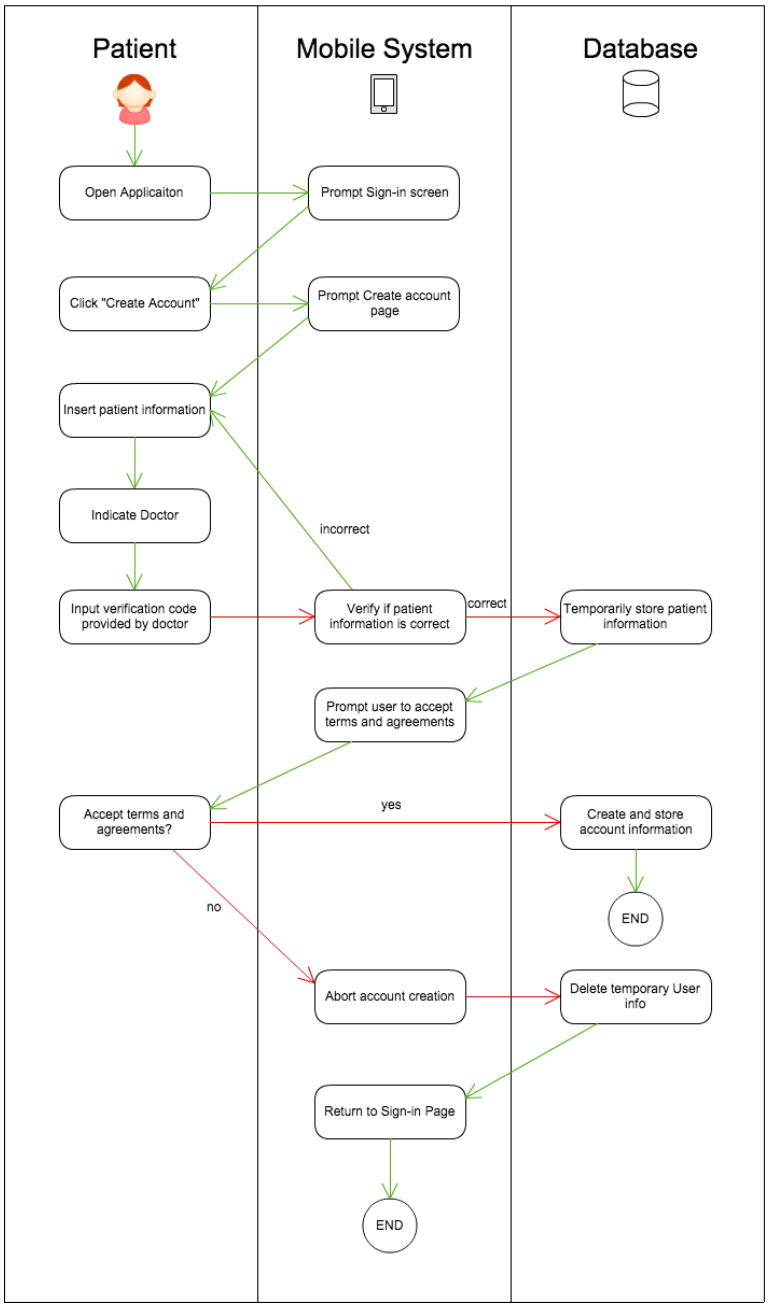
The doctor (or physician assistant) has the permission to update and view patient treatments and medication reports on the desktop system. Shown below is his interaction with the system and how the doctor may view and update a patient's treatment. Control flow and data flow are outlined with designated arrows. Red arrows represent the transmission of data from one entity to the other (data flow). The green arrows represent the response to certain inputs (control flow).

If the doctor wishes to only view the patient's profile, the model indicates the end to this scenario in the first point labeled "END." If the doctor continues operating through the desktop system, he or she can update the patient's treatment plan.



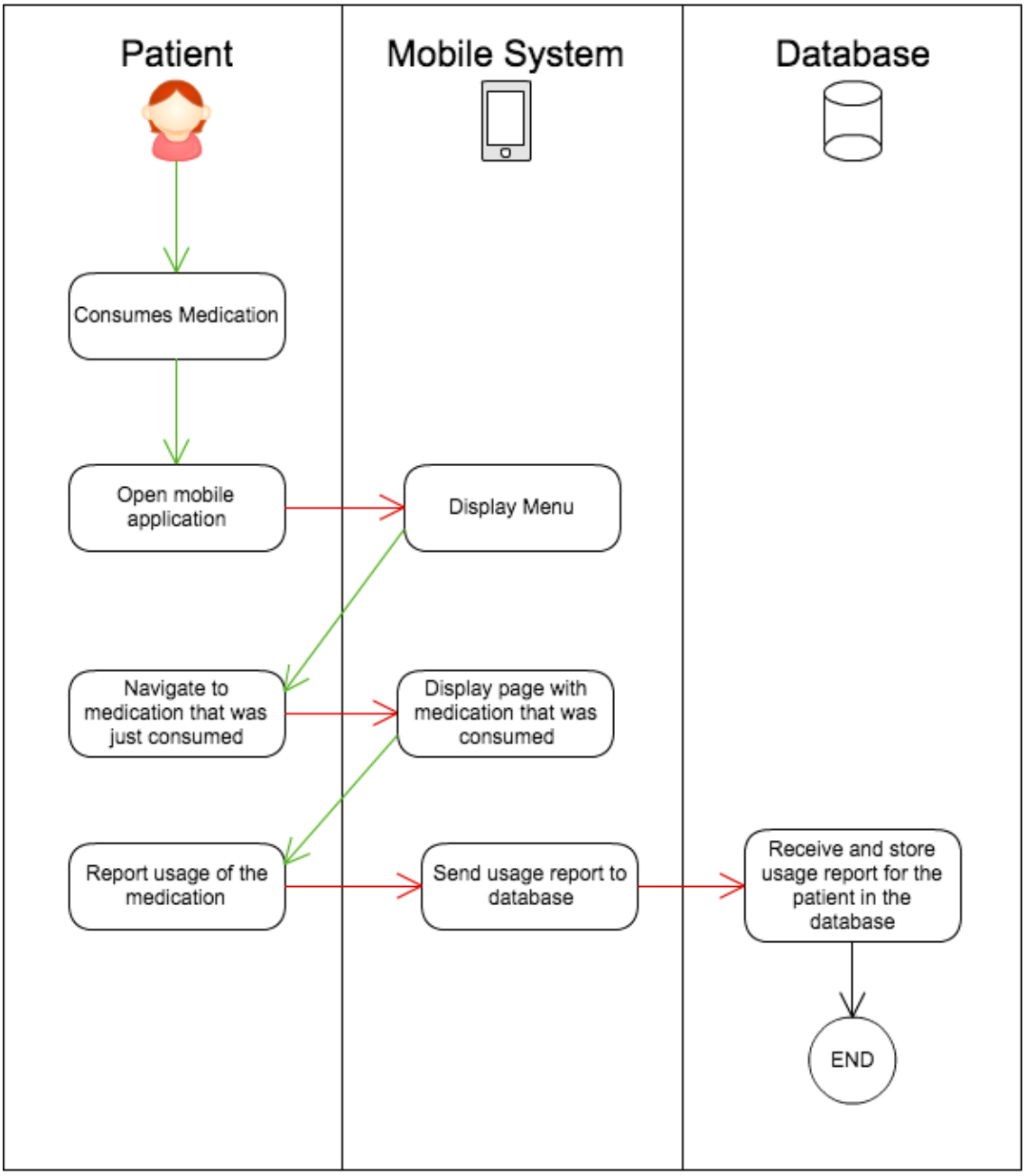
Scenario 2: Patient creates an account

To use the mobile application and participate in the functionality of the system, the patient must create an account and profile. This would contain all of the basic information of the patient. To create the profile, the patient would need a special access code provided by the desktop system in the medical practice to synchronize that patient's information and data with the desktop system of the corresponding medical practice. This would be included in the "Indicate Doctor" step of this scenario. Control flow and data flow are outlined with designated arrows. Red arrows represent the transmission of data from one entity to the other (data flow). The green arrows represent the response to certain inputs (control flow). The process of creating an account is standard and comparable to doing so on many other software systems.



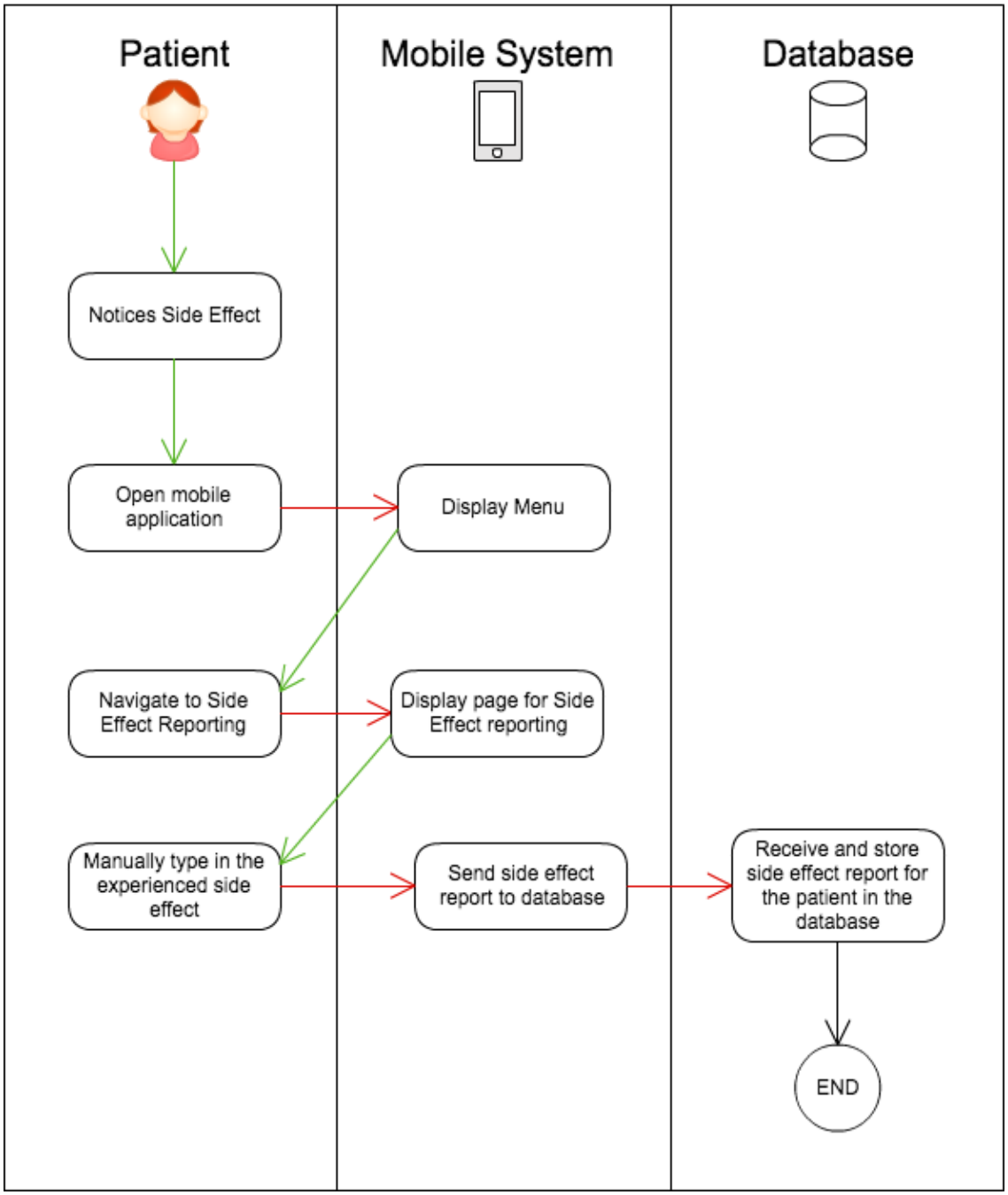
Scenario 3: Patient reports medication usage

This is the key scenario that the system is based upon. The patient has the ability to report his or her usage of medication at any time. The data that the patient reports is sent to the system's database and retrieved by the desktop system of the medical practice. If there is no Internet connection, the data of the report such as the date, time, and medication used will be stored locally on the mobile device until a stable internet connection is established. Only then will the data be sent to the database. Control flow and data flow are outlined with designated arrows. Red arrows represent the transmission of data from one entity to the other (data flow). The green arrows represent the response to certain inputs (control flow).



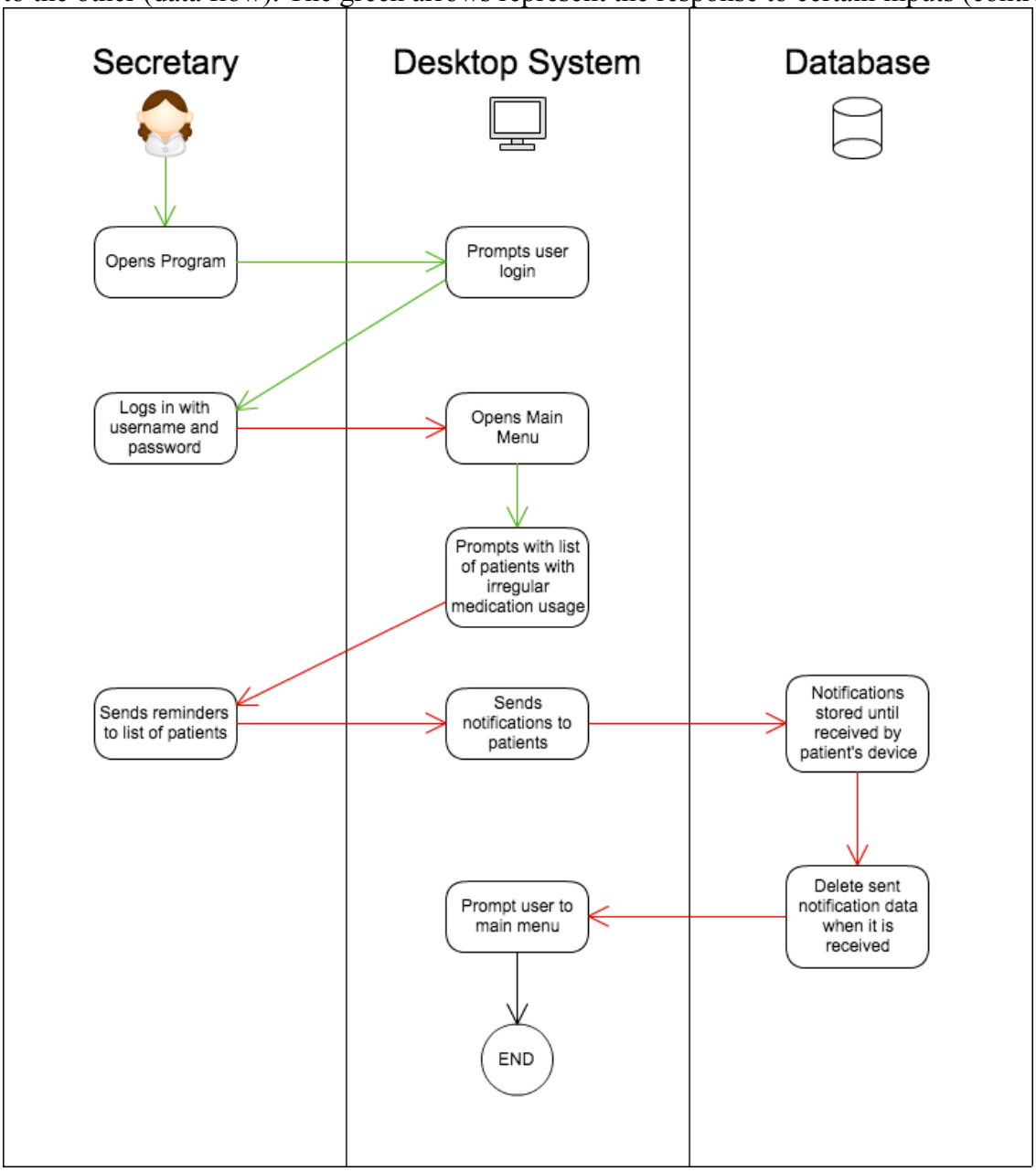
Scenario 4: Patient reports side effects of medication

The patient has the ability to report side effects that may have resulted from taking prescribed medication. This process is derived from and is very similar to reporting medication usage. Control flow and data flow are outlined with designated arrows. Red arrows represent the transmission of data from one entity to the other (data flow). The green arrows represent the response to certain inputs (control flow).



Scenario 5: Secretary sends reminder to patients

The secretary is not licensed to influence any health care treatment but may access the desktop system to send reminders to patients to take their medication. On any given day, the system will detect which patients have not consumed their medication as directed and will present the secretary with a list of such patients. To his or her discretion, he or she may send reminders to those patients on the presented list. The reminder will be stored in the database until the patients' mobile devices have received the notification. Control flow and data flow are outlined with designated arrows. Red arrows represent the transmission of data from one entity to the other (data flow). The green arrows represent the response to certain inputs (control flow).



Non-functional Requirements

The purpose of defining non-functional requirements is to highlight certain qualities that the system must adhere to that do not define any specific functions that it will perform. In this model, there is a focus on the Project Cognatio's deployment, development process, constraints that limit the system, and requirements that establish the quality of the system. Of course, this list is not exhaustive, but the most important and tangible requirements are stated and will be met.

Standard Model

NFR	Description of Requirement
Rationale	Goal that the requirement is derived from
Satisfaction Criterion	Metric that needs to be achieved
Measurement	How the metric will be determined/measured
Risk	What does it mean if the requirement is not met

Deployment Requirements

NFR	System will be tested by one medical practice and multiple patients before it is released
Rationale	Develop separate but connected parts of the system for patients and medical practices
Satisfaction Criterion	System is stable before final release for commercialization
Measurement	Make sure system does not crash and communicate correct information
Risk	Must iterate through implementation again

NFR	Publish publicly by June 2015
Rationale	Dominate Market share
Satisfaction Criterion	Mobile application is available on the Play Store and App Store. Desktop application is purchasable as an individually customized product.
Measurement	Either it is published or it is not.
Risk	Application is not available publicly. Majority of goals (sustainability and not) are not achieved.

Process Requirement

NFR	Design mobile application before desktop application
Rationale	Develop separate but connected parts of the system for patients and medical practices. (mobile application should be easier to develop. It is not as complex)
Satisfaction Criterion	Mobile application is completed before desktop application
Measurement	Either this is done or it is not.
Risk	Desktop application has little foundation for development

Quality Requirements

NFR	GUI is user friendly on both desktop and mobile applications
Rationale	System is easy to use on both ends
Satisfaction Criterion	Approval from beta testers
Measurement	It takes only a few (<4) taps/clicks on the UI to navigate to desired page.
Risk	Few customers will want to use the application. All large-scale goals (sustainability goals) will not be met if application is not adopted. Opens up market for other apps with similar functionality and more user friendliness.

NFR	Information exchange is efficient. Uses internet speeds
Rationale	Medical practice can update patient condition list and treatment options. Medical practice can remind patients to take medication and follow treatment. Medical practice can view patient activity and adapt treatment to activity
Satisfaction Criterion	Information on each domain (desktop/mobile) will be updated within 10 seconds
Measurement	Time how long it takes for information to reach one domain from the other.
Risk	Patients and practices may receive information in an untimely manner. Reminders to take medication may come late and the goal of the system will be moot.

Legal Requirements

NFR	System is legal
Rationale	Does not violate any laws or patents
Satisfaction Criterion	The patent for this system will be the first to exist
Measurement	It must be determined by a patent lawyer
Risk	Developers could get sued and lose money, possibly go to prison

NFR	Does not violate any EPA standards
Rationale	Improve environmental sustainability
Satisfaction Criterion	System does not harm the environment
Measurement	We would be notified by the EPA if this does infringe on the environment
Risk	One of the main goals of the project would not be achieved. The environment may be harmed. We may be fined.

System Constraints

NFR	Creation of a database and a server
Rationale	Need a database and a server
Satisfaction Criterion	Patient and medication data is stored, organized, and accessed
Measurement	The system either does or does not have access to a hub of information to read and write upon.
Risk	Large amounts of application data cannot be stored, organized, and accessed for patients and medical practices to operate upon.

NFR	Side effects must be typed in.
Rationale	Patients can report side effects at any time
Satisfaction Criterion	Side effects cannot be assigned to one medication of multiple medications are taken. Therefore they must be documented manually.
Measurement	Either the functionality is present or it is not.
Risk	Side effects cannot be effectively reported and doctors will not be able to know quickly enough how to adapt a patient's treatment.

4. Discussion

4.1 Business Case Analysis

The Business Case Analysis for this requirements specification goes into great detail on how Project Cognatio will impact sustainability. The Business Case Analysis displays the perspective that the stakeholders have on the problem that will be solved by the software system in development. At its core, it contains (1) a detailed explanation of the *problem* at hand, (2) the *analysis* of the problem that contains statistics as to what causes the problem and why it is a problem, (3) the possible solutions, including the software solution that is in development, (4) a description of the project that will be pursued, (5) a cost-benefit analysis weighing the pros and cons of the solution options, and (6) the recommendations for pursuing the desired project. In addition to these core elements, the Business Case Analysis for this requirement specification also included a project timeline and a whole section devoted to how the pursued project will contribute to sustainability.

4. 2 Stakeholder Model

The stakeholder model documents all of the stakeholders involved in the system and if their relationships directly or indirectly impact the development of the system. When considering sustainability, the Environmental Protection Agency (EPA).

The EPA is the governing body that makes sure all technologies, goods, and services comply with governmental environment protection standards. They would of course be indirectly involved, but definitely considered for the development of this system when thinking about the impact that this system has on *Environmental Sustainability*. This would not necessarily change how the system is developed, but this governing body is definitely something to consider for the development of any new software or technology.

If sustainability were to not be considered, the involvement of the EPA would have been absent because it is not a direct stakeholder in the development of the system. Most software development does not consider the involvement of environmental regulations because software does not typically effect the environment unless it introduces a new device or physical component that could be disposed when its product life ends.

The purpose of a sustainability expert is to document how specific services and products would affect the different types of sustainability. If not considering sustainability for the development of this system, a sustainability expert would not be consulted. Doing so would incur more costs, introduce more challenges to creating the system, and occupy more time. One would have to weigh if it is truly necessary to consult a sustainability expert when developing software.

4.3 Goal Model

Since the goal of the system is to improve all 5 types of sustainability with this system, the Goal Model considers all 5 types of sustainability. In fact there is a specialized blue key on the legend that is used to distinguish sustainability goals from all the other goals. Almost half of the Goal Model contains sustainability goals. If not considering sustainability, the top half of this model would have been absent from this document and the primary goal of "Improving Medication Adherence" would be the top goal rather than improving all 5 types of sustainability. Because most of the sustainability goals are results of second or third order effects, they would probably still occur or at least be possible with the development of the system, but they would not be documented if sustainability were not considered as a goal.

The consideration of sustainability certainly plays a part in choosing the compatible operating systems for the system. *Technical Sustainability* would be achieved if more people with older devices could use the system in order to prevent them from disposing of their older

devices. This is why Windows 7, Android 4.0, and iOS 7 were chosen as the compatible operating systems for Project Cognatio. Of desktop computers, Windows 7 is the dominant operating system, running on 50.06% of machines as of April 2014 (techtimes.com). For Android, if the mobile application is compatible with older operating systems, it will be compatible with newer operating systems. All OS's that are Android 4.0 and above occupy just over 85% of all Android devices as of July 2014 (androidcentral.com). And 90% of all iOS devices are running on iOS 7 as of July 2014 (appleinsider.com).

If the sustainability were to not be considered, the goal to target popular operating systems would be based on dominating market share by reaching as many consumers as possible. But, this would not change any goals to develop for any other operating systems. Only the motive for developing for other platforms would be changed and the two subgoals that denote which OS to develop for would stem from the goal to "dominate market share for unique service." The overall goal of the system and its development would not change with the consideration of sustainability. The system would still promote human sustainability regardless of its consideration, but the emphasis on the sustainability goals would be absent because they would not be considered.

4.4 System Vision

The System Vision gives a focus of the function of system and the involvement and roles of stakeholders on the system's development. When considering sustainability, the only real factors in the System Vision that accounts for sustainability are the involvements of a sustainability expert and the EPA.

If sustainability were to not be considered, the involvement of the EPA and consideration of consulting a sustainability expert would have been absent for the same reasons outlined in the discussion of the Stakeholder Model.

Domain Model

This rendition of the Domain Model contains no reference to any source of sustainability outside of the inner components of the system. The Domain Model is simply a model of how different entities in the system are related to each other and what characterizes these entities. The scope of the Domain Model is to focus solely on the components of the system in order to understand the facets of the system and how they work in more detail. The consideration of sustainability for this model of this system is really absent unless one were to consider the fact that this is a health related system aimed at improving *Human Sustainability*.

4.5 Usage Model

The various components of a usage model focus on the different scenarios and cases that depict how the different users interact with the system. The usage of the system does not really address any aspect of sustainability; it simply involves a black box view of how what the system does and how it works under certain circumstances outlined by the user's needs for the system. The usage model for Project Cognatio does not specifically address any aspects of sustainability other than the improvement *Human Sustainability*, the main goal of the entire system.

4.6 Non-functional Requirements

The model for non-functional requirements merely documents the various components of specific, important requirements and goals that the system must meet when it is deployed for usage. In this model, *Environmental Sustainability* and *Human Sustainability* are specifically addressed while the reference to all other types of sustainability is more implicit. In this model,

the consideration of sustainability involves the involvement of the EPA and few of the second and third order impacts on sustainability when addressing the risks if certain requirements are not met.

If sustainability is not considered when documenting this model, the consideration of these risks and the EPA would be absent. It would not be entirely necessary to consider the regulations of the EPA when developing a software system like Project Cognatio when physical devices are not being created or tampered with which may impact the environment. The second and third order sustainability goals would also not be considered because sustainability would not necessarily be a desired goal. Referring back to the Goal Model, if *Technical Sustainability* were to be eliminated from the model, the development of the software to be compatible with certain operating systems would be done to meet the goal of dominating market share. For this model, if the sustainability goals were not considered, business goals would be the main drive to meet certain requirements.

For example, if the requirement to make the GUI user friendly is not met, then the risks would not include a focus on adherence to sustainability goals but rather a more primary focus on business risks. In the case of this requirement, the risk of opening up the market for other competitive products would be encountered.

5. Conclusion

When following the AMDiRE model for RE, the consideration of sustainability amounts to a few different approaches to each artifact. Earlier artifacts, such as the Business Case Analysis, the Goal Model, and the System Vision are impacted the most with the consideration of sustainable development. Later artifacts, with the exception of the Non-functional Requirements, are impacted very little with the consideration of sustainability. This approach to

would lay the groundwork for more sustainable RE for future projects. When considering each artifact in future software projects, especially in the medical domain, the consideration of sustainability should parallel that of Project Cognatio.

6. Acknowledgements

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