Hospital Infections Monitoring System

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- 1241E -

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1. PROBLEM DEFINITION AND PROJECT SCOPE

"The current health care system is neither healthy, caring nor a system" (Walter Cronkite). This quote accurately describes the current situation in all hospitals in Romania. The Romanian health system does not support a genuine well-being of the patients and doctors.

The Infectious Disease hospitals have an even higher risk of spreading the infections. Nevertheless, this risk exists in all types of hospitals. The infectious diseases, also called transmissible diseases, are illnesses resulting from infections that can easily be passed from one person to another through multiple media including direct or droplet contact. In order to reduce the spread of such diseases, certain prevention rules can be respected as well as taking immediate action in case there are signs that an infection may occur.

This problem, served as starting point in creating the Hospital Infections Monitoring System - a new system for preventing and monitoring infections, through the use of proximity sensors and technologies.

Why? We believe in an optimal health environment.

How? By knowing:

- the infection type of the patients,
- the spread risk of the disease,
- the amount of time the patients are in contact,
- and if certain rules are respected by patients and doctors.

Doctors are able to take actions, prevent the spread of infections and even ease the treatment of them in case an infection occurs.

What? A system that aims to develop the safety of patients in an environment where there is a high risk of getting infectious diseases.

The scope of the project is about what the project will produce in the end (the what) as well as about the processes required to ensure that the project will be completed successfully which will be described through multiple sections of the paper including the features and characteristics of the system.

Our overall objective is to create an infection control system helps building an optimal healing environment. The system aims to fulfill the following objectives:

· Patient monitoring done on a real-time basis;

· Minimize the time doctors need for consulting patients;

· Ease the decision making process for an infection type;

· Higher accuracy of diagnosis;

· Decrease the rate of occurring diseases in hospital by taking preventive actions.

Figure 1. Hospital Infections Monitoring System - Welcome Page

2. CURRENT APPROACHES

Surveillance of healthcare-associated infections is a cornerstone of infection prevention programs, and reporting of infection rates is increasingly required. Most organizations utilize a targeted surveillance methodology based upon an annual risk assessment. Traditionally, surveillance is based on manual medical records review; however, this is very labor intensive and vulnerable to misclassification. Existing electronic surveillance systems based on classification algorithms using microbiology results, antibiotic use data, and/or discharge codes have increased the efficiency and completeness of surveillance by preselecting high-risk patients for manual review. However, shifting to electronic surveillance using multivariable prediction models based on available clinical patient data will allow for even more efficient detection of infection. With ongoing developments in healthcare information technology, implementation of the latter surveillance systems will become increasingly feasible. As with current predominantly manual methods, several challenges remain, such as completeness of postdischarge surveillance and adequate adjustment for underlying patient characteristics, especially for comparison of healthcare-associated infection rates across institutions - data from one hospital are more valid and more effective when they are compared with those from other hospitals. In order to avoid false conclusions, comparisons are only possible when identical methods of data collection with fixed diagnostic definitions are used. Because different stations and departments gauge risks differently and differ in patient composition, these differences are compensated for by a standardisation and stratification process in data calculation and analysis.

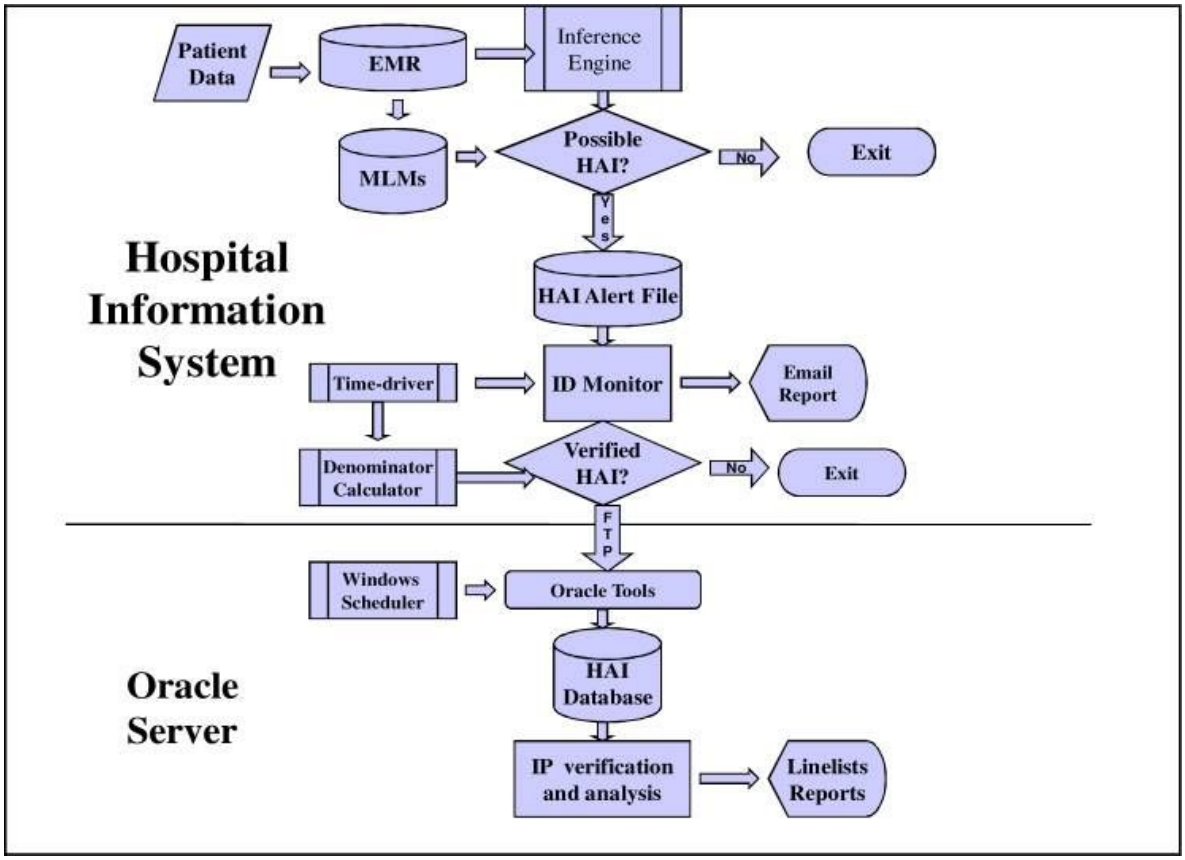

Figure 2. The process for the identification, verification, analysis and reporting of infections.

Key Facts:

- Electronic surveillance replaces the manual chart review process so that infection control practitioners (ICPs) can focus efforts on prevention. Traditional retrospective surveillance is labor-intensive and limited to 10% of patients at high risk of infection.
- Automated real-time surveillance alerts caregivers to potential infections and guides treatment selection. Traditionally, infection control specialists focus clinical guidance on select, high-risk patients.
- Traditional surveillance underreports infection rates by as much as 20% for some infection types.
- Infection tools are often combined with antibiotic guidance and other error-reduction applications.

These key facts led the way to Preventing Spread Of Disease With Real-Time Location System (RTLS).

RTLS is a valuable technological asset that can be implemented to provide instant tracking of healthcare staff, patients, and equipment, as well as help optimize the results of infection control and prevention programs and staff training. Strategic implementation of an RTLS system can improve a hospital's readiness to protect patients, staff,

and the surrounding community from an infectious disease outbreak.

To optimize the value of an RTLS system, specially trained hospital staff should be given the responsibility of utilizing the technology. IPs are preferably suited to this task but, although they are recognized as an important asset to infection control, over half of hospitals employ one or less IPs for their entire facility. These specialists are trained to collect, analyze, and interpret health data to plan prevention and intervention measures. They establish infection prevention policies and practices and ensure that they are appropriately implemented. The majority of hospitals could benefit from adding IPs to their staff as they are in a unique position to utilize an appropriately implemented RTLS system to prevent the spread of infections like Ebola.

Real-Time, Accurate Visibility With Use Of RTLS

IPs can use an RTLS system to improve compliance with infection control policies and practices (e.g., handwashing) to decrease the spread of disease. They can also track patients that may have a communicable disease and their interactions with hospital staff, other patients, visitors, and equipment. IPs also have the knowledge to properly collect, analyze, and interpret real-time data provided by the RTLS system in order to recognize and track trends, plan interventions, measure success, and report outcomes. The way RTLS works is shown in the figure 3.

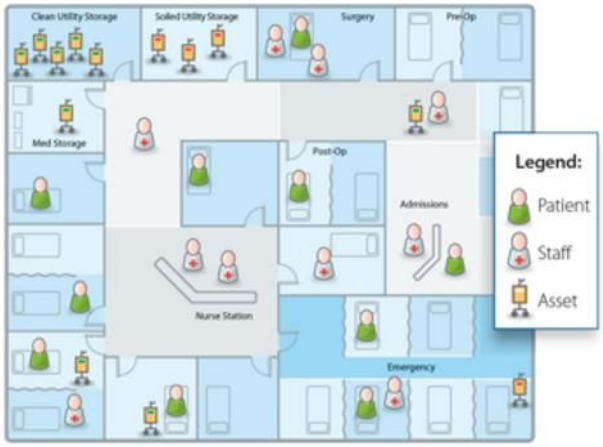

Figure 3. RTLS

Besides our Hospital Infection Monitoring System, Versus company is also offering such services:

Monitoring Hand Hygiene Compliance in Real-time

Versus Advantages™ Hand Hygiene Safety technology removes the "estimation game" and provides accurate, unbiased data. By monitoring hand hygiene participation in real-time, all the time, we give caregivers and infection control managers the data they need to foster a culture of safety and accountability.

When you monitor participation with RTLS, you can:

· Know the who, when and where details on dispenser use;

· Allow caregivers to see how their participation rates against peers;

· Report compliant/non-compliant percentages by unit or individual;

· Automatically monitor compliance rates and trending in real-time;

· Automatically document improvements in compliance over time.

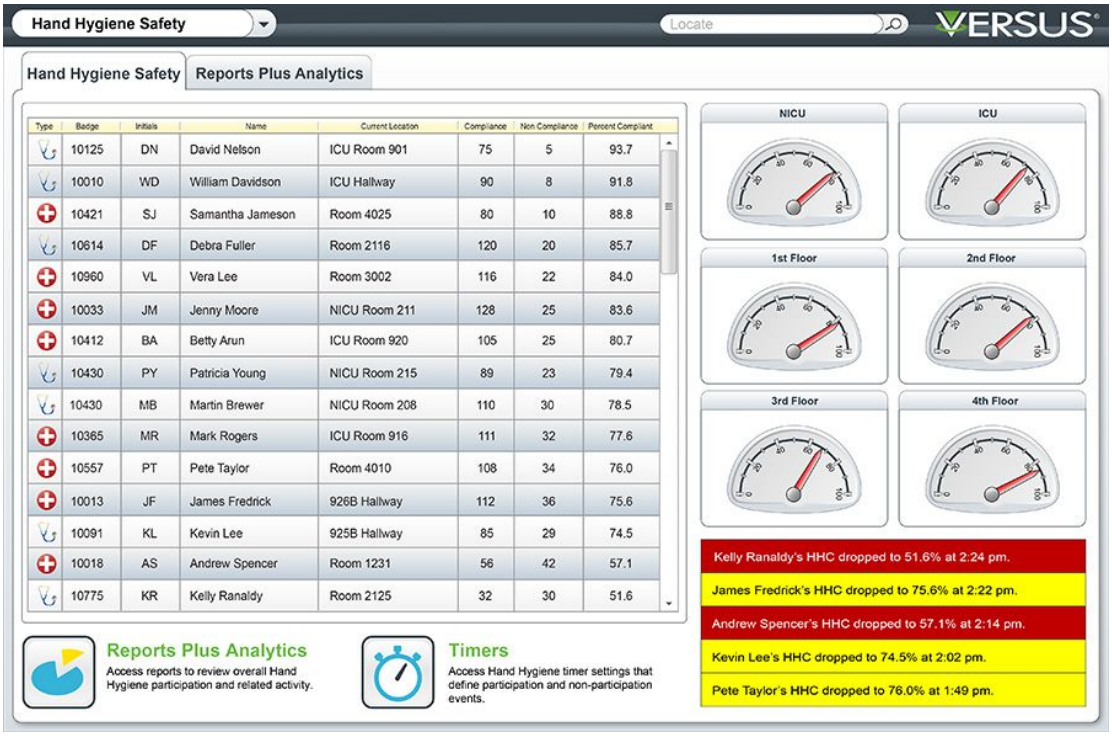

Figure 4. Versus

Controlling the Spread of Infection by Identifying Exposure

When a patient is found to have a contagious infection, determining everyone who may have been exposed can be time-consuming and costly. With Versus Advantages, interactions between patients, staff and equipment are automatically recorded. Using the Exposure Control reports in the Reports Plus™ Analytics software, there is immediately captured who (and what equipment) was exposed, and to what degree. No more guessing — easily locate, notify, test and treat only those who came into contact with the contagion. Plus, direct your disinfection efforts to the rooms and equipment exposed.

Effectively Managing an Epidemic

The Versus Advantages patient flow system can handle an influx of patients should an epidemic occur:

- Manage a surge of patients with our patient flow software
- Communicate which patients are contagious
- Communicate which patients are at heightened risk (i.e. pregnant or elderly)
- Clearly mark isolation areas on unit floorplan views
- Identify significant and casual contacts between patients and staff
- Direct disinfection efforts to the areas and equipment exposed

In the end, learning curves, user involvement and administrative support are key variables in the success or failure of automated surveillance. There is a concern that technology, if not properly utilized, can lead to information overload and overdependence on technology itself. It is important to recognize that data obtained from electronic surveillance obviates the need for manual abstraction, but does not necessarily meet surveillance definitions without further analysis (i.e. NHSN definitions). The threshold for detection of patterns and clusters is usually

low. It is important to recognize that data must be evaluated to determine its significance. Central to this theme is that technology is not a substitute for critical thinking, but is an important tool to assist the infection preventionist in obtaining and utilizing information to drive improvements. An annotated bibliography on surveillance technology resources can be found at http://www.apic.org/Resource_/TinyMceFileManager/Practice_Guidance/Surveillance-technology-literature-references.pdf.

3. STAKEHOLDERS AND THEIR NEEDS

Stakeholders, include not only our system's intended users, but also any person or organization that have an effect on creating the system or with an interest in it. Generally, besides the users it includes: clients, engineers for the system development and maintenance, managers, sponsors, external bodies such as domain experts and regulators.

Taking into account the above definition we have identified the following stakeholders:

· Doctors - they receive alerts in case the prevention rules are not respected and decide to take further action upon the received data from the system. Moreover, they also receive alerts in case two users of the system, out of which one with high risk infection, are in contact and the amount of time they have been in contact which will serve to reach a faster and more accurate diagnostic as well as possibly prevent the infection spread.

· Patients - they interact with the system by wearing the bluetooth bracelet from the moment they are hospitalized which allows the system to monitorize them. The data collected from patients is crucial in avoiding the risk of infection spread and ensuring their health and safety.

· Developers - they are directly involved in the development process of the system.

· Ministry of health - it is crucial for the system to comply with the current health safety standards. Therefore, he/she decides whether this is respected.

· Government - The system is intended to be implemented in all the public hospitals of the country which are owned by the government. Therefore, the primary customer of our system is the government. Nevertheless, the option of private hospitals using our system needs to be further discussed, taking into account the opinion of the main customer as well.

· Suppliers of monitoring equipment - certain equipment are required for the system to function such as beacons for the location proximity and bluetooth bracelets for the interaction

person-location and person-person. These materials need to be of high quality and the suppliers handle their delivery.

4. SYSTEM REQUIREMENTS

The Hospital Infection Monitoring System is a complex system which will intertwine different development domains. The different requirements of the system can be classified into 3 broad categories:

Financial Requirements

Such an innovative system will require a large financial investment for a successful deployment. Therefore, we predict the need for a total sum of €800,000 that will represent the budget allocated for this project.

Human Resources

This is one of the most important areas in this complex system. It must be carefully managed to ensure a fluent development process. They are split up into different departments that are closely interact with one another:

- Research Department
- Development Department
- Quality Assurance Department
- Legal Department

Technological Requirements

The system for preventing and monitoring infections is a complex system which requires several modules to achieve its purpose. We have split it into two sides:

1. The Client Side

- Information gathering module

This represents the central element in the bluetooth bracelet used in Hospital Infections

Monitoring System. Once it is in the signal area of the beacon, it gathers information about the user's interaction status with people or assets (eg sink).

· Communication Module

This must allow long range transmission and fast exchange of data using the latest communication protocols. It ensures confidentiality by means of data encryption.

· GUI Module

Bridges the gap between the infection preventionists (IP) and the device. Provides a simple and intuitive design to which users can easily become accustomed.

2. The Server Side

· Communication Module

It must be able to sustain high data traffic and offer a wide spread coverage area in order to offer reliable services.

· Data Processing Module

After the system receives the system receives the patient data, it converts the string of bytes into information that can be understood by the medic.

· Data Storage Module

All processed information is recorded in a database, including diagnostics, prescriptions, user statistics, etc. A detailed view of the requirements of the system can be seen in the Requirements Diagram.

5. APPROACH TO SOLVING THE PROBLEM

We made use of the WBS diagram in order to divide the complexity of our project into smaller, more manageable tasks, as follows:

1) Planning;
2) Project requirements;
3) Detail design;
4) Development;
5) Integration and Testing.

These tasks are also divided into simpler objectives, to clearly set milestones and achievements so far.

For an efficient planning ahead and allocation of resources within the team, we leveraged the Gantt Chart. Each project development phases enumerated above and its respective deliverables are chronologically linked and also present the different resources that have been applied.

Since goals are too broad and it is difficult to derive specific system characteristics from goals, we used requirements to concretize our envisioned goals by describing in detail what features and characteristics a system must offer in order to satisfy the stakeholders. As such, we used requirements diagram, which provides an easy overview of your system and ensures traceability of product development. Others diagrams we build to easy our road to develop the application in an organized manner are the block definition, package, activity, and use case diagrams.

Work breakdown structure

Through the work breakdown structure diagram we separated each member's work into

manageable sections. The scope of the project is derived into these sections so the team can carry the project objectives easier and faster while focusing on each aspect, rather than a whole subject. (Annex 2)

Gantt chart

The work sections that were separated before in the work breakdown structure diagram are present here and described a little bit further in terms of time intervals, priority and dependency between activities. (Annex 3)

Block definition diagram

This diagram comprises of parts of the system and relationships between them. It is an easy way to represent the system, its components, and the interaction between them, while explaining its [system] structure. (Annex 4)

Package diagram

Through the package diagram we structured the elements of the software part of the project grouped by categories. It adds an easy upgrade to seeing the components of the software. (Annex 5)

Activity diagram

This diagram represents the main flow of a scenario which involves a patient being hospitalized. The main role of this project is showcased in this activity diagram and expresses the way in which the project helps the doctors and the patients. (Annex 6)

Use case diagram

The use cases represent an event which can be triggered by an actor while interacting with the system. They are basically the main functionalities that a system should have. Each use has a result only available by triggering it. It also shows which actors interact with which use case.

(Annex 7)

Requirement diagram

Through the requirement diagram we established what requirements does the system need and the methods that satisfy these requirements. (Annex 8)

6. CHALLENGES AND ISSUES

Risks relate to possible future problems, and involve a possible cause and its respective effects. Taking into account the complexity of such system, it is crucial for the success of our project to follow the steps for approaching risks:

- Risk identification – What are the risks to our project?
- Risk analysis – What is the probability and impact on the project?
- Risk prioritization - Which risks are important for us?
- Risk planning – What shall we do?
- Risk monitoring – Has the planning worked?

Therefore, risks are described in detail in the attached Risk Management Plan (Annex 1).

Apart from the risks that you can read about in the aforementioned Annex, one of the most important challenges we may encounter is regarding the environmental aspect, more specific the impact the system will have on its end-users. Taking into account that this system is an innovative one on the Romanian market, it can occur that the hospitals are reluctant to change, even if the buyer supports the project. This is why, we are planning a good promotion campaign such that not only the buyer is well-informed about the system, but also all the hospital staff and country population.

Even though there are several identified risks, they do not create problems if are properly managed. Fact for which, they will be closely monitored.

7. QUALITY ASSURANCE PLAN

The quality assurance plan is designed to provide a common framework for effective communication, documentation, deviation identification and correction throughout the project. In order to ensure the quality of the product, we must specify a series of quality standards which we must fulfill. We impose the following goals of the quality assurance procedures:

1. Produce high quality deliverables on time and specification in accordance with the work schedule;

2. Identify deviations from the work plan in an early stage;

3. Take remedial actions as soon as possible.

Taking into account the above goals, we have developed a strategy for fulfilling them:

· Identify criteria and standards that ensures the quality of both the development process and the resulting outputs

· Provide documentation for tools, methods and techniques for the insurance of quality

· Constantly monitor the development process and record all deviations from the norms

· Proper transfer of information – any and all notification must be submitted to each department head, to be disseminated amongst the staff

The metrics we thought of are:

1) False positive alerts

To evaluate accuracy/correctitude, we consider a proper way is by measuring "false alarms", given conditions marked as having been fulfilled, when they actually have not been fulfilled (a patient/doctor washing their hands, when they actually just went close to the sink).

To gather the necessary data, there should be some supervisors to check for a limited period of time the probability of false positive being encountered, in patients with different ages, and in doctors with different specialization (some are more stress prone and in the rush, they may only create false positive).

Formula: $\frac{False\ positive}{True\ positive}$;

2) Signals' length

We want the best performance, and we are aware that in order to obtain it, our beacons, readers should have the proper signal length, in order to catch proper signals and not additional, useless information. Through testing with IP, what information they find relevant, this can be achieved.

Formula: $\frac{False\ positive}{True\ positive}$;

8. CONCLUSIONS

“The current health care system is neither healthy, caring nor a system” (Walter Cronkite). Not anymore! The Romanian health system will be able to support a genuine well-being of the patients and doctors through the use of Hospital Infection Monitoring System.

The Hospital Infections Monitoring System is a complex system, which needs careful planning in order to succeed. The system requires apart from proper planning, proper design, implementation and testing. The data obtained from the patients needs to be securely transmitted to the server. Together with the disease type and spread risk of infections, the system has all the necessary data in order to provide a safety environment for the medical staff as well as patients.

In an environment where there is a high risk of getting infectious diseases, such a system is more than needed for assuring an optimal healing environment. We are confident that Hospital Infection Monitoring System will revolutionize the health status in many hospitals around the country!

9. REFERENCES

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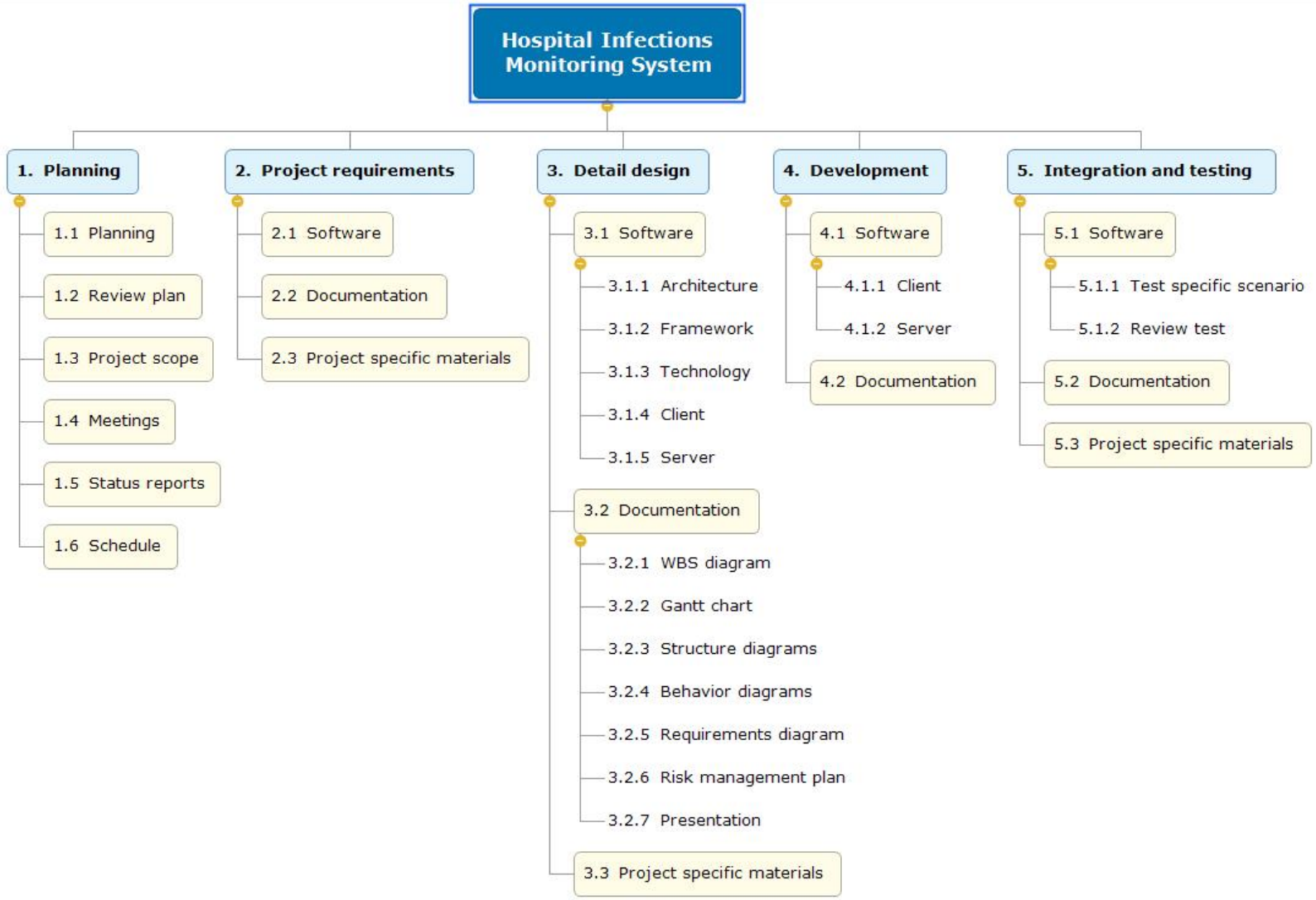
Hospital Infections Monitoring System
1. Planning
1.1 Planning
1.2 Review plan
1.3 Project scope
1.4 Meetings
1.5 Status reports
1.6 Schedule
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5. Integration and testing
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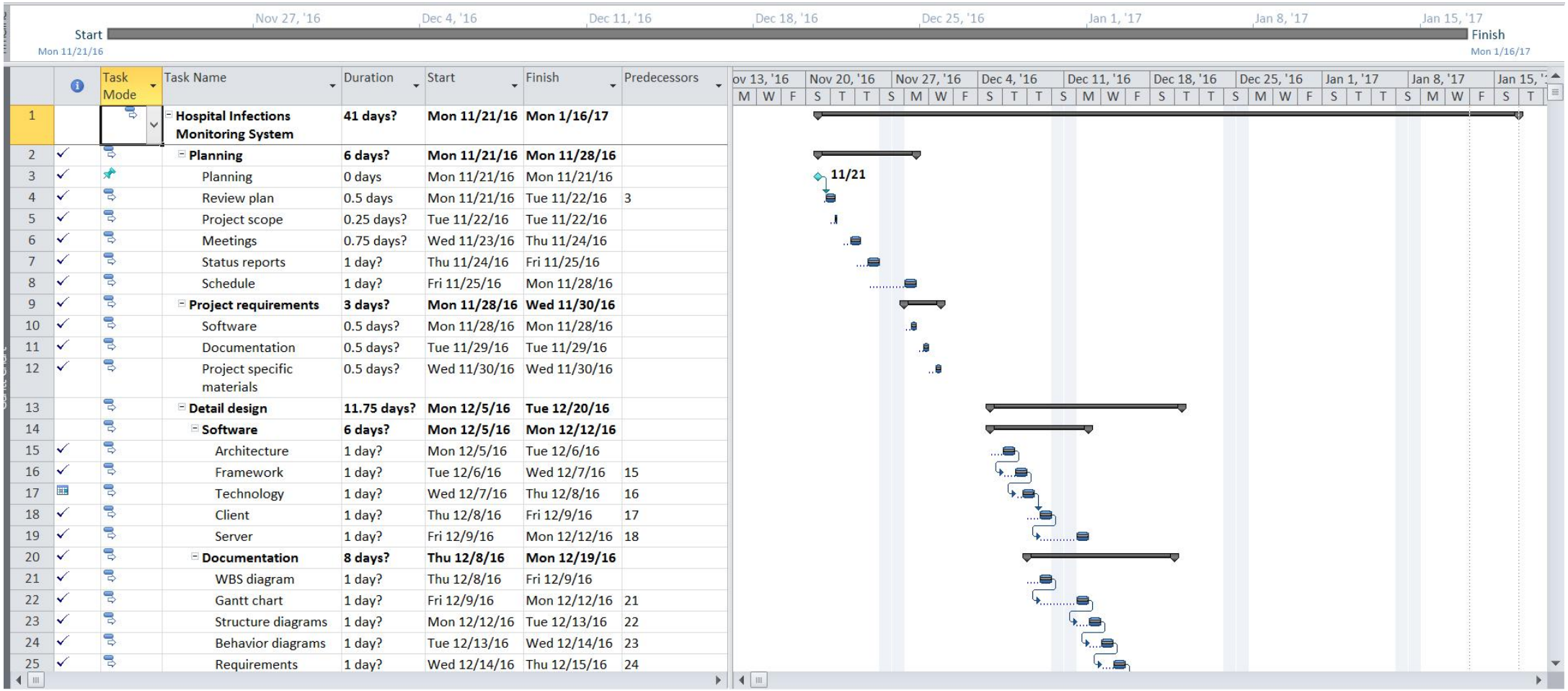
5.1.1 Test specific scenario
5.1.2 Review test
5.2 Documentation
5.3 Project specific materials



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3	✓	Planning	0 days	Mon 11/21/16	Mon 11/21/16	
4	✓	Review plan	0.5 days	Mon 11/21/16	Tue 11/22/16	3
5	✓	Project scope	0.25 days?	Tue 11/22/16	Tue 11/22/16	
6	✓	Meetings	0.75 days?	Wed 11/23/16	Thu 11/24/16	
7	✓	Status reports	1 day?	Thu 11/24/16	Fri 11/25/16	
8	✓	Schedule	1 day?	Fri 11/25/16	Mon 11/28/16	
9	✓	**Project requirements**	**3 days?**	**Mon 11/28/16**	**Wed 11/30/16**	
10	✓	Software	0.5 days?	Mon 11/28/16	Mon 11/28/16	
11	✓	Documentation	0.5 days?	Tue 11/29/16	Tue 11/29/16	
12	✓	Project specific materials	0.5 days?	Wed 11/30/16	Wed 11/30/16	
13		**Detail design**	**11.75 days?**	**Mon 12/5/16**	**Tue 12/20/16**	
14		**Software**	**6 days?**	**Mon 12/5/16**	**Mon 12/12/16**	
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22	✓	Gantt chart	1 day?	Fri 12/9/16	Mon 12/12/16	21
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	Task Mode	Task Name	Duration	Start	Finish	Predecessors
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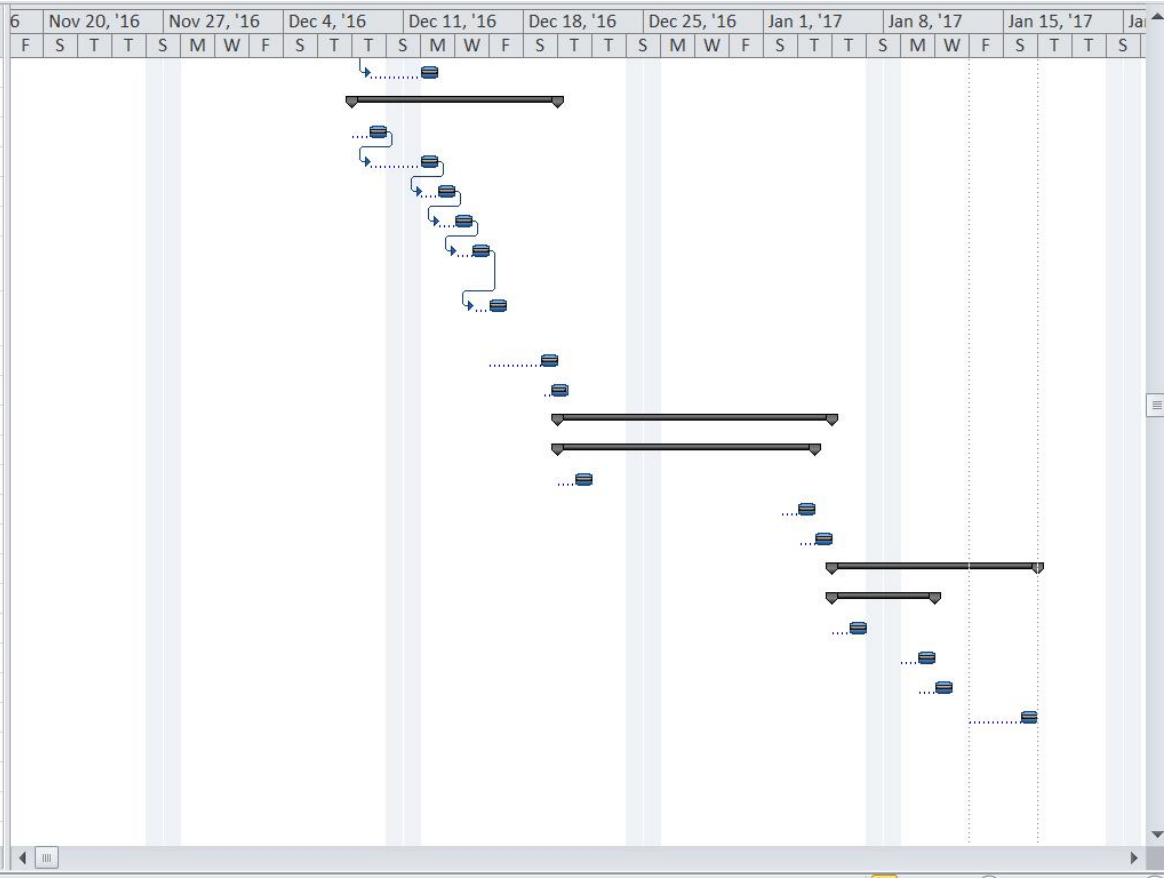

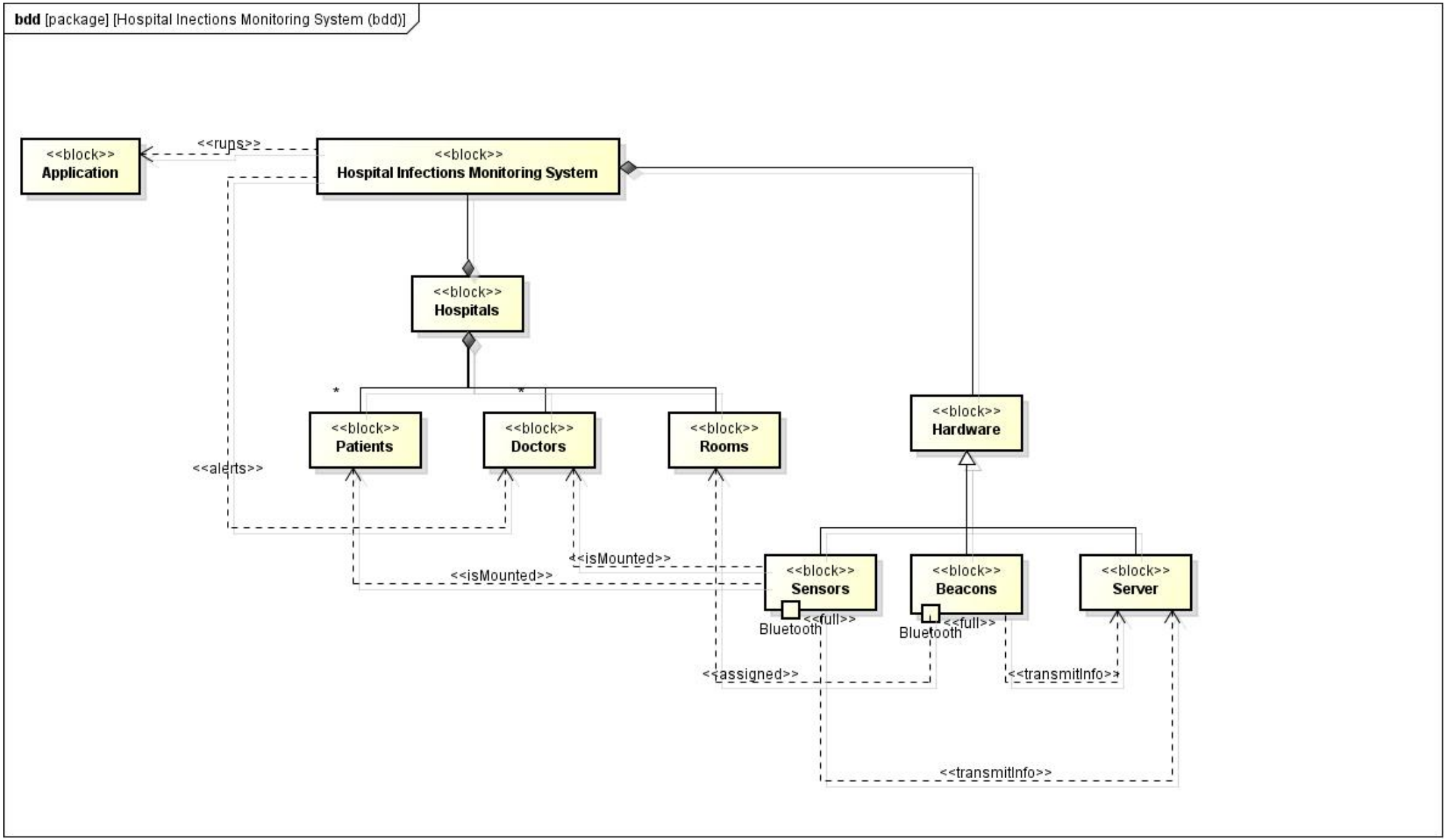
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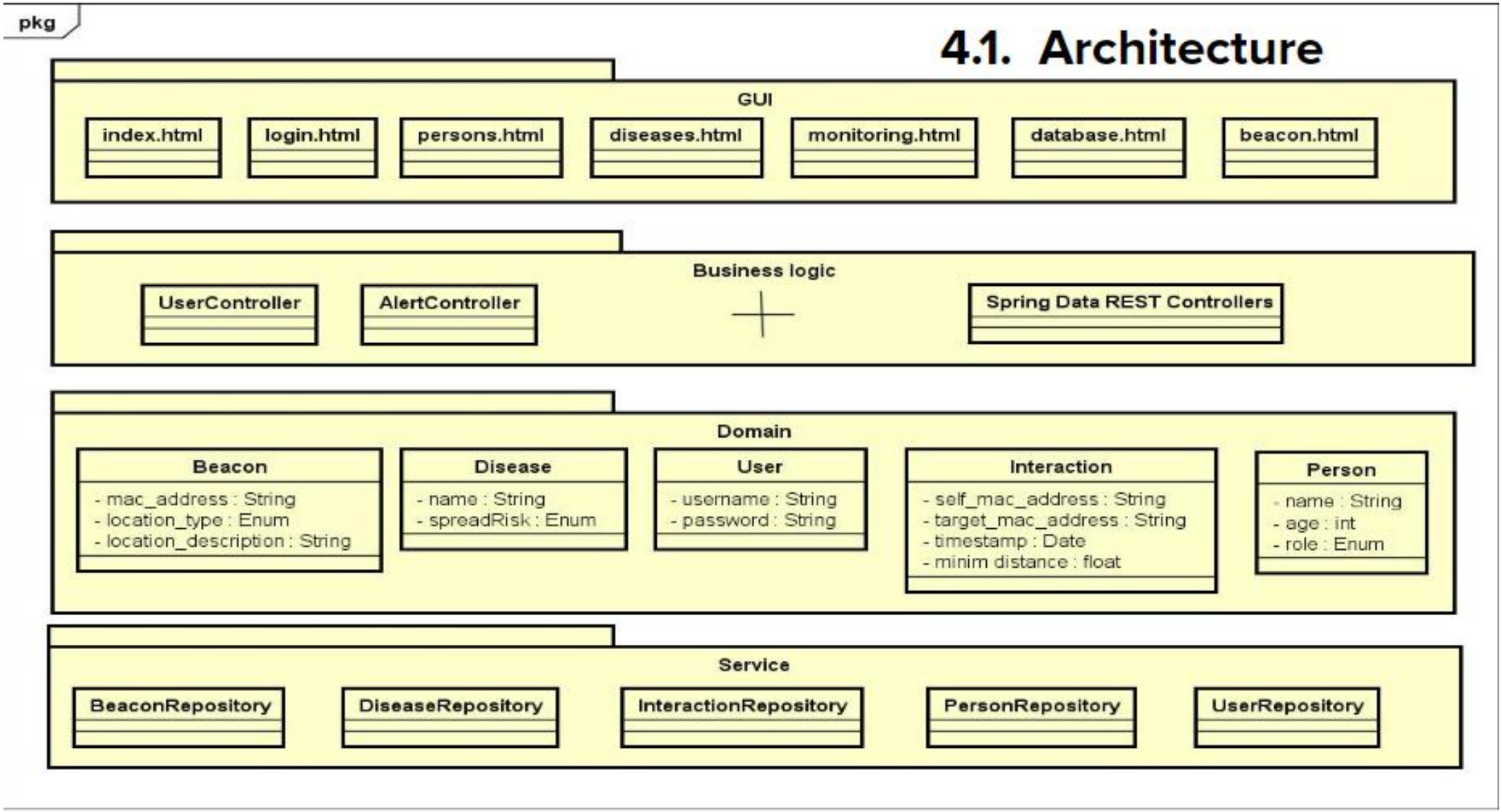
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4.1. Architecture
GUI
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beacon.html
Business logic
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AlertController
Spring Data REST Controllers
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- location_description : String
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- name : String
- spreadRisk : Enum
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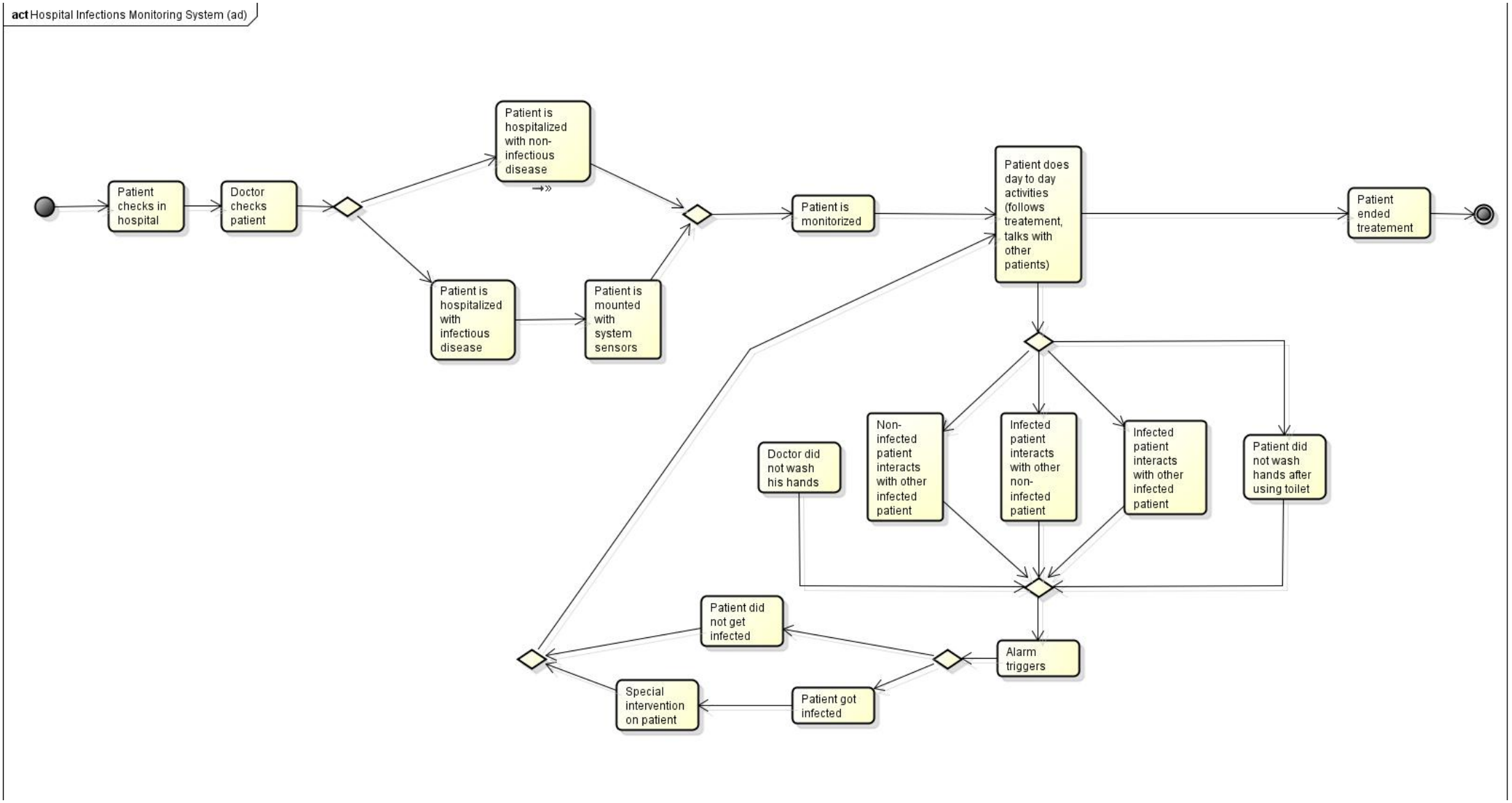
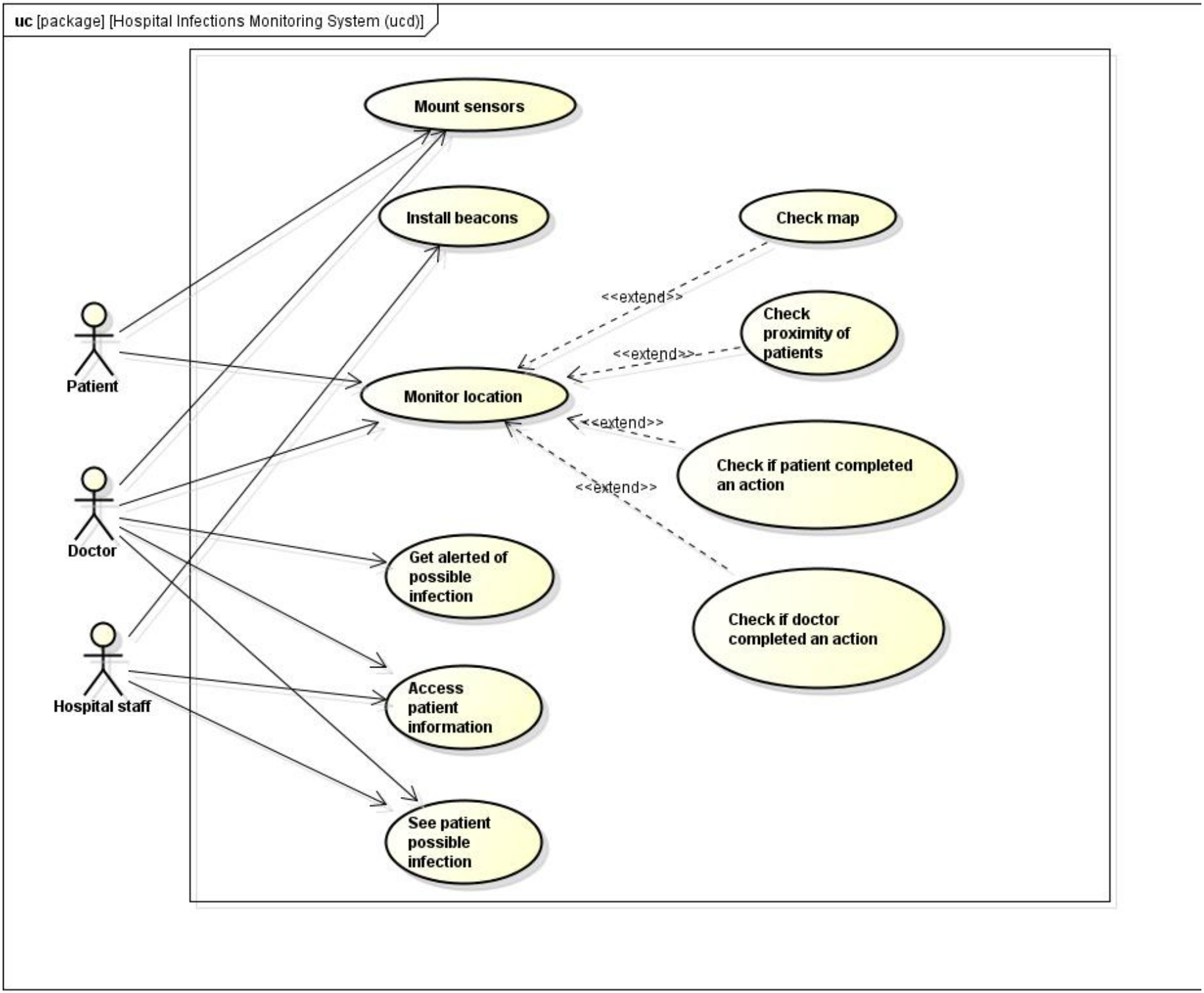
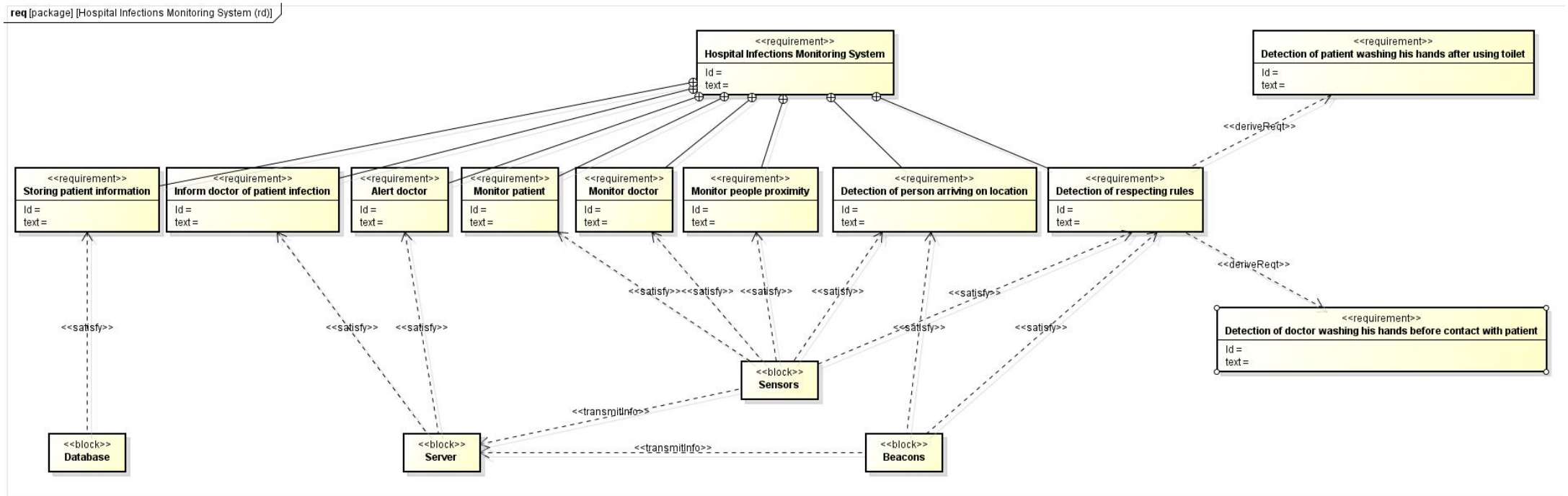

act Hospital Infections Monitoring System (ad)
Patient checks in hospital
Doctor checks patient
Patient is hospitalized with non-infectious disease
Patient is hospitalized with infectious disease
Patient is mounted with system sensors
Patient is monitorized
Patient does day to day activities (follows treatement, talks with other patients)
Patient ended treatement
Doctor did not wash his hands
Non-infected patient interacts with other infected patient
Infected patient interacts with other non-infected patient
Infected patient interacts with other infected patient
Patient did not wash hands after using toilet
Alarm triggers
Patient did not get infected
Special intervention on patient
Patient got infected

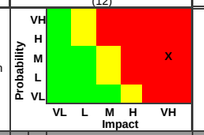
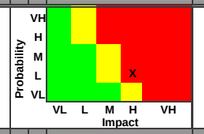
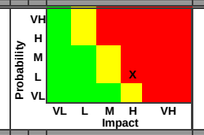
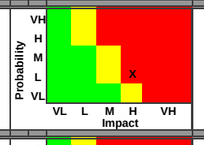
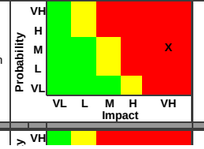

uc [package] [Hospital Infections Monitoring System (ucd)]
Mount sensors
Install beacons
Check map
<<extend>>
Check proximity of patients
<<extend>>
Patient
Monitor location
<<extend>>
Check if patient completed an action
<<extend>>
Doctor
Get alerted of possible infection
Check if doctor completed an action
Hospital staff
Access patient information
See patient possible infection


req [package] [Hospital Infections Monitoring System (rd)]
<<requirement>>
Hospital Infections Monitoring System
Id =
text =
<<requirement>>
Detection of patient washing his hands after using toilet
Id =
text =
<<deriveReqt>>
<<requirement>>
Storing patient information
Id =
text =
<<requirement>>
Inform doctor of patient infection
Id =
text =
<<requirement>>
Alert doctor
Id =
text =
<<requirement>>
Monitor patient
Id =
text =
<<requirement>>
Monitor doctor
Id =
text =
<<requirement>>
Monitor people proximity
Id =
text =
<<requirement>>
Detection of person arriving on location
Id =
text =
<<requirement>>
Detection of respecting rules
Id =
text =
<<deriveReqt>>
<<requirement>>
Detection of doctor washing his hands before contact with patient
Id =
text =
<<satisfy>>
<<block>>
Sensors
<<transmitInfo>>
<<block>>
Database
<<block>>
Server
<<block>>
Beacons
<<transmitInfo>>

Date

Project Mngr Name

PROJECT RISK MANAGEMENT PLAN

Priority	Identification							Qualitative Analysis				OPTIONAL Quantitative Analysis			Response Strategy			Monitoring and Control		
	Status	ID #	Date Identified Project Phase	Functional Assignment	Threat/Opportunity Event	SMART Column	Risk Trigger	Type	Probability	Impact	Risk Matrix	Probability (%)	Impact ($ or days)	Effect ($ or days)	Strategy	Response Actions including advantages and disadvantages	Affected WBS Tasks	Responsibilty (Task Manager)	Status Interval or Milestone Check	Date, Status and Review Comments
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15) =(13)x(14)	(16)	(17)	(18)	(19)	(20)	(21)
	Active	1	28.12.16 PID	Management	Bad Estimation Time	Overdue in finishing the project. Can have as result increase of costs(paying people, resources, etc.) as well as unsatisfied client.	Bad evaluation of the project complexity	**Schedule**	Moderate	Very High		50%	30	60	Avoidance	Properly compute the amount of time necessary as well as evaluate regularly the progress. (after each phase of the project)	WBS 100 Project Management	P.M.	Project Start	13.01.17
	Dormant	2	28.12.16 PA&ED	Management	Competition	Potential competitors having same kind of product with better marketing promotion.	Product released/announced by competition. Commercial.	**Cost**	Low	High		30%	5000		Acceptance	In case it happens, invest more in marketing and eventually add a functionality that the competitor does not have.	WBS 100 Project Management	P.M.	Beta Testing	13.01.17
	Active	3	29.12.16 Construction	Testing	Compatibility Issues	The bluetooth bracelet is not compatible with the other devices (such as the beacons)	Not the best implementation and mainly technology	**Quality**	Low	High		30%	30		Mitigation	Switch to better technology that is compatible.	WBS 190 Prepare Structure Site Plans	P.M.	Construction	13.01.17
	Active	4	30.12.16 Construction	Construction	Beacon failure	The system highly relies on the communication between bracelets and beacons. In case the beacons malfunction, the system will only fulfill part of their role, receiving only data from person-person interaction.	Bad choice of beacon components	**Cost**	Low	High		30%	5000		Avoidance	Research the best beacon components and pick the suitable ones. Have a prototype testing before the production.	WBS 160 Perform Preliminary Engineering Studies and Prepare Draft Project Report	P.M.	ial phase and prototy	13.01.17
	Dormant	5	05.01.17 Construction	Environmental	Market impact	The system might not attract the main buyer due to the low promotion or price or lack of seeing its benefits	Bad marketing and proj. mang.	**Cost**	Moderate	Very High		50%	ed money pr		Avoidance	Good marketing. Respect deadlines such that costs are not increasing.	WBS 150 Develop Project Initiation Document (PID)	P.M.	All phases	13.01.17
			30.12.16			The system highly relies on the data											WBS 160 Perform			