Project Deliverable C: Conceptual Design, Project Plan, BOM and Feasibility Study

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C.1 Conceptual Design. As a group:

1. Based on customer needs, clarify core functionality by breaking down required product functions (functional decomposition) into smaller basic sub-functions, identifying external sub-system boundaries.

Saint Vincent's Hospital is looking for a product that helps accurately and quickly detect (and ideally prevent) falls when a caregiver is not present.

- The fall detection system is adaptable for use with patients who have varying degrees of mobility.

- The fall detection system runs 24/7 providing a continuous analysis of the patient's state.
    - The device is scanning/monitoring the patient

- The fall detection system sends an immediate alert to caregivers right after a fall is detected.

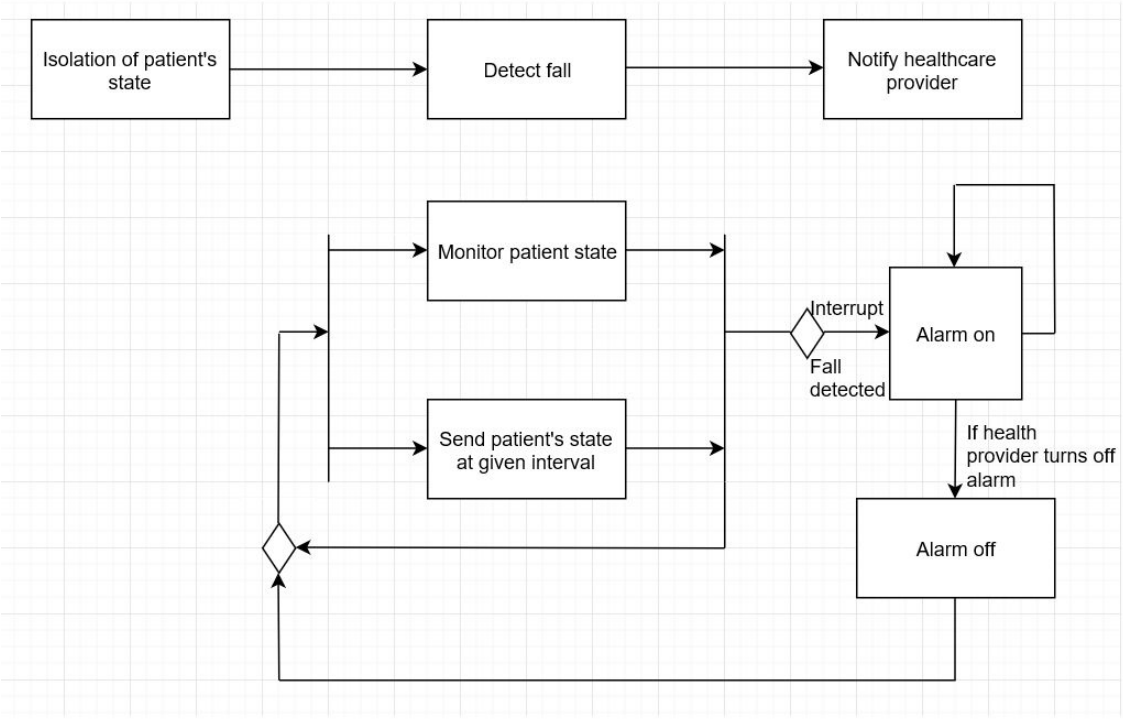
- The fall detection system is affordable and is easily deployable.
    - The cost is further explained in the BOM

- The system integrates with the patient or caregiver without disrupting routine/typical activities.

- The system works with surrounding medical and hospital systems without modifying their behaviour.

- The system detects falls such as slips, tumbles, buckles and rolls with a high level of accuracy and efficacy.

The high-level, abstract, functional decomposition is portrayed by the diagram provided below. In general, any fall detection (or prevention) system must follow the states outlined in the graphic provided. In the case of a fall prevention system, the state named "alarm on" would also act as the state that handles the mechanisms of prevention.



2. Provide a minimum of 3 product concepts per team member (clearly identify each concept's creator).

The following 12 ideas were identified as potential concepts from the team. The ideator is listed within square brackets, and the list is sorted by team member's name.

- Sensor pad jacket/vest (reacts/alerts when there's an impact with the ground) **[Karim]**
- Walkie talkie (fall monitor) **[Karim]**
- A necklace that alerts the caregivers when pulled **[Karim]**

- Better handles and railings around the room/bed + warning signs ("Use the handles in order to prevent a fall") **[Vanessa]**
- Customizable impact sensor clothing **[Vanessa]**
- Cushion mats that prevent injuries and inform caregiver **[Vanessa]**

- Robot that grabs person before falling **[André]**
- Accelerometer + belt **[André]**

- Spiderman weblike grapple that catches patient that falls **[André]**

- Auto-inflating vest that reduces injury from falls **[Manit]**
- Camera that tracks falls using object recognition **[Manit]**
- Soft floor + Pressure Detection **[Manit]**

3. Analyze and evaluate all concepts provided by each team member based on the target specifications of Project Deliverable B. Use simple calculations and/or simulations to make decisions. Justify the process and methods used for analysis and evaluation.

As the suggestions provided aboved overlapped, it was not necessary to evaluate each concept individually; rather, some ideas were consolidated for the study. Additionally, criteria of evaluation were also not considered entirely individually. Take for example the length, width and volume of product (which directly correlate to patient comfort); these three metrics were combined into the metric called “Geometry of Product.” For the purposes of comparison, this is sufficient and arguably more efficient.

Selected criteria	Auto-inflating Vest	Accelerometer+Belt	Sensor pad jacket/vest	Necklace that alerts care givers	Improved handles and railings around the bed	Customizable impact sensor clothing	Object recognition camera	Robot that grabs person before falling	Cushion mats that prevent injuries and inform caregivers	Spider-Man weblike grapple that catches patient that falls	Soft floor+ Pressure Detectors
Detection Time	2	1	1	3	5	1	1	2	3	5	2
Accuracy	5	1	1	3	4	1	3	2	2	2	2
Mass of product	2	2	2	1	1	1	0	5	0	0	3
Geometry of Product	2	1	1	1	1	1	1	3	1	3	2
Electrical Power Required	1	1	1	1	0	1	3	2	2	0	2
Production Cost Estimate	2	2	2	2	3	2	4	5	2	2	2
Product Implementability	2	1	1	1	1	1	1	5	2	2	1
Total	16	9	9	12	15	8	13	24	12	14	14

All of the solutions above are ranked on a scale from 1 to 5, 1 being the best and 5 being the worst. A “0” only means that the concept doesn’t require that component at all and therefore doesn’t have a significant impact on the overall product implementability. Based on the total of all the columns,the best solutions are the one with a total less than 10.

4. Choose one or a few promising solutions you wish to develop further based on your evaluation.

From the analysis and comparison done above, the three leading concepts all had a similar theme. As such, they are all listed as promising solutions that the team believes will eventually become the final, implemented prototype.

- Sensor Pad Jacket/Vest
- Accelerometer + Belt
- Customizable impact sensor clothing

5. Develop a group design concept which is either an integration or modification of the promising concepts chosen in the previous step, or a brand-new concept created from these ideas. Justify your approach.

Due to the similar nature of the projects chosen to be best amongst all options, a combination and substitutions of these concepts was primarily used to develop the eventually chosen concept. The process is captured by the following, customized table.

The table works by noting the major components that each of the narrowed concepts entailed and assigning a status of being kept or being discarded for the final concept.

Concept Name	Concept Component	Status
Sensor Pad Jacket/Vest	Vest	Discarded
	Force Sensor Pad	Kept
	Computation Element (microcontroller)	Kept
Accelerometer + Belt	Accelerometer	Discarded
	Computation Element (microcontroller)	Kept
	Belt	Discarded
Customizable impact clothing	Impact Sensor	Discarded
	Customizable Clothing	Kept

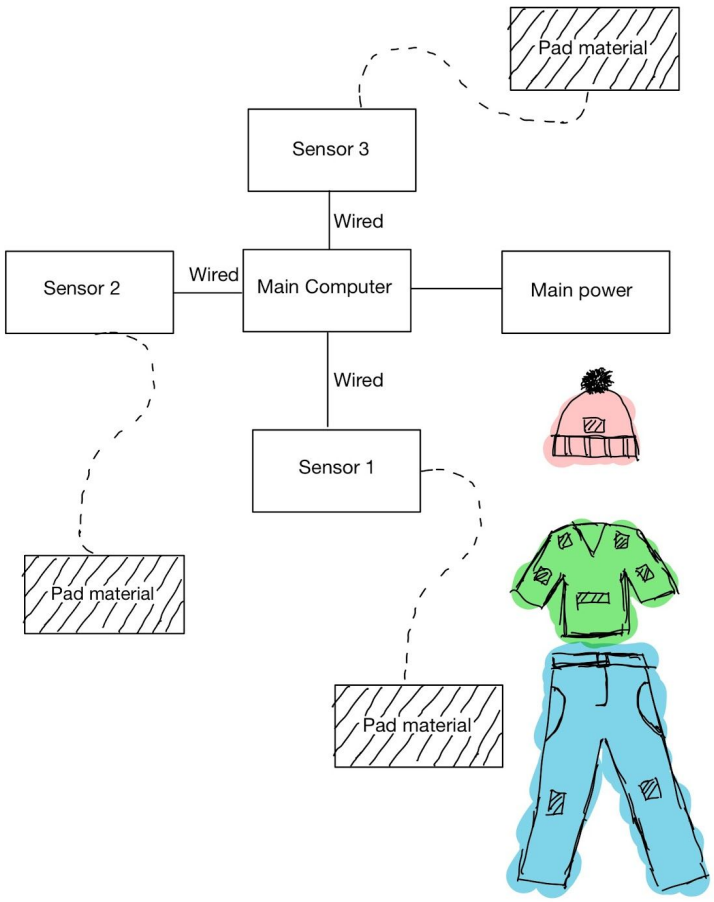
	Computation Element (microcontroller)	Kept

To explain the lines of this table, the group decided to keep the idea of having sensing pads on a line of customizable (and potentially fashionable) clothing with the main computation element being a simple microcontroller. What is not captured in the table above is the notion this product will involve a careful and meticulous development of software that provides the magic, so to speak, of calibration and detection of falls.

To summarize: The solution to the client's desire for a non-intrusive product that helps track falls of patients is a line of clothing with cleverly integrated force sensing pads from which data will be collected and analysed for the detection of a falling event - upon which a caregiver will be informed. This solution provides a simple implementation to a difficult problem and also allows for future improvements in truly meaningful, and perhaps unexpected ways.

6. Visually represent (sketch, diagram, CAD model, etc.) your group concept.

The chosen concept's hardware can be quite easily visualized from the following diagram:



The diagram is only meant to provide the reader of this document an idea of the concept and does not provide any details of implementation. Furthermore, the number of sensing pads on clothing will be a topic of optimization and research. To achieve the most accurate results, these pads will be strategically placed to improve the odds of positive detections, while reducing the odds of false positives.

7. Provide a few lines explaining your concept's relationship to the target specifications, as well as its benefits and drawbacks.

In reality, what the client truly wants is an effective fall prevention product. However, with the constraints of resources (particularly financial and temporal) a successful project in that domain is difficult; but, a good step in that direction is an accurate fall detection platform that further testing, via implementation, can be performed. For that reason, the chosen solution is ideal in the context of both the course requirements and the client's desires. The following two lists specify the benefits and drawbacks.

Benefits

- The patients are able to wear a fashionable clothing piece without the addition of further discomfort
- In case the fall detection alarm goes off after a fall has been detected, it will not interfere with the system already implemented at the hospital
- Once the hardware is implemented and calibrated, different algorithms can be eventually tested for better fall detection rates

Drawbacks

- Doesn't prevent falls in any way
- The simple hardware may mean that some types/mechanisms of falls are not accurately captured

C.2 Project Plan, BOM and Feasibility Study. Using the Project Management Workbook provided in class:

1. Develop a project plan and ensure you address each point in the workbook.

The overarching plan of this project will follow the natural flow of prototype development. The three major prototypes and their intentions are listed first.

Prototype 1 - Conceptual

The intention of the first prototype will be to test the comfort levels and visual appeal of the eventual product. Furthermore, the prototype will provide a gauge of the level of difficulty of hiding/protecting the electrical components that will eventually be in place (such as wires and

piezoelectric discs). From these findings, the team will be able to vary the materials used for the final prototype - to increase both comfort, by reducing restrictive constructions, and increase product lifetime.

The required materials for this prototype are provided in the BOM table relating to “Prototype 1” later in this document.

Prototype 2 - Functional

The second prototype will allow for a primary testing of the functionalities required of the final product. That is, all of the sensing pads will be assembled and hooked up to the main computing unit. A choice of main computing unit can be decided by integrating different choices at this stage. This prototype is what the team is calling a “Flat product.” That is to say that while none of the exteriors are implemented, the electrical system is almost fully connected in the way that it is supposed to be. This allows for iterative loops of software design as well as testing complex relations between the sensor readings and the desired outputs of monitoring patient states.

The required materials for this prototype are provided in the BOM table relating to “Prototype 2” later in this document.

Prototype 3 - Final

The final prototype is referred by the team as a “Client hand-off.” This is the prototype that resembles a final product the most. In other words, the “Flat product” will be transformed into the final prototype by adding all exteriors. In this case, those exteriors are attaching the pads to clothing, to create the initial clothing lineup. This prototype will be handed off to the client for further testing on their end as well as be used for demonstrations.

The required materials for this prototype are provided in the BOM table relating to “Prototype 3” later in this document.

Now that the three prototypes have been explicitly stated, the desired timeline for the project can be fully defined; it is provided here in table format (but which can also be provided in the form of a gantt chart if desired by the client):

Task No.	Task Name	Task Description	Task Owner	Prerequisite Tasks	Task Deadline
1	PD C	Conceptual design + Project plan	Milestone	-	Feb 3rd

2	Circuit Diagram	Fully develop the diagram specifying all electrical components and connections	Vanessa	-	Feb 8th
3	Initial Software Design	Develop state and activity diagrams for the required software	Karim/Andre	-	Feb 8th
4	Prep for Prototype 1	Gather all required materials for first prototype	Manit	-	Feb 6th
5	Build Prototype 1	Assemble the conceptual prototype	All members	4	Feb 8th
6	PD D	Detailed Design + Prototype 1	Milestone	5	Feb 10th
7	Presentation Preparation	Create the slidedeck for progress presentation	Vanessa	5, 6	Feb 10th
8	PD E	Project progress presentation (in lab)	Milestone	7	Feb 11th
9	Collection of Fall Data	Collect data on fall mechanisms from online datasets	Karim	-	Feb 13th
10	Analysis of Fall Data	Achieve first pass list of major body positions where sensor pads would be most effective	Manit	7	Feb 15th
11	Prototype 2 Prep	Gather/order all required materials for first prototype	Vanessa	2, 3, 6	Feb 15th
12	Business Model Prep.	Write up the business model	Andre	1	Feb 23rd
13	Build “Flat Product”	Connect all electrical components together	Vanessa Manit	11	Mar 1st
14	PD F	Business model	Milestone	12	Mar 3rd
15	Implement Software	Write all software necessary to perform functions	Andre/ Vanessa/ Manit/ Karim	13	Mar 6th

16	Test “Flat Product”	Test all functionality of prototype 2	Andre/ Vanessa/ Manit/ Karim	15	Mar 8th
17	PD G	Prototype II and customer feedback	Milestone	16	Mar 10th
18	Prep Economics Report	Write report describing economic study in detail	Manit/ Karim	-	Mar 15th
19	Prep Video Pitch	Record and edit 1 min video	Vanessa/ Andre	17	Mar 15th
20	Final Prototype Prep	Order and gather all components needed for final prototype	Karim	17	Mar 15th
21	PD H	Economics report + 1 min video pitch	Milestone	18, 19	Mar 17th
22	Build final prototype	Turn the implementation from “Flat Product” into final product	Andre/ Vanessa/ Manit/ Karim	20	Mar 22nd
23	Test Final Prototype	Test all functionality of prototype 3	Andre/ Vanessa/ Manit/ Karim	22	Mar 28th
24	PD I	Design day presentation (w Judges+ clients)	Milestone	23	Mar 29th
25	Final Demonstration Prep	Develop the final demonstration	Vanessa/ Karim	23	Mar 31st
26	Final Presentation Prep	Create slide deck for final presentation and practice	Andre/ Manit	23	Mar 31st
27	PD M	Final presentation with final prototype	Milestone	25, 26	Mar 25th or Apr 1st
28	IP and Patent Prep	Complete required tasks for PD J	Andre/ Vanessa/ Manit/ Karim	23	Apr 5th

29	PD J	Intellectual Property, Patent/Creative Commons Search	Milestone	28	Apr 5th
30	Final Report Prep	Write final report	Andre/ Vanessa/ Manit/ Karim	27	Apr 12th
31	PD L	Final report	Milestone		Apr 12th

While it is expected that this desired timeline will likely get delayed, there are cushion/contingency periods assigned between each milestone (deliverable) to account of these delays.

The definition of the planned prototypes and the timeline of detailed tasks completed, the project plan is fulfilled. The team will follow the plan described above and below to complete the project on schedule and budget.

2. Provide a detailed bill of materials and parts (BOM) for each prototype, which will be presented to your project managers for approval and purchase. You will be given up to $100 for the development of your final prototype only.

The Bills of Materials (BOM) are provided for each of the three prototypes discussed in the project plan.

Prototype 1 : Conceptual, Low Budget						
Item No.	**Item Name**	**Description**	**Quantity**	**Unit Cost [$]**	**Extended Cost [$]**	**Cost to Team [$]**
1	T-shirt	One of the most simple clothing items that will be developed in the initial line	1	$15	$15	$0
2	Toque	Another potential clothing item that will be developed in the initial line	1	$20	$20	$0
3	A132412-DS-ND	24 AWG Copper wire	25 ft	$0.5064	$12.66	$0
4	Analog for	3mm thick Cardboard/plywood	1 board	$17.20	$17.20	$0

	Sensor - G1S Plywood	cutouts that will mimic the piezoelectric plates that will eventually be used	[24in x 48]			
5	Double Sided Tape	Used to temporarily attach the pad material to clothing	1 Roll	$5.80	5.80	$0
6	Pad Material	Likely thin nylon or scrap fabric laying around somewhere	To make 4 pads	-	-	-
Totals					$70.66	$0

Prototype 2 : Functional, Low Budget						
Item No.	**Item Name**	**Description**	**Quantity**	**Unit Cost [$]**	**Extended Cost [$]**	**Cost to Team [$]**
1	Arduino Nano	Main computing element candidate I	1	$15.02	$15.02	$15.02
2	Arduino Uno	Main computing element candidate II	1	$35.99	$35.99	$0
3	A132412-DS-ND	24 AWG Copper wire	25 ft	$0.5064	$12.66	$0
4	Piezo Discs	27mm piezoelectric discs with leads attached	1 bundle [12 pcs]	$6.95	$6.95	$6.95
5	Double Sided Tape	Used to temporarily attach the pad material to clothing	1 Roll	$5.80	5.80	$0
6	Pad Material	Likely thin nylon or scrap fabric laying around somewhere	To make 4 pads	-	-	-
Totals					$76.42	$21.97

Prototype 3 : Functional, Full Budget						
Item No.	**Item Name**	**Description**	**Quantity**	**Unit Cost [$]**	**Extended Cost [$]**	**Cost to Team [$]**
1	T-shirt	One of the most simple clothing	1	$15	$15	$15

		items that will be developed in the initial line				
2	Toque	Another potential clothing item that will be developed in the initial line	1	$20	$20	$20
4	Sewing Thread	To stitch the pads onto clothing in a more permanent fashion for client delivery	1 roll 200 yards	$6.40	$6.40	$6.40
5	Arduino Nano	Main computing element candidate I	1	$15.02	$15.02	$0
6	Arduino Uno	Main computing element candidate II	1	$35.99	$35.99	$0
7	A132412-DS-ND	24 AWG Copper wire	25 ft	$0.5064	$12.66	$0
8	Piezo Discs	27mm piezoelectric discs with leads attached	1 bundle [12 pcs]	$6.95	$6.95	$0
9	ESP8266 Esp-01 Serial Wireless Wifi Transceiver Module	Wifi module for main computing element to coordinated with a centralized computer upon which notifications of a fall element will appear	1 bundle [4 pcs]	$12.48	$12.48	$12.48
6	Pad Material	Sheets of flannel	1 meter roll [48in width]	$7.99	$7.99	$7.99
Totals					$132.49	61.87

Totals for All Prototypes	
Prototype ID	Cost to Team [$]
Prototype 1	$0
Prototype 2	$21.97
Prototype 3 [Final - hand off to Client]	$61.87
Total Cost to Team	$83.84

One important note about this initial BOM is that the total cost is heavily dependent on the type of clothing that is chosen for basis of the line. In other words, the client could chose different, cheaper clothing (or clothing already available to them - such as hospital gowns) to reduce the price per unit of product. The entire business case is not shown here, but will rather be provided at a later date.

3. Conduct a feasibility study by discussing the five TELOS factors.

The feasibility of the chosen solution is presented through the TELOS method below:

Technical (T)

The mechanisms of falling are wide and not easily detectable to a certainty. In the clinically ill or elderly, the rate of falling and corresponding consequences are high, even just due to a physiological nature. For this reason, the product must achieve a high rate of detection to help caregivers provide the highest quality of care. Technically, this means that every component chosen must perform within certain tolerances/ranges. The feasibility of achieving these ranges is directly related to the expertise present on the team and the available resources, which of course include time and cost. The following lists present all available resources (and their magnitude):

- Expertise of Team
    - **Karim : Chemical Engineering Student**
        - Experience with sequence optimization and 3D modeling
    - **Vanessa : Electrical Engineering Student**
        - Experience with electrical circuits and low-level microcontrollers
    - **Andre : Software Engineering Student**
        - Experience with writing fully integrated and industry grade software
    - **Manit : Electrical Engineering Student**
        - Experience with physics based modeling and simulation

- Facilities
    - “Maker” Ecosystem
        - Brunsfield - provides tools and some materials for machining
        - Makerspace - provides 3D printing facilities and materials
        - MakerLab - provides meeting location and simple tools
    - SITE + CBY
        - Computers with software
            - Solidworks
            - Ansys
            - MatLAB

- Other Important resources
    - Time
        - 7 weeks from submission date
        - 12 productive person-hours in total per week
        - 84 productive person-hours in total
    - Financial
        - $100 for final product prototype
    - Scrap Material
        - Access to many recyclable material from “Maker” Ecosystem
            - Plywood
            - Scrap metal

From a forward looking perspective, the following steps are likely required to :

- Steps Required for Completion of Project (not entirely ordered)
    - Develop system specifications based on requirement specifications
    - Conduct a survey of available (COTS) central processing computers that will act as the gateway between sensing pads and notifying method
    - Conduct a survey of available (COTS) pressure/impact sensors
    - Literature review of topics in segmentation of digital events, mechanics of falling, statistical analysis of common impact points and comfort/fashion
    - Determine components based on a system development approach
    - Design of robust software to provide ease of use and adaptability
    - implement designed system
    - Implement designed software
    - Test and validate all functionality while also developing an appropriate demonstration for the client
    - Document process and client facing manuals/instructions.

Based on the lists provided, the feasibility of the project on a technical basis is covered. To elaborate, taking every item in the list of required steps matches an item, or derivative thereof, in the list of available resources. More specifically, all forms of expertise are present, the required actions and materials can be formed within the facilities available and the time and finances to develop the prototype are sufficient.

Economic (E)

This project presents a special challenge to heavily consider the economics of a hospital ecosystem. The patients are likely elderly and may not have a wide pool of financial resources to draw from - on that point, the hospital also doesn’t have this. For that reason, the following cost and economic analysis is provided here.

Economics is a game of cost management. Therefore, the first step is to consider the total cost of this project. The budget restrictions are of $100; in other words, the total cost of this project from the point of view of the team is $100. An assumption can be made that the product cost will be approximately 60% of this amount due to prototyping and other activities. Therefore assuming the final product costs less than $60, the following, and likely naive, analysis can be conducted.

The success of this project is based ultimately on the client's ability to implement and further expand upon the designed product. The calculations below show an approximated cost of implementation for SVH.

Number of Patients Considered for Implementation: [per year]	20
Base Cost per Patient: [assumed]	$60
Maintenance Cost per Patient: [approximately required every 6 months]	$5 per sensor pad replacement
Number of Pad Replacements Per Patient:	4
Total cost: [over a 20 year lifespan]	$32000

Or in other words, a total cost of about $1600 per year; for a hospital, this is a very reasonable number to spend for an additional item in the medical technology category of their budget. Of course, these costs would also likely be offset by patient medical or health insurance itself. The exact business plan for this project is not yet determined, but the simple analysis conducted shows the potential of multiple avenues of business methodologies resulting in success.

An important note is that it is expected that an entirely new technology will make this product obsolete within 20 years. Therefore, the analysis was conducted over that period of time.

With these potential of market success, the project is deemed economically feasible: for both the team as well as the client.

Legal (L)

A hospital is an organization like many others, with one major exception: the medical laws and regulations that one must adhere to. Issues of upholding confidentiality and integrity of medical equipment and systems must be carefully considered and followed. While these laws and

regulations are vast in both quantity and complexity, the client provided some guidelines that the team can follow.

The first is to never tamper with equipment that is present. That is, the solution must not need to integrate with onsite equipment, including the existing call system. This is for reasons pertaining to liability and the lack of time to ring up any contract that gets around such liability. The second major guideline is to not interfere with any hospital routines. Following these two major guidelines, the project is sure to avoid any issues facing legality.

Operational (O)

The operation of the team is intrinsically varied due to the nature of studentship.
The group has agreed to meet once per week to get caught up and make major decisions. However, meetings with vague or undetermined agendas tend to end up unproductive. On top of this, course schedules will likely throw off any schedule the team makes. Knowing and understanding this is powerful. In this way, every timeline will have fairly large margins of cushioning between task completion and deadline date.

Furthermore, there are only about seven weeks before the final deliverable needs to be presented - not a lot of time. Therefore, the team will keep this in mind every week, when working towards the end goal.

Scheduling (S)

The table below presents the timeline of the project deliverables. A brief discussion of this timeline follows.

Deliverable	Delivery Date
PD C: Conceptual design + Project plan	Feb 3rd 2019
PD D: Detailed Design + Prototype 1	Feb 10th 2019
PD E: Project progress presentation (in lab)	Feb 11th 2019
PD F: Business model	Mar 3rd 2019
PD G: Prototype II and customer feedback	Mar 10th 2019
PD H: Economics report + 1 min video pitch	Mar 17th 2019
PD I: Design day presentation (w Judges+ clients)	Mar 29th 2019

PD M: Final presentation with final prototype	Mar 25th or Apr 1st
PD J: Intellectual Property, Patent/Creative Commons Search	Apr 5th 2019
PD L: Final report	Apr 12th 2019

From the table, each major deliverable for this project occurs approximately one week after it's predecessor. While the number of deliverables for a project of this nature seems excessive, the timeline is not unreasonable. However, it may be the case that some, less important (for the overall success of the project in the eyes of the client), deliverables may suffer from a dip in quality to achieve them.