Project Deliverable M: Team A3 Final Project Report

Solution for a Cost effective, Comfortable and Reliable Fall Detection System

GNG 2101: Introduction to Product Development and Management for Engineers and Computer Scientists

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Saving lives through *easy* to use and *comfortable* technology

Submitted on: November 10th, 2018
Due: November 10th, 2018

Abstract

AAR Project Solutions was tasked with creating a product that helped to resolve St. Vincent Hospital's need for a reliable fall detection system. Through client meetings with St Vincent hospital and their technologist, Bocar, we were able to identify the client's needs which aided in our design process.

Through research and a decision making process, it was determined that the best solution to the client's problem would be through a portable call button that sent an alert to hospital staff phones through a mobile application.

The call button itself was to be outsourced and purchased from a 3rd party company and then integrated with an app built by AAR Project Solutions. Through multiple prototyping phases and client feedback meetings, a final, functioning product was created that provide a much needed service to St. Vincent Hospital and can be eventually worked on to be made more effective.

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Introduction

An issue that was being faced by patients and staff at St. Vincent Hospital was that they did not have a reliable fall detection system. When patients fell down, they would not be able to get back up without help or assistance. Left unattended and with no help, the patient could suffer from potentially life threatening injuries if not given the proper care in timely fashion.

The hospital hads 2 ways to counteract this problem: A stationary call button located at the head of the patient's bed and a siren that activates when the belt on patients' wheelchairs were unbuckled.

These solutions were ineffective as discovered through primary client meetings. The call button was stationary and patients were unable to reach it once they had fallen down. The belt was restraining and the siren was disturbing to the patients as revealed through user stories. Patients kept the belt buckled behind their bodies as they sat down, effectively removing its functionality.

AAR Project Solutions was given the task of solving this problem with a budget of $100. Through client meetings, client needs were identified and used to generate design criteria. Based on our design criteria, solutions were generated and this report is a summary of our findings and design process leading up to our final solution and product.

Prioritized Customer Needs Statements

Table xx: Client and Needs Statements

Need #	Client Statement	Need
1	Mr. N'diaye stated that his work and the scope of this project is about "finding a balance between patient independence and safety"	The product maintains the client's independence and privacy.
2	Most of the time, they shout to the patient across their room to call for help.	The product activates the call bell when the user has fallen swiftly.
3	Our client, Mr. N'diaye told us a story about a past project: "A past project was a belt that was worn above the waist and patients would often take it off and hang it up.	The product is light and non restraining.
3	According to Mr. N'diaye the patients lose even more mobility and possibly go numb when they fall	The product is not manually operated by the patient
4	The patient we met with stated he suffered from knee and hip pain from falling. "I take 20 pills a day for my hip pain from falling down while getting out of my wheelchair."	The device does not provide additional strain on knees or hips through added weight
5	The patient we met with said nurses often take too long to respond when the call bell is activated for help moving around. They may have other patients to tend to as well who may have higher priority needs.	The device is accurate enough so that false alarms do not occur
6	Some patients are required to wear pacemakers or other life preserving devices.	The device does not interfere with client's life preserving devices

Problem Statement

After our first client meeting we were able to take the quotes and information that was gathered and translate it into needs statements for our product. The needs statements allowed us to develop a problem statement based around them, giving us a self-made success criteria. The problem statement allows us to define our goal early in the design process and at each step we checked to see if the constraints are still being met.

The hospital needs to find a solution for a reliable fall detection system in the interest of protecting their patients from injuries as a result of dangerous falls. The patients will ultimately decide if the solution does not impede upon their independence and the hospital will decide if the patients are being protected adequately. The solution can be in the form of a product that is automatically operated but does not require constant surveillance of the patients by the hospital staff.

Design Criteria

Based on the constraints created by our problem statement we were able to establish our design criteria. In the design process, the solution does not necessarily have to meet all of the criteria however, the solution should be selected based on how many criteria it meets and the importance of the criteria.

a) The product must be light and non restraining
b) Device must be within range of the desk that receives alerts should as it will more than likely be in the form of something that sends out a signal to the hospital.
c) The product will not require surveillance
d) Ideally no physical force required, not manually operated.
e) Device activates quickly to spare the patients from suffering or injuring themselves further
f) The product will only require one person for assistance to allow the workers to attend to their many responsibilities
g) Low powered to elicit low maintenance.

Conceptual Ideas/Analysis and Evaluation

To ensure proper representation, each of us came up with 3 concepts that met our problem statement in some way, they can be seen in the list below:

- Heart rate monitor
- Floor sensor
- Wearable call button system
- Voice activated call button
- Protective, pressure sensitive body gear

At this point in the design process we were very unclear of the direction to go with our solution as all the solutions provided their benefits and equally their downfalls. So we had to critically analyze and evaluate each solution based the benefits (pros) and downfalls (cons) on our design criteria and problem statement and eventually came to the decision of the **Wearable Call Button System.**

We followed a simple model that identified any trade-offs with our design criteria. The design criteria were lettered in order of their importance to the customer. The analysis stated whether each criteria was "met" and if not it will explain why there is a conflict. With limited time and resources conducting a more complex model on all 12 concepts would not have been feasible. This is beneficial because it allows us to identify any early conflicts with the criteria. The analysis of the wearable call button system can be seen below.

Table xx: Design Criteria Analysis of Call Button

Design Criteria	Call Button System
The product must be light and non restraining	Requires patient to press the button and they may lose feeling upon falling
Button must be within range of the receiving system.	Met
The product will not require surveillance	Met
Ideally no physical force required, not manually operated	Requires slight force to push the button
Device activates quickly to spare the patients from suffering or injuring themselves further	Met
The product will only require one person for assistance to allow the workers to attend to their many responsibilities	Met
Low powered to elicit low maintenance.	Met

For the evaluation process we created a weighted pros and cons list. Each pro and con were selected and graded on a scale from 1 to 3 based on well they either met our problem statement or how little they impeded upon it. To ensure uniformity, each group member assigned a grade to each point and then the results were tallied and discussed to move forward with system that had the highest score, being the **Wearable Call Button System.** The evaluation for this system can be seen below:

Call Button System

Pros	Pros Grade	Cons	Cons Grade	Total Score
Very accurate (patients alert the hospital themselves)	(3, 3, 3)	Not automatic, places some responsibility on the patients	(-2, -2, -3)	8
Light, non restraining	(2, 2, 2)	Requires physical force even though patients can lose feeling when they fall	(-2, -1, -2)	
Easily designed to send signal to an application	(3, 3, 3)	Patients might use it for non emergencies	(-2, -1, -1)	

Figure xx: Weighted List for Call Button

Target Metrics

With a concept set in stone the next step was to translate our needs into actual physical metrics. We developed and prioritized the following target metrics for our button (not including the app or response system):

- Range of Device (Meters) // TARGET: 30 m
- Weight of Device (Pounds) // TARGET: < 1 lb
- Size of Device (Diameter in Centimeters) // TARGET: $\leq$ 5 cm
- Time b/w incident and alert (Seconds) // TARGET: < 5 s
- Battery Life (Days) // TARGET: 365 days

Later on in the design process our solution took the form of an app to receive the bluetooth signal from the button. We wanted to design our app based on the following target metrics:

- Loudness of alert (Decibels) // TARGET: 80 Db
- Time for signal reception (Seconds) // TARGET: < 5 s
- #buttons/device (#) // TARGET: 3 buttons
- #devices/button (#) // TARGET: 10 devices

Benchmarking

Direct Alert:

Wireless emergency system that allows for communication with the response center.

Pros	Cons
Has the ability to detect a fall without the push of a button.	Not wearable nor compact.
Maximum range of approximately 180 meters.	Costs include a $29.99 monthly fee and a $199.95 fee for the cost of equipment.

Figure xx: Direct Alert Equipment

Apple Watch Series 4:

Application of the wearable Apple Watch that contacts emergency services.

Pros	Cons
Detects falls based on bodily movement (non manually operated)	Bodily movement system is not 100% accurate and therefore unreliable.
Always worn on the wrist. Compact and comfortable.	User must input if they are ok (manually operated)
	Variety of functions which is not intuitive for the intended consumer, the elderly.
	Costs include $519 for one watch.

Figure xx: Apple Watch Series 4

BOM

Item Number	Part name	Description	Quantity	Unit cost	Extended Cost
1	**Sensor to activate bluetooth**	**Flic programmable bluetooth button. Programmable and customizable (can even have a button with an "emergency alarm" symbol on it (See Figure 1) https://flic.io/customized-flic**	**1**	**$66.60**	**$66.60**
Total					**$66.60**

Feasibility study

Technical:

Our team has a wide base of technical talent in having a software, computer, mechanical and civil engineer. Our combined expertise and knowledge should be enough to handle the technical challenges we will face.

At the same time, we have valuable resources in the form of our TA's and PM, Rob and Justine. After our second client meet, we discussed some technical challenges we may face with Rob. He has offered his help and told us we can approach him for guidance.

Notably, the most technically challenging aspect of our project would be handling communications between our remote device and the indicator outside the room (i.e. bulb or speaker). It would be the first time working with wireless technologies for most our group

members. With guidance from our PM and primary research on our group's parts, it should not be a major issue.

Economic:

Economically, our project is very feasible. At $100, our budget should be able to burden the costs of our project at this a small scale. Notable costs include a microcontroller perhaps, wireless communication devices, a bulb and possibly a touch screen. Thankfully, electronics nowadays are relatively cheap and readily available. See the BOM for a more detailed breakdown of costs regarding the parts for our product.

Legal:

Our product seems very similar in terms of functionality to another market leading product in Life Alert. Their product involves a pendant, which when pressed, alerts emergency services nearby. Our product involves a wearable pendant as well but its end goal differs in that it activates an indicator outside the patient's room instead of emergency services.

Legally, our products should differ enough to not infringe on their patent. Also, since we are not making a profit off this product and it being deployed at such a small scale there should not be any issues.

Operational:

Organizationally, issues may occur from not having enough time together as a group in person to be able to put together our project wholly. As we have to complete separate parts of the project individually, putting it together may be troublesome if there is not enough communication to make the parts compatible. To reduce this risk, we need to keep each other updated on certain specifications to make sure related parts are compatible.

Scheduling:

There have been some issues regarding deadlines in the past within our group. This should not occur again as this time we have a very defined set of deadlines with some leeway to provide some time buffer if needed due to unforeseen delays. See project plan section for details.

Design Sketch and Prototype I

The first step in the project plan and design process was to create an initial design sketch. This allowed us to take our solution and physically conceptualize it. We realized exactly what materials we needed to acquire and the technology that is requires to harmonize together. The original solution involved an adjustable strap for the patient's comfort and allowing it to be wearable. The sketch also had a button and casing for the battery and other hardware. The next step was creating an initial prototype. At this point we had yet to agree on a direction to go with the button so it was decided to create a physical non-functioning prototype. This could test the strap and the button for comfort and durability. We had a few test subjects wear the prototype for a day and they reported no discomfort. The prototype was manufactured entirely with household items. Both the original design sketch and the first low fidelity prototype can be seen below:

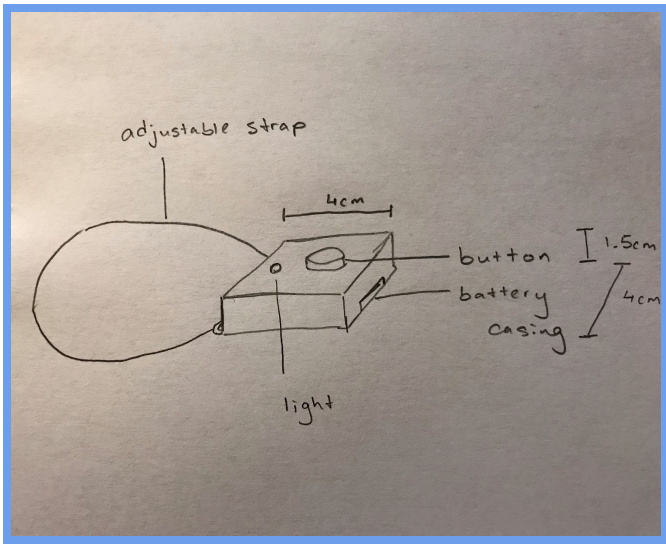

Figure xx: Design Sketch

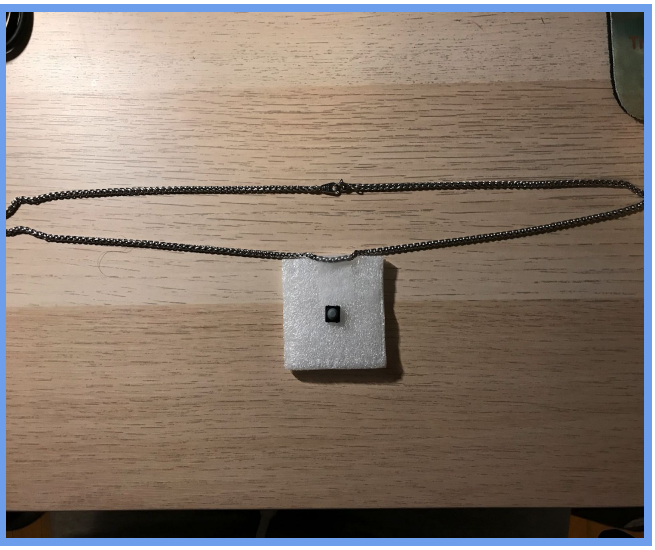

Figure xx: Low Fidelity Prototype I

Prototype II: Flic Button

Clearly, at this point in the design process we had a goal in mind but no actual plan on how to achieve it. We had a very clear concept of using a wearable call button system but we we had yet to decide how to bring this technology to life, hence why our first low fidelity prototype was non-functional. We came to our solution for a button by a stroke of luck actually. We had been working on a deliverable that required us to construct a budget and coincidentally we had to choose our materials, so a quick google search turned up the Flic Button. It was well under the project budget and although we did not fully understand the function of it, it appeared to perform our desired need of being pressed and transmitting a wireless bluetooth signal to a mobile device or a hub of some form. So we concluded to temporarily move forward with the Flic Button and make any necessary changes in the next stage of the design process.

However, upon further research we quickly discovered how many target metrics for a button are met by this product and how many complementary benefits to our problem statement it has. The following table summarizes the target metrics and how they are met by the Flic Button:

Table xx: Target Metrics and Flic Button Metrics Comparison

Metric	Physical Target	Flic Button Metrics
Range of Device (meters)	30 m	30 m = 30 m (OK)
Weight of Device (Pounds)	< 1 lb	7 g = 0.015 lb < 1 (OK)
Size of Device (Diameter in Centimeters)	< 5cm	3 cm < 5 cm (OK)
Time between incident and alert (seconds)	< 5 s	1 s < 5 s (OK)
Battery Life (Days)	365 d	2 yrs = 730 d > 365 d (OK)

Essentially, the Flic button is very light, non restraining and comes with a clip making it wearable. It is very easy to press, has a reliable signal, is cost effective and environmentally friendly by running on Bluetooth Low Energy and having a two year battery life.

Figure xx: Flic Button Size Comparison

Figure xx: Flic Button Composition

Essentially, the Flic button is very light and non restraining and comes with a clip that can allow it to be wearable and clip to seniors clothes. It is very easy to press, has a reliable signal, is cost effective at a cost of $27.99 plus shipping and tax per button and environmentally friendly by running on Bluetooth Low Energy and having a two year battery life.

Aside from meeting all of our target metrics for a button, Flic's greatest benefit to us is their experience working thousands of developers to program an app on Flic's SDK that performs a desired function. When the button is pressed it emits a bluetooth signal that can be received by any mobile device that is connected to it. By programming an app on Flic's SDK we can have the signal

received on a mobile device and immediately let of a loud and distinguishable sounds to alert the nurses that an emergency has occured.

Why not make our own button?

Flic has partnered with many tech titans to program a function with their app, some include; Spotify, Chromecast, WAZE, Apple Music, etc. In the tech industry your brand is everything so if these major corporations are willing to trust their brand and reputation with this product we should feel comfortable trusting our solution with Flic as well.

Additionally, we received the following quote from our client: “Our biggest issue with this arrangement with the University is the students come they do the coursework and they leave.” Bocar is pointing to the fact that many students approach this assignment as just another school project and never realize the magnitude and importance of the problem they are trying to solve by empathizing the customer. By using the Flic Button we are essentially creating an insurance policy for our solution because if the client does not like our app, we are still leaving behind a viable and economical path for a solution.

Primarily, the use of the Flic Button allows to create a non brick and mortar business model and inversely a combination of a Freemium, Advertising and Subscription based business model. This allows for no risk on investment as we have no need to make any purchases of product, the only cost to us is the development of our app since that is our product. Additionally, we will be able to take advantage of their established website, shipping and material supply system.

We may have been able to cut costs marginally by manufacturing our own bluetooth button however, we will save a lot more money in the long run by following this business model. This will be discussed in further detail in the economics report section.

Fall Detection App by AAR

Our app is available for download on the app store, currently on for IOS but our future plans include expanding our compatibility to android and critically for our business model, desktops. If it is economically feasible our app will be free in order to optimize the downloads. This will be investigated in the economics report section.

The app is very easy to download and easily connects to the button through bluetooth the same way you would connect to any other bluetooth device on your mobile phone. The only responsibility placed on the patients is to press the button, a major trade off by making the solution manually operated, yet we meet all of our other targets, especially cost. Currently, we are placing a lot of responsibility on the nurses by requiring them to monitor their phones for alerts. Eventually, our goal is to have a decentralized database that will allow for multiple devices to receive the signal if

within range. This is done to eliminate human error in the system by taking responsibility off of just the one nurse and ensuring that the emergency alert can not be missed.

The next important step is to expand the application to desktop and have the app open on the hospital desktop at all times, ready to receive and notify of an emergency alert. This is not only additional insurance for patient safety but it allows us to develop our business model. We have the intention to strategically market to our target consumer by establishing advertising partners who have a product that is of interest to our app user. It should be mentioned that the advertisements can only be in the form of banner ads since any pop-ups or notifications may distract from the problem that we are trying to solve. Usually, this type of marketing relies on selling people's information to target them on a micro scale. However, we don't have to go this route as we already have a very clear idea of the target demographic. The only user of the application will be hospital or nursing home nurses. Coincidentally, a nurse is actually a very well defined graphic. In Ontario over the past several years over 90% of nurses are Female and at least 65,000 out of 100,000 are between the ages of 35 and 54, shown in the below figures. This is a very clear buyer persona that we can strategically market to through the application that is open all day on the hospital desktop.

Figure 3.6: Nurses employed in nursing in Ontario: Gender distribution

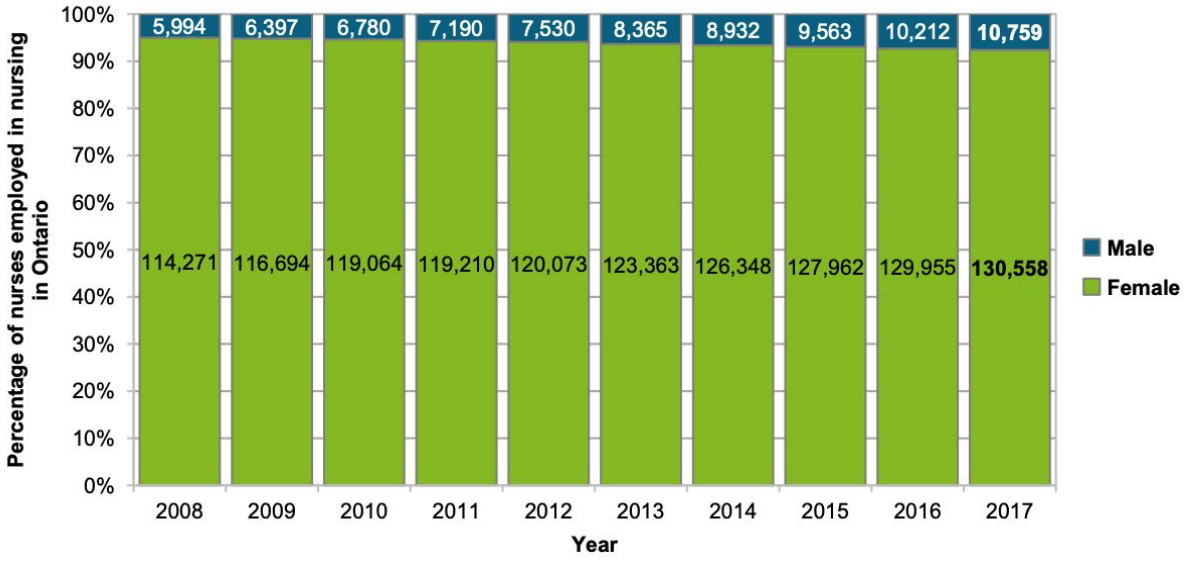

Figure xx: Ontario Nurses Gender

Figure 3.5: Nurses employed in nursing in Ontario: Age distribution[7]

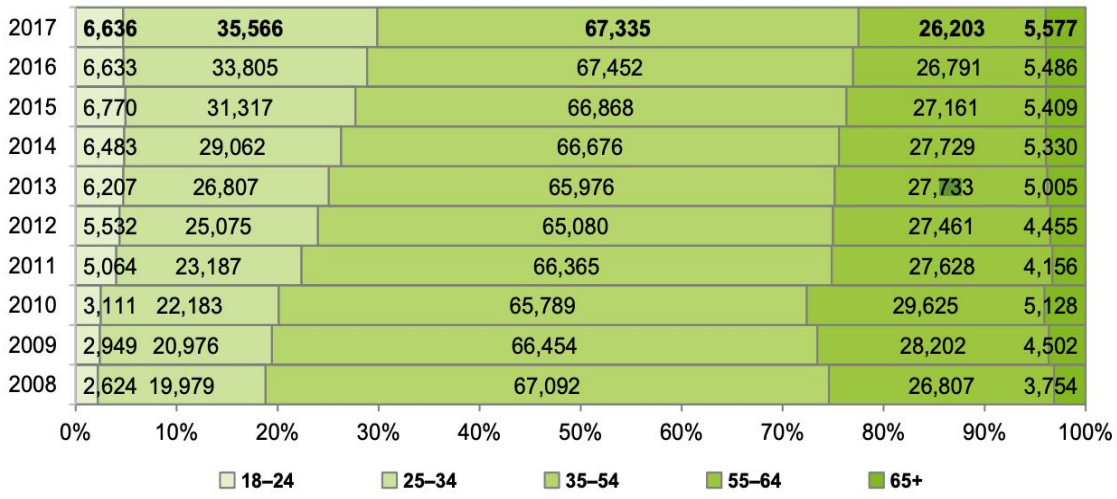

Figure xx: Ontario Nurses Age

Development Process:

The development of the app was done in XCode available on MacOS. The language used was Objective C. Swift is a more intuitive and simpler language but the Flic library/SDK was made in Objective C so development needed to be done in the same language. The libraries and code examples provided on Flic's GITHub repository were invaluable in this process by providing documentation frameworks needed.

Business Model

Primarily, the use of the Flic Button allows to create a non brick and mortar business model and inversely a combination of a Freemium, Advertising and Subscription based business model. This allows for no risk on investment as we have no need to make any purchases of product, the only cost to us is the development and maintenance of our app since that is our product. Additionally, we will be able to take advantage of their established website, shipping and material supply system. The business model canvas that we developed can be seen below:

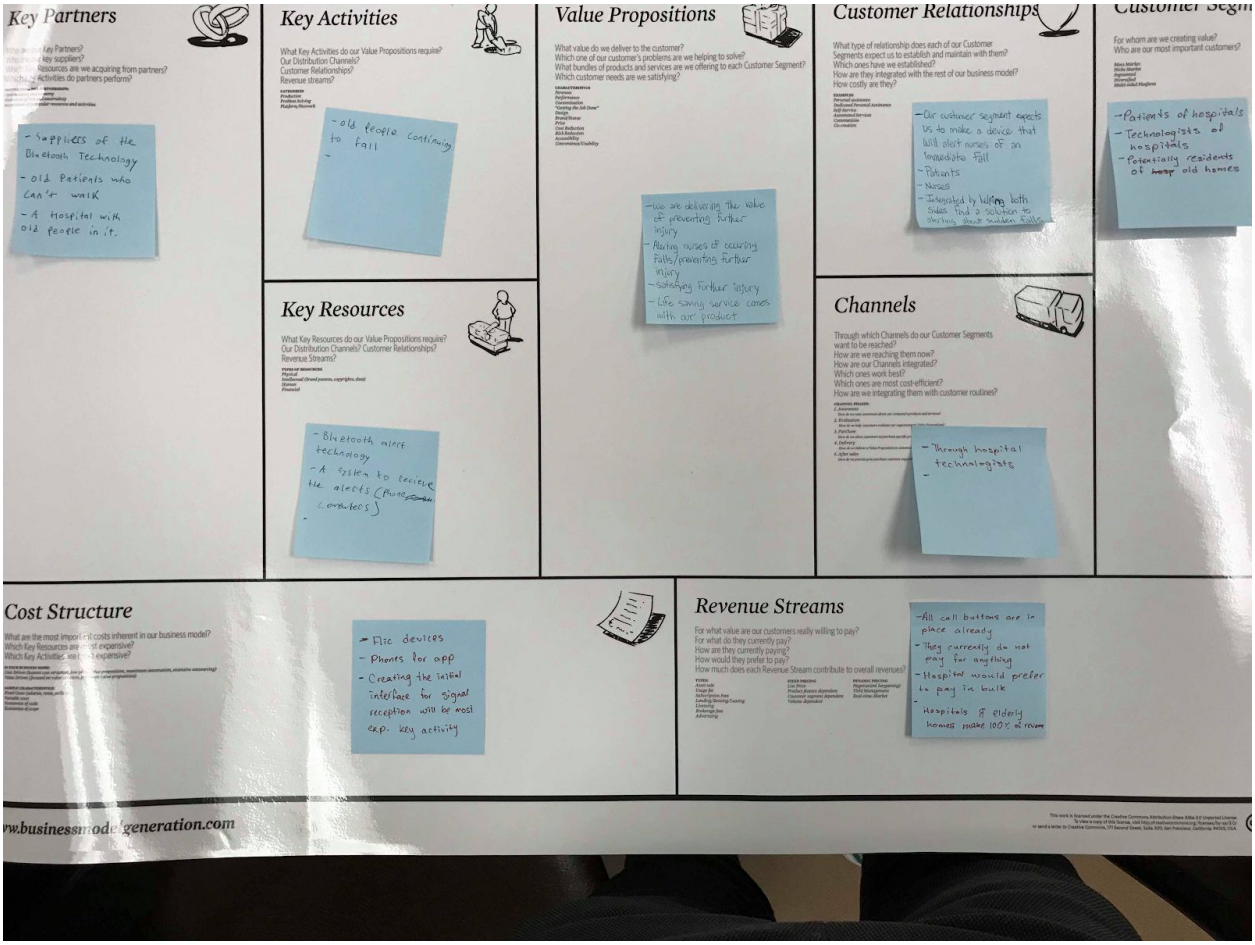

Figure xx: Business Model Canvas

Economics Report

The following briefly summarizes our costs for each classification. As is shown, we have a very limited variety of costs to our business.

Variable

- Need to hire and pay programmers a salary to perform maintenance/troubleshooting and help us achieve our future goals.
- Cost per Install Method of Application marketing (discussed in further detail)

Fixed

- Flic Button for prototyping and testing (Need for 1 button will not grow in this case)

Indirect

- Liability insurance
- Employee benefits (Health and Dental)

Programmer Costs

As a general rule of thumb we predict that we will need to hire programmer per every 100 downloads. Hence why this is a variable cost. For simplicity we will assume that the worker salary is the average programmer salary in Canada of $48,633 per year. So for every 100 downloads we will incur a cost of $48,633 per year.

Cost Per Install

The initial business plan that we put together involved paying salesman to market our app to hospitals and nursing homes. Forget paying salesman. A much more modern and economically efficient method of advertising mobile apps is the Cost per Install method (CPI). The CPI method is specific to mobile apps, involving a major digital marketing service, such as Leadbolt, placing digital ads of your product over a variety of digital media interfaces, charging you a fixed rate per download of the app. Globally, the average CPI for an IOS app is $0.86 and we will perform our analysis with this value.

Flic Button Fixed Costs

The lone fixed cost that results from our business model is purchasing a single Flic Button to test the compatibility with our app and confirm all of our target metrics are met. Currently, with tax and shipping included a single Flic Button sells for $49.99 USD or $66.60 Canadian (currently).

Liability Insurance

Liability insurance is something that every project manager must provide for their engineers and design team. Let's say an engineer designs a product and puts it out in the market. Shortly after the product fails and inflicts harm on to the client. In this situation the engineer is legally liable to pay for any potential lawsuit and the resulting fees. A responsible project manager will insure their employees with the protection of paying for any risks and liabilities.

Since we are hiring a programmer for every 100 installs, they will be responsible to ensure the safety of their 100 patients. They are responsible to monitor the buttons and the application and if one the patients that they are monitoring experiences an injury they are liable and need to be protected. Liability insurance runs at about $50 per month. This means for every 100 downloads we will incur a cost of $600 per year.

Health and Dental Benefits

In Canada the average cost for employee insurance is $100 dollars monthly. Again, our only employees are the programmers, so for every 100 downloads we will incur a cost of $1,200 per year.

Income Statement

Key assumptions:

- We are not manufacturing our own
- Assuming we can have at least 3 partners running ads 24 hours a day.
- Each hospital has 50 residents
- We are meeting our sales goal
- 1 programmer can handle the workload of 100 customers
- Uses a value for Global CPI

Our income relies solely on an initial purchasing price for the app and advertising within it. Facebook has a choose your own rate option for advertising. Say we charge $5/hour for ad time and allow our partners to choose how much they wish to pay and how long their ad will be viewed. You may be asking, why will we have no trouble finding advertising partners? Facebook and other apps require selling information to the marketing partners to gain simple demographic, information such as age and gender in order to strategically market to the user. We already have a defined buyer persona and won't have to charge our partners for that information while securing the privacy of our users.

We Predict to sell to 3 hospitals year 1, each hospital has an average 50 residents who require the system. In year two we will sell to 5 hospitals and year 3 10. Those are the sales goals we have set for ourselves. The following is how we plan to charge for our service:

$50 download fee year 1 ($10/hour for the ads)
$45 download year 2 ($20/hour for the ads)
$40 download year 3 ($40/hour for the ads)

As our number of downloads increases we are charging less per download and more for advertising as the demand for advertising will increase.

Table xx: Income Statement year 1

Sales	= (150)*($50) + ($10)*(8760)	= $95,100
Costs of Goods Sold		= $0
Gross Profit on Sales		= $95,100
Operating Expenses	= (2)*($48,633)	= $97,266
Marketing Expenses	= ($0.86)*(150)	= $129
General Expenses	=$(600 + 1200)*(2)	= $3,600
Total Operating Expenses	= $(97,266 + 129 + 3,600)	= $ 100,995
Operating Income	= $ 95,100 - $100, 995	= $ -5,895

Table xx: Income Statement year 2

Sales	= (250)*($45) + ($20)*(8760)	= $186,450 + $95,100
Costs of Good Sold		= $0
Gross Profit on Sales		= $ 281,550
Operating Expenses	= (4)*($48,633)	= $194, 532
Marketing Expenses	= ($0.86)*(400)	= $344
General Expenses	=$(600 + 1200)*(4)	= $7,200
Total Operating Expenses	= $(194,532 + 344 + 7,200)	= $ 202,076
Operating Income	= $281,550 - $202,076	= $ 79,474

Table xx: Income Statement year 3

Sales	= (500)*($40) + ($40)(8760)	= $370,400+ $281,550
Costs of Good Sold		= $0
Gross Profit on Sales		= $651,950
Operating Expenses	= (9)*($48,633)	= $ 437,697
Marketing Expenses	= ($0.86)*(900)	= $774
General Expenses	=$(600 + 1200)*(9)	= $16,200
Total Operating Expenses	= $(471,750 + 774 + 16,200)	= $ 488,079
Operating Income	= $651,950 - $488,079	= $ 163,871

NPV Analysis

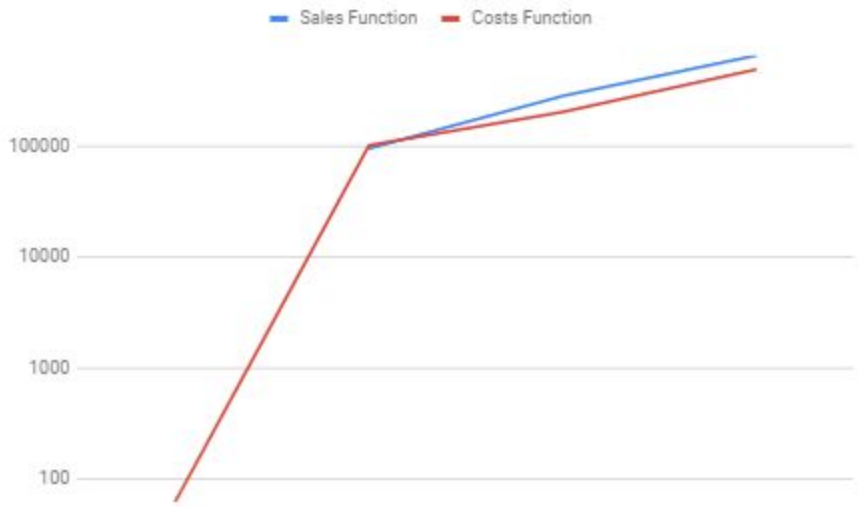

Figure xx: Break Even Analysis

This shows that our business will break even at exactly $100,000 in sales which will occur in year 2. We will be charging $45 per download and $20 per hour of ad time. We will require to be in business with at least 4 hospitals and have at least 1 advertising partner. In order to reach this sales goal.

With this business model, our revenue will continue to grow, without a significant increase to our costs. We have the unique ability to be able to earn a profit just after year 1 in operation if we meet our very modest sales goals.

User manual

Please look at the Guide for “getting started” on the Flic website for steps on how to connect the Flic button to your phone: https://start.flic.io/

Instructions for our App:

1. Install the App on your phone through XCode “build” button
2. Open the App
3. Press the “Grab Button” button. This will open the Flic App
4. Here, select the Flic you want to connect to our app. This will take you back to our app.
5. The app is now ready for use

Flic button Functionalities:

1. Press once to send an alert.
2. Press and hold to disarm the alert

Troubleshooting:

1. “Not receiving alert”: Check that the button is properly connected to the Flic App AND our app. Then make sure our app is open in the foreground of your device. Make sure the ringer is on and volume is at an appropriate level on device.

Replacing the Battery on Flic Button: Please refer the the flic website.

Future work:

The mobile app is currently only on iOS. To improve accessibility the next logical step would be to port it to other platforms such as Android and desktop computers. One of the most crucial things to be done next is to add wifi and database functionality so that alerts can be sent to all devices that have the app. Background functionality must be added so that alerts can be received even when the device is locked. Push notifications can also be added on iOS but requires the purchase of a Apple Developer key.

References

https://start.flic.io/