

UNIVERSITY OF OTTAWA – FACULTY OF ENGINEERING

INTRODUCTION TO PRODUCT
DEVELOPMENT AND MANAGEMENT FOR ENGINEERS
AND COMPUTER SCIENTISTS

GNG2101

WHEELCHAIR DRIVING AID

DELIVERABLE L: Final Design Report

GROUP B3

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Abstract

Throughout the the Fall semester of GNG 2101, Group B3 was tasked with a final project titled: Wheelchair driving aid. During the past 4 months, Group B3 has made significant progress towards a final goal, and a functional prototype. This work (and its progress) can be recorded in increments, in terms of deliverables that were assigned throughout the term. This document will encapsulate all relevant work to demonstrate the key aspects of solving problems and implementing a solution for the final prototype that was created, and can therefore be used as as a complete document that officially records all work completed on this project prototype throughout the Fall term of 2017.

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1.0- Introduction

At the beginning of the course GNG-2101, we were asked to choose a project to work on which was to have a completed prototype by the end of the term. Our chosen project was: “Wheelchair Driving Aid”. This chosen project, and all of the work leading up to its final design, is recorded within this document. This document will serve as a final and complete report of all applicable work completed for this final prototype, along with all applicable deliverable aspects from the course GNG-2101.

2.0- Team Formation and Contract

At the beginning of the course we chose a team that we were to work with, throughout the entirety of the course, to work on a final prototype together. This team includes the following members (in alphabetical order by first name):

Dylan J. Doyle	8711441
Elyse Hodgson	8699991
Kelton Lohrum	8165013
Steph Chiarotto	8675310

Additionally, we had the option for choosing a final prototype topic, from a lottery type system. The prototype that we had put as our first choice, and ended up getting was: “Wheelchair Driving Aid”.

3.0-Need Identification

The purpose of this section, Need Identification, is to demonstrate the early work of our final project and its inception.

3.1- Client Observations obtained from clients interviews

To begin the process of developing our prototype we must first identify the specific needs of the client.

- We will not be addressing the needs of one person but rather one style of wheelchair as suggested by our client Bocar, who is representative of all the patients at St. Vincent’s Hospital who may benefit from our product.
 - There are many styles of wheelchairs including those that are
 - Manual
 - Motorized
 - Rear wheel drive
 - Mid wheel drive
 - Front wheel drive

- Each style presents it's own set of set of challenges
- Solution must be compatible with any kind of wheelchair the client desires
- Wheelchairs often run into everything be it walls, curbs, doorframes or elevators
 - Durability is key
 - Product shouldn't increase the length or width of chair
- Aesthetic is important
 - Patients may refuse to use objects they find visually displeasing, regardless of their effectiveness
- Patients have trouble seeing beside them in addition to behind
- Simple mirrors have already implemented, but are ineffective
 - Low height prevents sight over the shoulder
 - The flat mirrors used do not amplify the size of objects

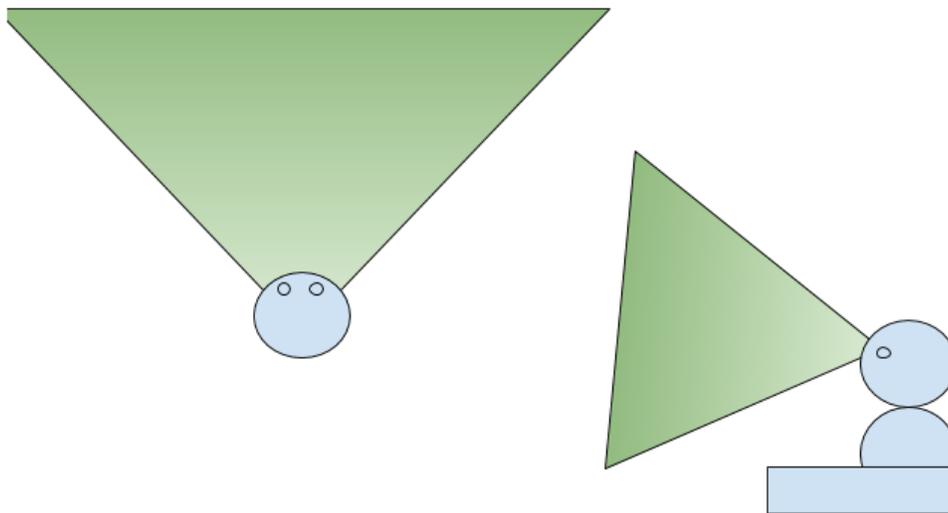


Figure #1: Simple Representation of the clients limited visibility

3.2- Customer Needs

Customer needs include: Awareness of what is behind them when backing up, a method for determining what is behind them, protection from collisions while operating their wheelchair.

3.3- Problem Statement

The problem that we are tasked to solve is to resolve the issues that arise for patients at St. Vincent Hospital when they have to backup their wheelchairs. We will therefore be developing some solution that will attach to the wheelchair to assist them backing up.

3.4- Benchmarking

There are similar products on the market that will be mentioned below, and they can all be applied to this particular problem, however most of them aren't directly marketed at solving our particular problem.



Figure#2: Previous Solution: A Small Mirror



Figure#3: Previous Solution: A Car Backup Camera System

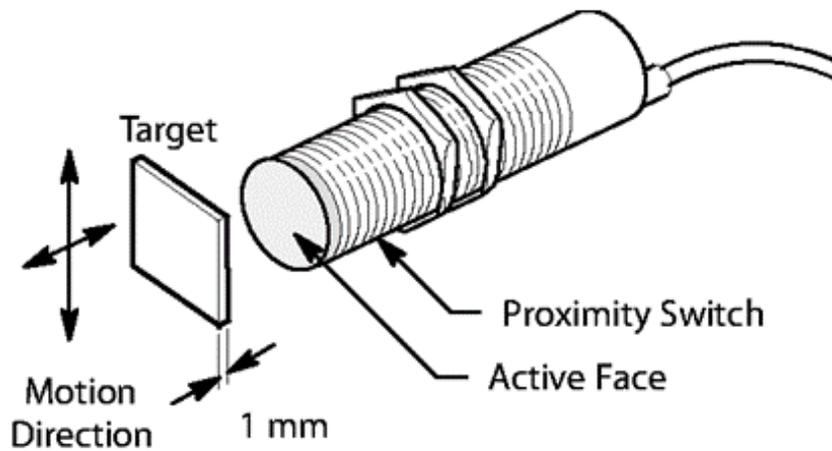


Figure #4: Plausible Solution: Proximity Sensors

3.5- List of Metrics

Additionally, we considered the metrics of each solution, and tabulated the results into a metrics table, as follows:

Metric	Mirror	Sensors	Camera
Price (Minimum)	3	2	1
Complexity (Hardware)	3	2	2
Complexity (Software)	0	2	2
Ease of Use	3	2	2
Size	1	3	2
Weight	1	3	3
Ease of Installation	3	1	2
Visual Assistance (Side)	2	2	0
Visual Assistance (Rear)	2	2	3
Total	18	19	17

Table #1: Metrics Table

3.6- Set of target specifications

In addition to the metrics table, we determined a set of target specifications (both ideal and marginally acceptable values), which are listed as follows:

Mirror: The minimal specification for the mirror, includes that the mirror must be in a convex shape to allow the client a wide angle of viewing to allow optimal spatial awareness while backing up. Additionally, the mount that the mirror will attach to will have to be unobtrusive and also be able to adjust to a wide range of motions including all directions in the x, y, and z plane.

Backup Camera: The camera must provide a wide range of rear sight (close to 180°) to accommodate the lack of lateral sight assistance. Display screen and camera must clamp firmly to frame and hand rail to prevent hardware damage to the sensitive electronics as well as the integrity of the wheelchair itself.

Proximity Sensors: The sensors must be intelligent enough to know when to warn the user that they are about to hit something. Must be useable in all lighting conditions. May also consider including an auditory component in alignment with the sensors to prompt the user when they are close to hitting something.

3.7- Reflection and concluding remarks from 1st Client Meeting

Upon reflecting on our client meeting, we gained valuable insight of what our client deals with on a daily basis. This has allowed us to modify our ideas and come up with new ones which are superior to our original ideas that we had before meeting with the client.

During our visit it was noted that this product can be created to be very universal with minimal modifications to suit the needs for virtually any patient at St. Vincent Hospital. In addition, they have very minimal existing options when it comes to visibility. The only affordable option is a flat bike mirror which attaches to a tray. This can be very cumbersome and next to useless if they do not have the range of movement needed to constantly re-adjust.

Our clients made it clear that they would want something durable and stylish as many will not use something that makes them appear helpless. They may be limited in their movement but they still care about what their appearances says to the world.

4.0- Problem Statement and Target Metrics

The purpose of this section of the report, Problem Statement and Target Metrics, is to analyse the problem statement to develop our design criteria. Additionally we will also provide the target metrics of our prototype.

4.1- Develop design criteria

For our project, we have set out minimum specifications that will be required for it. Design criteria will include the following: for all options including the mirror, video camera, and a hybrid of both the mirror, camera and the monitor (to display what's behind them) mounting on an adjustable mount which can be modified to any height and angle will be required. Additionally this mount must be mounted to the arm of the wheelchair so that when the wheelchair itself is adjusted, the mount will tilt with it, so that it won't need to be manually modified every time the wheelchair is repositioned. This mount would also need to be extremely sturdy and removable due to the constraint of it not being able to be attached with screws or anything similar to maintain the integrity of the original chair.

Concerning the video camera, the video image must be clear with a wide viewing angle to produce a clear understanding of what is behind the wheelchair. The video camera must be able to operate under any lighting conditions, for example when it's dark or when outside in the bright sun. Also, the camera along with the monitor must be able to operate off of a battery, and must be able to last for at least one day of useage.

Concerning the proximity option, the proximity sensor must have sufficient logic to know when it should be turned on, (only should activate when backing up), and should be able to accurately communicate with the user how close they are to a wall, or solid object. Additionally, much like the video camera option, the proximity sensor should be able to run off a battery for at least one day of useage.

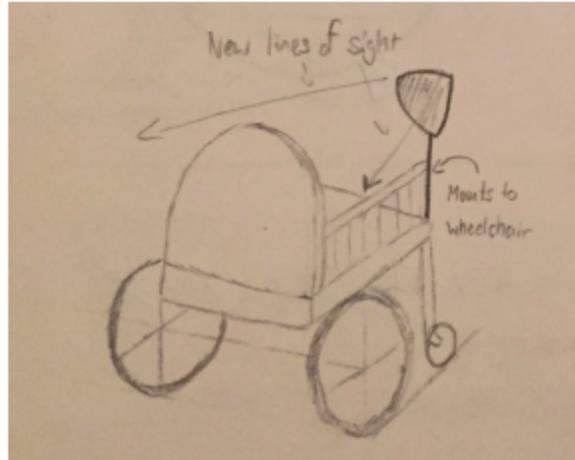
In conclusion, the project that we would like to achieve would be a combination of the proximity sensor, and the video camera because the combination of them would result in what we believe to be one of the best solutions to this project. However, to implement this successfully, the above design criteria will have to be followed closely and re-evaluated through the duration of the project.

4.2- Analysis and evaluation of all solutions

A list of all solutions proposed by all group members are as follows: A concave back up mirror, a back up camera, proximity sensors, and a combination of the proximity sensor along with the back up camera.

The process for the mirror was one of the first ideas generated. Our first visit to the hospital revealed that the only existing assistance for reversing in the wheelchair was a simple bicycle mirror. This mirror was extremely ineffective, small, and rather awkward.

In response to this, the group came up with the plausible solution for a completely adjustable mirror that was larger and concave (similar to the one that they have in hallways). This solution would be a huge improvement over the already existing mirrors that are implemented at the hospital.



Figure#5: First Idea Generated

The second solution, the backup camera, was then considered. Similar to backup cameras on vehicles, our back up camera would be similar in functionality. The video camera would basically accomplish the same thing as the mirror, however we believe that while it is more 'high tech', it would be more useful, and more aesthetically pleasing than a mirror. Additionally, the video camera solution would probably be less likely to break, or be damaged compared to the mirror. However, like any solution implemented with technology, the video camera and the monitor would have to operate off of a battery source, and would consequently have a limited battery lifetime and would need to be recharged. Overall the video camera solution is a practical and feasible solution that would solve the core problem (the inability to see what's behind them) effectively.

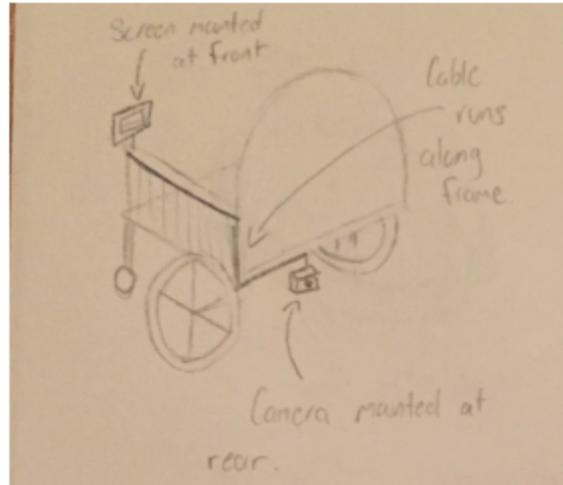


Figure #6: Second Idea Generated

The third solution, the proximity sensors, was one of the last feasible solutions to be generated. The proximity sensor will inform the user when they are about to hit a solid object while backing up, through sounds of increasing intensity (as they got closer to the solid object). The proximity sensor would require less power than the video camera (meaning that the battery might not have to be charged daily). Additionally it would not require a mount to be mounted onto the armrest of the wheelchair thus making it more aesthetically pleasing. However, the proximity sensor would be required to have a lot of intelligent logic programmed in it in order for it to know when to turn on, and to accurately and correctly notify the user when they are approaching an object while backing up.

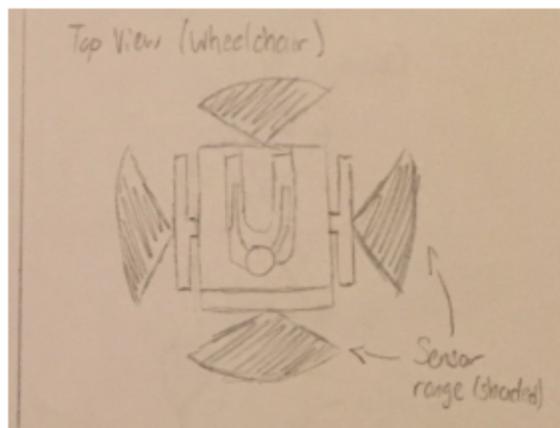


Figure #7: Third Idea Generated

The fourth idea was a circular bumper around the entire chair. While there is no doubt this would prevent any damage to the wheelchair, it has far too many drawbacks to be considered for implementation. The idea was that the bumper would allow the user to collide gently with objects without fear of damage to themselves or the chair. This could however cause damage to nearby equipment, walls or even people. The low hanging device could also create a tripping hazard for those nearby. The bumper would greatly increase the size of the chair, restricting the already limited access to narrow or crowded hallways. Furthermore, a patient with limited mobility would experience greater difficulty getting into the chair with the added obstacle surrounding it.

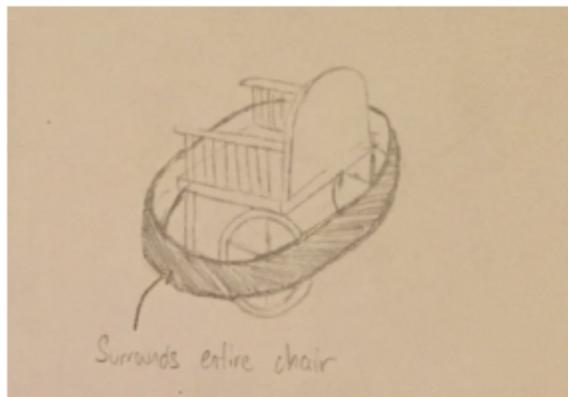


Figure #8: Fourth Idea Generated

The fifth possible solution, would be a combination of the backup video camera and the proximity sensor. This solution provides the best of both worlds, which allows the user to view what is behind them, and additionally a system to that detects the distance from nearby objects. This solution is the most technical of all proposed solutions, however we believe that it would be the best solution to the problem and would provide the best experience for the user.

4.3- Promising Solutions

The solutions that we believe that are the most promising include: The mirror, video camera, and the proximity sensor solution. These 3 solutions seem to be the most promising because, we believe that we can implement these projects within the constraints of the small budget, and that we could implement these solutions before the due date. Additionally we feel that these would be the most practical of all solutions, and that these solutions are the most user friendly. The mirror provides a reasonable amount

of additional sight given the low cost and complexity. The sensors are more complex to implement, they are also user friendly and rather inexpensive. The camera would be the most expensive, but it would provide the most comprehensive rear sight. While the bumper would be the cheapest and one of the simplest to implement, it has too many drawbacks to be a reasonable solution.

4.4- Development of a design concept

A solution that our group has agreed upon is the combination of the video camera and proximity sensor solution. If we were to combine both the video camera and the proximity sensors, we have all agreed that this is the ideal solution that would provide the best user experience overall while best solving the problem at hand.

4.5- Visual Representation of the concept

A few angles from a CAD design, that illustrates the video camera option:

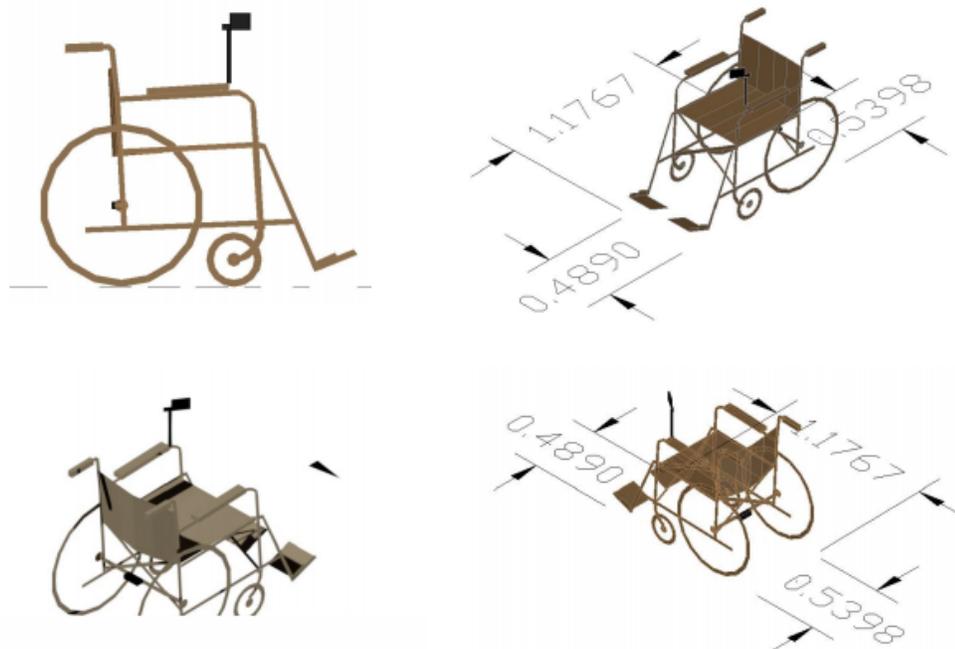


Figure #9: CAD Models of the Chosen Generated Idea

4.6-Core Functionality of the concept

Functionality of the solution includes: situational awareness behind the user, a clear image of their surroundings, and information of their proximity to other objects. With the solution of video camera and proximity sensor, the video camera would provide an real time image of what is behind the user, and would display those images onto a monitor. The proximity sensor would provide additional information, in the form of audio beeps, or even a value on the monitor displaying the distance from objects (such as walls, people, etc) while the wheelchair is reversing. A potential drawback of the video camera is that if the connection is poor, the lag in real time imaging may be stressful or irritating for the user. The time it takes the batteries to charge as well as the individual battery life of both options need to not be forgotten when planning to implement these solutions.

5.0- Complete Project Plan

The purpose of this section of the report, Complete Project Plan, is to present the Project Plan (along with its many components), along with a Feasibility Study.

5.1- Project Plan

This section of the deliverable will discuss our project plan, and the bill of materials associated with the project. This will include the following: A list of tasks needed to be completed, milestones, Gantt diagram, bill of materials, justification of the costs listed in the bill of materials, and project uncertainties and risks.

5.1.1- List of Tasks that still need to be completed

This section will list and briefly discuss all remaining tasks which need to be completed, including an estimated time for each task, as well as who is responsible for each task and the task dependencies

Task Name	Brief Description	Team Member responsible	E.T.A	Task Dependencies
3-D Modeling for 3-D components	The various housings and miscellaneous plastic parts required for the project will need to be	8675310 8699991 8165013	2-3 Weeks	Availability and knowledge of 3D cad

	modeled first, before they are then 3-D printed			software
3-D Printing	The 3-D Modeled Parts will need to be 3-D printed, tested, and redone if the print doesn't come out as expected	All	2-3 Weeks	Availability of 3-D printers
Proximity Sensors	Obtain cheap Proximity Sensors to stay within budget, and to completed the project	8165013	1 week	Availability of Sensors available online
Finalize Coding	Finalize the Coding, remove any bugs, and optimize code, for optimal functionality	8165013	2-3 weeks	Dependant on Time available to allocate to this
Raspberry Pi Zero Or Raspberry Pi 3B	Obtain a relatively cheap raspberry pi zero, However if unavailable a RP 3B will work as well	8165013	1 week	Dependent on the availability of parts online
Obtain cheap monitor compatible with raspberry pi	Obtain a cheap RB compatible monitor for us to use on the final project	8165013	1-week	Dependant on the availability of the parts online
Disable SSH on final project	A feature of the RB's is SSH, which will need to be disabled for client privacy	8165013	1 day	Dependant on Time available to allocate to this
Construction of the monitor arm	Using Brunsfield and other resources offered by the university, an 'arm' which will house the monitor and RB will need to be constructed. Its construction must be sleek, and elegant, but also Sturdy. Additionally, it must be able to adjust to	8711441	4-5 weeks	Dependant on Time available to allocate to this

	a variety of heights.			
Assembly and testing of the monitor arm Test fitting the Assembly arm and 3-D printed Parts	First attempt and fitting everything together, and seeing how everything works out. If incompatibilities arise, New parts will need to be made, and adjusted to fit and work correctly.	All	3-4 weeks	Dependant on Time available where all team members are able to participate
Final Assembly and Cleanup of the Project	The Final Assembly will consist of merging all components of this project in an operational manor.	All	1 week	Dependant on Time available where all team members are able to participate

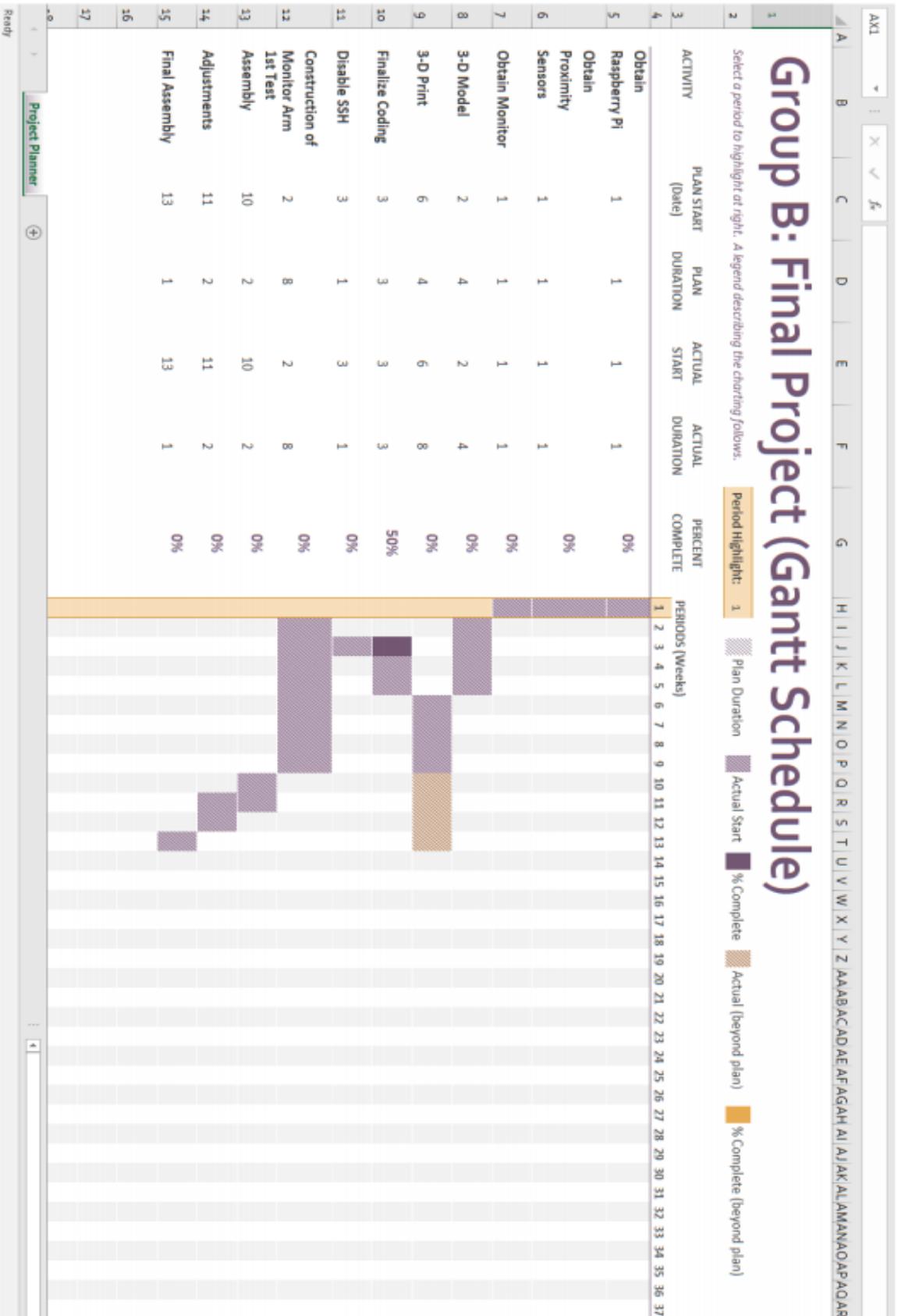
Table#2: Breakdown of Tasks that need to be completed

5.1.2- A List of MileStones

This section describes a list of milestones that will need to be overcome in order to complete fully complete the project.

1. Obtain raspberry pi
2. Obtain Proximity Sensor
3. Obtain cheap Monitor Screen
4. 3-D Model Plastic Components of the Project
5. 3-D Print all Plastic Components of the Project
6. Construct the monitor arm
7. First Test fit Assembly including plausible adjustments and reprints
8. Final Assembly

5.1.3- A Gantt Diagram



5.1.4- Bill of Materials

This section of the report will include the Bill of Materials that were used to develop and complete this project.

The expected total of the project is: 88.80\$. Which leaves approximately 11.2 Dollars left over for flexibility and unexpected costs. In conclusion, if everything goes according to plan we will be within our budget.

Name	Cost per item	Quantity	Sub-Total
Raspberry Pi	47.80 Cad	x1	47.80 Cad
Camera	20.00 Cad	x1	20.00 Cad
Monitor	16.00 Cad	x1	16.00 Cad
Proximity Sensor	5.00 Cad	x1	5.00 Cad
3-D Printed Parts	0 (free at University)	Multiple	0\$
Monitor Arm	0 (free at University)	x1	0\$
Total:			88.80 Cad

Table #3: Bill of Materials

5.1.5- Justification of Costs Associated with the Project

This section will attempt to explain the costs associated with each material to be used. Additionally, there will be justifications to explain said costs associated with the materials used.

Raspberry Pi

A Raspberry Pi is required opposed to possible cheaper options in micro-computers (Arduinos, 'Orange' Pi, and other various companies that make similar micro-computers). It is required because it has a large library that makes it compatible with virtually an piece of hardware. The raspberry pi Os, Raspbian, is Linux based making programming extremely easy and intuitive. Additionally, it is one of the most popular micro-computer on the market, therefore there are a plethora of forums online that can answer almost any question involving the raspberry pi. Additionally, the raspberry pi, can handle video inputs, and has the ability to process the stream, and display the inputted video with virtually no latency. Furthermore, the raspberry pi (because it is linux based) is compatible with virtually any USB device, including webcams and monitors, without the need to install kernels, or additional drivers, further

making the project less difficult than it could have been. Our client Bocar is also familiar with the Raspberry Pi option therefore making it more appealing to him as a client.

Camera

A camera was required for our project due to the nature of the problem (being aware of what is behind the client). A reasonably good quality camera is required as a cheaper quality camera could possibly break, and its output would be of poor resolution.

Monitor

Again, due to the nature of the problem, we needed a device to be able to display a video output, so a monitor is literally the only product solution. However, the monitor must be small enough to not be intrusive to the client, and must be power efficient enough so that it does not drain the battery of the project.

Proximity Sensor

In addition to the monitor camera combination, sometimes it is hard to judge the distances when displayed on a monitor, therefore we felt the need to include the proximity sensor. It was also highly recommended by our project managers and the clients of the hospital. A proximity sensor is an inexpensive addition to the project that further improves the functionality to the final project.

Other

The other parts of the project are expected to be free, by frugally using spare parts, and using free services provided to us by the University of Ottawa.

5.1.6- Discussion of Projects Uncertainties and Risks

There are numerous uncertainties that surround this project, and many other gambles that we are taking to complete this project. In no particular order of importance or time of occurrence, risks and uncertainties will be discussed below.

Availability of spare metal used to construct the monitor arm is an uncertainty and a risk that we are gambling on to complete this project. Availability of 3-D printers is another uncertainty, because if the 3-D printers are busy, completion of the plastic components will be at risk. 3-D printers are shared by all the students of the University, making their availability at a premium during the semester. Availability of certain components online, is an additional uncertainty; if the components are not available, we will have to search for other stores (online or in Ottawa) in order to obtain the necessary components required.

Additionally, time is required from all team members, which may be at risk due to other workloads, and can impede on the progress of the final project, delaying it, or even possibly risking not completing certain aspects of the project.

An unforeseen risk that also affects this project is the budget constraints, specifically regarding the power of the Canadian dollar. Most components come from China, or USA (99% of the time). If the Canadian dollar weakens, budget constraints might not be able to be met, due to increased cost of components, at no fault on the team.

5.2- Feasibility Study

This section of the Report will include the Feasibility Study, which will include the TELOS factors (Technical, Economic, Legal, Operational, Scheduling).

5.2.1- Technical

Our team comes from a variety of different backgrounds in engineering thus having a wide variety of technical skills. We anticipate that our project requires basic programming knowledge as well as 3D printing for attachment pieces. If any additional metal or plastic mounts are required, we can use the resources available to us at Brunfield, which we are all technically trained to use

5.2.2- Economic

The main aspects of our project are a raspberry pi, camera, monitor and proximity sensor. The cost of each of these things are minor, and in combination with the free resources available to us at the university (3D printing, Brunfield materials), it is not unreasonable to remain within our \$100 budget.

5.2.3- Legal

There are no legal issues with releasing our solution to the public. There has never been an attempt at solving this problem in the past, therefore there is no conflict of interest or potential for unoriginal ideas. As long as we give credit to any external company resources we are using to achieve our project, there will be no issues with releasing this solution for the public to enjoy.

5.2.4- Operational

There should not be any operational constraints that will prevent our success. As long as we stick with our scheduling plan and manage our time effectively, we should have absolutely no issue with achieving our deliverable goals and obtaining the appropriate materials in order to have the best chance at success.

5.2.5- Scheduling

The deadlines revolve around the project deliverable dates which are intended to keep us on track with completing the tasks required to obtain the final product. It is vital to meet the deadlines in order to meet the organizational requirements for the project and to ensure that they are done on time. Most of the tasks we have to do depend on one another, therefore if they are not complete on time, the entire project will fall behind very quickly.

6.0- Prototype I & Client Meeting Preparation GNG 2101

This section of the report, Prototype I and Client Meeting Prep, will be an overview of our first prototype created. Additionally, it will be a recap of our first client meeting.

6.1- Client Feedback

The prototype we presented had a relatively positive feedback. The clients had no concerns regarding the functionality of what we presented. His notes reflected the needs of the patients. The only concern of the client was that our prototype did not provide any additional visual of the patient's feet. This is a common problem with wheelchair-bound clients, and our design focuses on the rear of the chair. He recommended that we add a secondary detection device, such as sensors for the front of the chair. Furthermore, the client stressed that a mechanism to alert the patient of any nearby objects would need to be included with the secondary device. Such examples provided would be a buzzing sound or bright light. These would preferably be close to the screen, decreasing the size of the prototype. The client also recommended that we use hose clamps (and/or zip ties) to attach the prototype to the chair. They are an alternative to traditional clamps, and might damage the paint of the wheelchair less. An additional note was that wheelchairs have the potential to get wet if patients spill or are caught in the rain. If possible, measures should be taken to waterproof the prototype to protect the sensitive electronics. These extra requirements are reasonable, and should be feasible to include in another iteration of the design.

6.2- The Test

We will not be able to test our product on the actual clients, due to hospital regulations. Instead, we could attach our system to one of the wheelchairs provided to us and organize an obstacle course. We could get students to try out the course and see how the technology works for them. This would allow for feedback on the functionality. If we filmed some of these we could use it for interviews with clients who would actually be

interested in using this technology in the future. The test course will test our prototype by using objects that closely mimic everyday obstacles that the client must deal with. Such objects include doors, chairs, narrow hallways, objects low to the ground and things to interact with (automatic door buttons). In addition to physical obstacles, the course will include everyday tasks, such as parking, reversing and turning. For increased immersion, test participants will have limited physical mobility, and will not be permitted to move their head or neck. The makerspace lab will be the optimal place to perform the tests, as there are tables, chairs, doors, open space and a narrow hallway, which can be rearranged to physically mimic a hospital. Two trials should be performed for each client. The first will be done without the aid of the prototype, and the second will include it. This allows the performances to be compared so that the strengths and weaknesses of the prototype can be highlighted and analyzed. The participant will be asked to reflect on their experience, compare their performance in each trial and provide any additional feedback they feel necessary.

6.3- Next Client Meeting

We will present a working backup camera with a monitor. This setup will also be equipped with a power source and mounted screen. We may also present our findings on public opinion of the project.

6.4- The Prototype

The prototype that we have currently performs the primary task of providing rear sight, which is acceptable for the first physical prototype. However it will take time to incorporate the secondary sensing devices and any additional features. Ideas for the final aesthetics and dimensions are still being considered and are very flexible at this time. We believe that the functional components must be finalized or at least almost established before the aesthetic and other non-functional physical components can be seriously analysed. Our prototyping design strategy will mimic the agile design model, where our early prototype will continue to be modified and changed to best suit the needs of the customer in the final product. Since our product mainly uses technology, it will be the most viable option to start working with it and getting it to function properly rather than tying up time and money in non-functional prototypes and then scrambling to get the final version to work well at the end.



Figure #10: Picture A of prototype 1



Figure #11: Picture B of prototype 1



Figure # 12: Picture C of prototype 1



Figure #11: Picture D of prototype 1

7.0- Business Model and Validation

The purpose of this section is to introduce the type of business model that our group will use for our project. Additionally, we will justify why we used this business model, and defend our choice.

7.1- Our Choice of Model

The Business Model we thought would be most effective was the canvas model. We chose this business model as it most clearly and concisely lays out all aspects of our

desired project. The model fits on one page allowing us to see at a glance what we are working with. It is thorough and allows for details and modifications as necessary. This ensures nothing will be overlooked. Another benefit is that this model is simple and easy to follow making it clear, and the best choice for us.

7.2- Validation

The validation model assesses our riskiest assumptions and checks them based on set criterion. This is a quick way to go over our venture to ensure we are making decisions that will benefit us in the future.

7.3- Introduction to our Business Model

Below you will find our business model that details the inner workings of our company. The goal of our business model is to give accessibility to those who are physically disabled in order to make their daily lives better and easier. This reinstates their freedom which may have been previously taken away by their disabilities. The customers we are targeting are the physically disabled who use wheelchairs, specifically the audience in hospitals. Our business is customer service oriented, and we have personalized relationships with our clients, giving us the ability to personalize the product to fit their wheelchair with minor adjustments. These minor adjustments will be what makes the difference between our company and any potential competitors, as the aid will be personalized thus being effective to use. Our marketing is targeted towards hospitals as well as individual clients. This is because one of our major channels is hospitals, where they will ideally be able to promote our product and allow the potential customers to see how it is useful. We will also promote our product through a website and a social media campaign. Since we are aware that older customers may not be thrilled with technology, we are also making it available for purchase directly through suppliers as well as through the hospital. The social media campaigning is targeting younger clients who are part of the technologically advanced generations and will be able to learn about our product that way.

The main value that our product is proposing is restoring the freedom to the client that they lost when their mobility was challenged. Our product is also ensuring the safety of the user by allowing them to increase their range of visibility with the backup camera and sensors, so they don't run into things. The product is cost effective, with a low expected cost to produce, and since it is such a valuable addition to the wheelchair we are hopeful that it will be a success on the market.

The key partners to make our product successful are suppliers, hospitals, insurance companies, and patent offices. The suppliers will be the basis of our product, giving us

the materials needed to make our product including Raspberry Pi, sensors, display screen, etc. Hospitals and insurance companies will be our key partners in purchasing and promoting our product. The key activities for our business are operating with mobility technology and based on supply or demand. By using supply and demand as a reference, we can ensure that we have enough of the product available at all times, which reduces the possibility of making too much of a product as well as not having enough to keep up with the demand. The key resources are technological firms, hospitals, and the link formed with suppliers. These resources will ensure that the product can be properly built and supported, thus making our product successful.

The direct costs associated with our product are materials, manufacturing and assembling. These costs are the basis for our product because without them, we will not have any sort of product. The hidden costs are in shipping, licensing and maintaining regulations. These are equally as important, but can often be forgotten since they are not directly related. That being said, all the costs put together still manages to present an affordable product. Our business will gain revenue from insurance companies, client's personal accounts and hospitals. These sources of revenue mainly come from the sources purchasing our product, and the avenues by which they are purchased.

7.4- Business Model Canvas

Key Partners <ul style="list-style-type: none"> ● Suppliers ● Hospitals ● Insurance Companies ● Patent Office? 	Key Activities <ul style="list-style-type: none"> ● Mobility Technology ● Supply & Demand 	Value Propositions <ul style="list-style-type: none"> ● Restoring lost mobility & freedom ● Cost effective ● Safety 	Relationships <ul style="list-style-type: none"> ● Customer service ● Personalized relationships with patients ● Marketing to hospitals & clients 	Customer Segments <ul style="list-style-type: none"> ● Physically disabled ● Hospitals
	Key Resources <ul style="list-style-type: none"> ● Technological firms ● Hospitals ● Link with suppliers 		Channels <ul style="list-style-type: none"> ● Hospitals ● Direct suppliers ● Website ● Social media campaign 	
Cost <ul style="list-style-type: none"> ● Materials ● Shipping ● Manufacturing ● Assembly ● Licensing ● Regulations 			Revenue <ul style="list-style-type: none"> ● Insurance companies ● Clients personal accounts ● Hospitals 	

Figure #14: Business Model Canvas

7.5- Assumptions

1. Reliability
2. People will want it
3. People will buy it
4. People can afford it
5. We don't have any competition

6. We conform to regulations

7.6- Validation Board

<p>Core Assumptions:</p> <p>Reliability People will want it People will people will buy it People can afford it We don't have any competition We conform to regulations</p>	<p>Riskiest Assumption:</p> <p>People will want it</p> <p>Able to manufacture and deliver at an acceptable rate.</p> <p>Able to perform installations on wheelchairs while conforming to the hospital rules</p>	<p>Invalid</p> <p>Our product had a very positive response from clients</p> <p>Able to manufacture and deliver at an acceptable rate.</p> <p>Able to perform installations on wheelchairs while conforming to the hospital rules</p>	<p>Valid</p> <p>People show interest in this product</p>
	<p>Method for validation:</p> <p>Opinion poll</p>		
	<p>Success criterion:</p> <p>70% of the public believes in the concept 50% of above believe in execution. 10% of people believe in us</p>		

Figure #15: Validation Board

7.7- Validation Board Description

Using a Validation board we will attempt to validate (or invalidate) our riskiest assumptions. From our validation board, the riskiest assumptions that we have concluded upon, are as follows: people will want the product, the price of the product will match consumption, and the product can be used in a hospital facilities legally.

To validate our first assumption, we must perform surveys with applicable clients. These surveys would ask a variety of questions that would confirm whether or not possible clients find this product attractive and if they would be willing to buy said product. During our visit to St. Vincent Hospital we conducted a quick survey to various patients and are happy to conclude that this product is attractive to them, especially if the product is affordable and is able to perform well consistently. Therefore this risk assumption is validated.

To validate our second assumption, we must first confirm what our production rate is and what the consumption rate of the product is. To date, we have not fully produced a complete product. This is because we are still in the prototyping phase of our product development, and are not able to produce a complete product without any bugs; this is still in the works. Additionally, if demand increased for the product, significant investment would need to be made to construct the 3-D printed housings of the product. We have not yet confirmed what the demand is for our project. While people seem to be interested in it as stated above, no one has come forward and directly said that they would want to purchase it. Therefore, the risk assumption of production rate, and consumption rate is an invalid assumption because it has yet to be confirmed

To validate our last risk assumption, we must first determine the specific regulations, and laws governing the ability to install our project in hospitals, legally. This would require communication between different accessibility government offices, along with hospitals that we wish to deploy our product to. In order to figure out the regulation that we must meet in order to sell our product in an approved legal fashion this communication needs to occur. To date, communication between hospitals and government accessibility office's has not been established to determine these specific regulations. Therefore, the risky assumption of rules and regulations conformation, is an invalid assumption.

8.0- Customer Validation

As mentioned in our presentation, we have discussed customer validation. Additionally, it was delivered in Slide Show Presentation. Please refer to the Appendix for any and all slideshow presentations, that are relevant to this report.

9.0- Economics Report

The purpose of this section of the report, economics, is to present our economics report in an attempt to show a theoretical case of us becoming an actual company.

9.1- Cost

Our project has a variety of different costs associated with it, including those that are direct, indirect, fixed and variable. In the table below there is a summary of the costs associated with our project with the appropriate type of cost.

Fixed	Variable	Direct	Indirect
<ul style="list-style-type: none">- Rent for the Workspace- Initial machinery cost	<ul style="list-style-type: none">- Materials- Manufacturing	<ul style="list-style-type: none">- Materials- Manufacturing- Assembly of Product/Labour- Shipping Cost for Materials- Licensing and Patents	<ul style="list-style-type: none">- Utilities of Workspace- Taxes- Depreciation

Table #4: Cost Table

The majority of the variable costs are costs directly related to the production of the product. This makes sense because they are directly proportional to the amount of product produced. Although the materials may be a fixed price individually, the amount required to be able to create the desired product is variable. It is also possible to get discounts for purchasing things in bulk.

Although cost is the exact amount that it takes to make something based on the respective direct, indirect, fixed and variable costs, it is not the same thing as price. Price is determined by a variety of different factors, but it is the value that is associated with a particular product based on its overall usefulness. Price is determined by the TIRES factors (time, income, risk, expense, state).

The expected cost for prototyping is much lower than the cost of mass production. Although there may be discounts for purchasing large volumes of materials at once, it is still considerably more expensive than those for a single prototype.

9.2- 3 Year Income Statement

Item	Year 0	Year 1	Year 2	Year 3
Depreciation expense?	0	2830	2264	18.112
TOTAL ASSETS	0	0	0	0
Cash	0	0	0	0
Licensing and Patents	500	0	0	0
Equipment	\$14 150	\$11320	\$9056	\$7244.80
Total current assets	0	0	0	0
Net revenue from sales	0	33500	33500	33500
OPERATING EXPENSES	0	0	0	0
Cost of Goods Sold	\$40000 (80 x 500 units)	\$80.00	\$80.00	\$80.00
Workers	\$130 000 (see below)	\$130 000	\$130 000	\$130 000

Office space	\$24 000	\$24 000	\$24 000	\$24 000
Shipping?	2400 (4.80 x 500 units)	2400	2400	2400
Total Operating Expenses:	\$210 550	\$196 400	\$196 400	\$196 400
Total current liabilities	144150	141320	139056	137244.80
Total expenses	354700	337720	335456	333644
Gross Profit	19350	52850	86350	119850
Operating income	33500	33500	33500	33500
Total	-321200	-304220	-301956	-300144

Table #5: 3-Year Income Statement

9.3- NPV Analysis

Using a NPV analysis, determine the break-even point (it is highly unlikely that your operating income will be positive in the first year because of fixed costs).

Rent a Space: Taxes, monthly rent

= **\$24000 per year**

Annual Wages (all 6 workers)

= \$73 hourly x 40 hours/week x 52 weeks/year

= **\$151840 per year**

Initial Cost of Machines:

= **\$14 150**

Cost per unit: materials, labour, equipment, rent

= \$90.00 (parts) + \$5 (hydro & equipment)+ \$5 (Shipping)

= **\$100.00**

Sale price: what the perceived value is

= \$175

(@ expected rate of 2500 units yearly, at a profit of 75\$ per unit sold)

3-year analysis

$$NPV (Analysis) = -Co + C1/1+r + C2/(1+r)^2 + C3/((1+r)^3)$$

$$NPV (Analysis) = -14150 + 33500/(1+0.02) + 33500/(1+0.02)^2 + 33500/(1+0.02)^3$$

$$NPV (Analysis) = 82460.09 \$$$

Sale number minimum to break even at our set price:

It would take 2054 units per year to break even with the rent, and an additional 200 units to cover the initial cost of machinery. Therefore at the end of the first year, to break even we would need to sell 2254 units.

9.4- Justification of Assumptions

In order to create our economics report, we have made several assumptions. For one, we have assumed that the creation of our project has been turned into an actual business, and that people will actually want to purchase our product. We have assumed that by purchasing materials in bulk that we will be able to get discounts. In addition, we are assuming that in the future we will be able to purchase only the parts we will need and not be re-purposing other products to accumulate the parts required. Another assumption would be the number of assembly hours. If all workers work 40 hours a week, five days a week for a whole year, the total amount paid to the workers each year will be \$130 000. Our office space rent is based off an average for the area and is therefore an estimate. We are assuming that our equipment will last 3 years and will not need to be replaced in this time frame. Advertising costs in our business plan is mostly through direct contact with the company but we may need to look into allocating more in the future to increase the success of the business. Even though all the sections above have some room for error we believe them to be as close to accurate as possible given what we know of other companies and of the area's pricing.

10.0- Prototype II and Client Meeting

This section of the report, Prototype II and Client Meeting, will summarize our second prototype along with any feedback our client gave to us after our meeting with them.

10.1- Client Feedback

Our client Bocar as well as the patrons of the hospital and our project managers were kind enough to provide feedback for our physical prototype. They mentioned that our

design itself seemed solid enough but could use some improvements. To start, our on/off button seemed sound but may be unnecessary as it's always better to avoid clutter. If we had time we should also look at attaching sensors that could detect backwards movement and utilize the sleep function of the Raspberry Pi. They noted that the mounting arm would work but perhaps we should lean towards an adjustable post instead of a fixed rod. In addition they mentioned that the system's durability and ability to function outdoors is a must. This means our components should be contained in a case of some sort, which we had already begun work on. Bocar in particular was happy with the choice of system being a Raspberry Pi as he is already familiar with it. At the end they listed some things that we should add if possible these included: sensors for the client's feet, an increased battery life, an audible signal, and sensors for distance. However they warned that students often take on too much and that they would still like to see a completed product.

10.2- Design goals

Our ultimate design goal is to make a functional physical prototype of our project that is aesthetically pleasing and fully complete by the project deadline. We believe that it is essential that our product performs its primary task properly.

The prototype of our project which we presented on design day accomplished the basic intended functions to our satisfaction. It included a functional camera connected to a display screen mounted to an adjustable arm clamped to the arm of the wheelchair. The display screen was enclosed in a 3D printed case, and all wires were ran along the framework of the wheelchair using zip ties to secure them. The camera was mounted to an acrylic shelf created to support the camera at the rear of the wheelchair, and this shelf was secured to the frame using an extensive amount of zip ties. Our prototype was fully functional and able to be tested by anyone who came by our table on design day, giving the full experience of our product.



Figure #16: Pictures of the Second and Final Prototype

10.3- Design Day Outline

Our group availability for November 29th is given by the following table. Green depicts when members will be present at the booth, red indicates when members have mandatory classes.

All members will have a thorough understanding of all the project components. Our booth will include a tri-fold poster board to document the process and function of the prototype through pictures and text. The schedule of who will be present at what times during design day is located in figure 1.

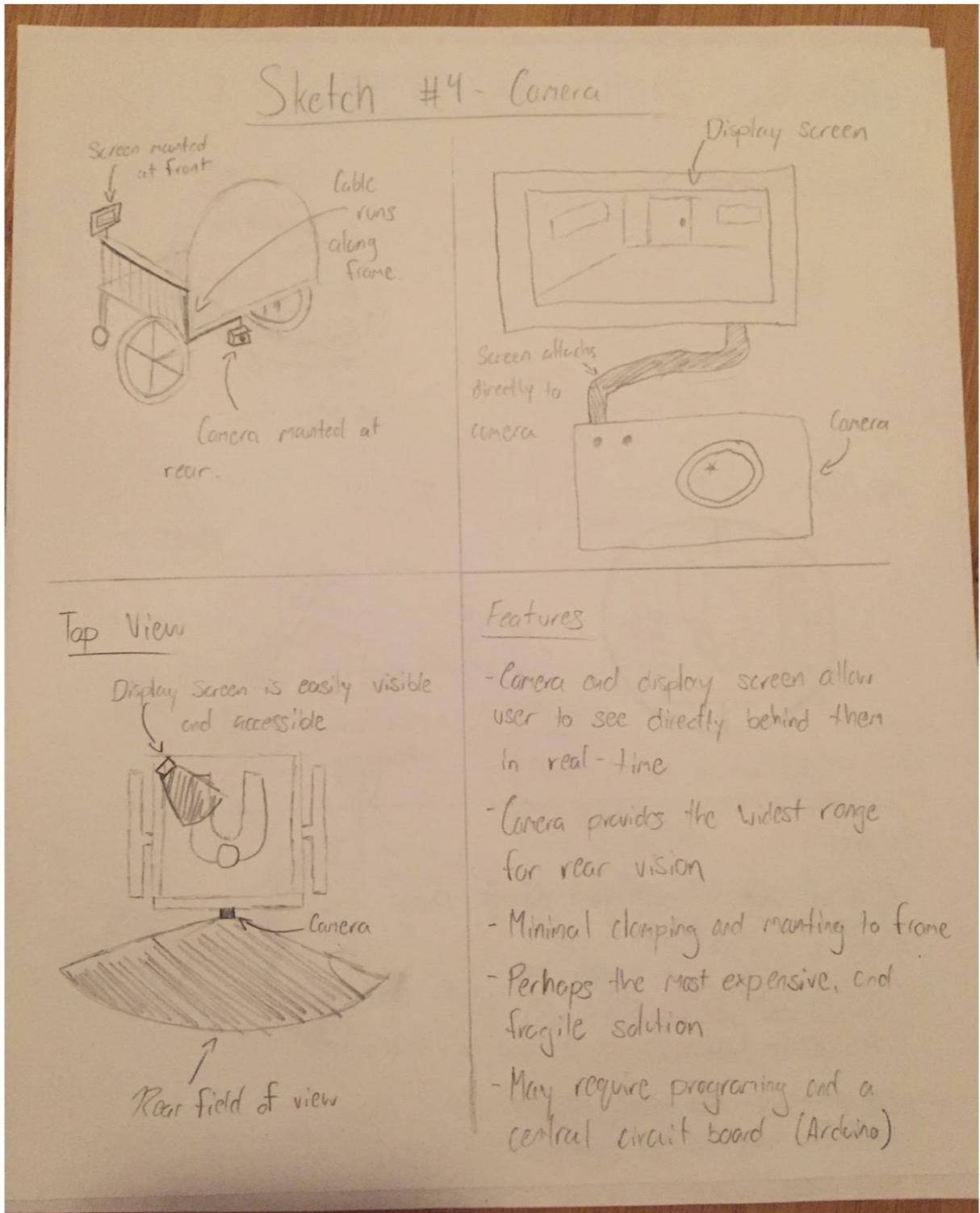
The prototype will also be present for live demonstrations. The public feedback we receive during design day will allow us to evaluate the success of our prototype and whether or not we have fulfilled our design goal.

Our pitch for the judges will focus on our strengths, namely that our design is completely functional, compact, aesthetic and under budget. Since there is a possibility that another group may have done the same project as us, it is important that we highlight these positive aspects of our project, and avoid talking about the things we couldn't get a chance to implement. We will also mention our future steps, which includes the implementation of functional sensors which can audibly beep when someone is backing up.

	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Steph	Available	Available	Available	Available	Available	Available	Available
Dylan	Unavailable	Available	Available	Available	Available	Available	Available
Kelton	Available	Available	Unavailable	Unavailable	Available	Unavailable	Unavailable
Elyse	Available	Available	Unavailable	Unavailable	Unavailable	Available	Available

Figure#17: Schedule of Availability on Presentation Day (Nov.29)

10.4- Our Prototype



Original concept sketches (Prototype 0.0)



Prototype 1.0



Prototype 1.1



Prototype 2.0

11.0- Future Work

In the future, we would like to continue working on our project. We believe that our final prototype presented on design day was a success overall, and with a few minor improvements can be a very successful product on the market and can be very helpful to people using wheelchairs. Since sensors did not end up being in our final prototype, we would like to implement them in the future ones. We would like to get them to display distance values on the screen from objects, and also have a light flash or an auditory beep when a certain distance is reached between a person and an object. This will give increased awareness to the client of their surroundings. It can be considered to implement these sensors to various locations on the chair, possibly including the back, the sides, and at the feet of the chair. The various sensor locations can produce different colour lights or different sounding beeps to tell the client where the obstacle they are to avoid is located. In future prototypes the aesthetic of the design can be further refined to make the wires completely concealed to avoid extra clutter on the chair. A better battery would also be considered so that it can last for longer than a day, as the longer something can go without being charged, the more appealing it is to the user.

12.0- Conclusion

Looking back on our final prototype and the three months leading up to its completion, our group is proud of what we accomplished. All members put forth a strong effort and pooled our strengths to create a functioning product that has the potential to improve the quality of life for many people. Despite financial, technical, time and creative obstacles, we triumphed. This was only possible through teamwork, applying the concepts taught in class, and expanding our knowledge and skill sets. Although at times work levels and tensions rose, we all recognized the success of the project depended upon our ability to adapt to and overcome any situation that came up. Though the purpose of the project was to apply the course material and develop our skills, it is without question that we all learned a great deal about ourselves and each other in the process. In addition to a great product, we also made professional contacts, fond memories and lasting friendships, which will serve us for years to come.