Project Deliverable M: **Final Report**

University of Ottawa

Accessibility Team A1

Introduction to Product Development and Management for Engineers and Computer Scientists

GNG 2101

December 14th 2018

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Abstract

This project was developed for the class GNG2101. The project chosen was to develop a portable ramp for wheelchair using clients. The ramp was specified to be used for 3 steps ideally. Additionally, it should be very portable meaning low weight, low size, and low setup time.
The design process used was specified by the class and involved 2 primary loops. The first loop was the problem refinement loop. In this loop, communication and feedback from the clients were used to discover the main issues to be solved. Once the problem statement was discovered we designed and implemented solutions. Through an iterative process of brainstorming, analyzing and prototyping, the portable ramp developed into a sturdy and portable solution. In the end, the ramp was constructed largely from aluminum. Using tension bars, cylindrical compression pieces and a tension band, the ramp was sturdy enough to resist the forces caused by weights greater than 700 pounds. Additionally, cloth hockey tape was used as a traction surface for the wheel. For portability, the ramp was foldable using hinges, and could be carried using a shoulder strap.

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1.0 Introduction

In the events leading up to the first meeting with our clients at Partners in Parenting, some preliminary research was conducted by the team (PD A) as to attempt to establish a better understanding of what the potential clients might be facing. We had found that the organization centers its focus around youth and children with disabilities and helps to establish an appropriate curricular network to teach these individuals valuable lessons. Following the first interview, It was made clear that accessibility was a major issue in the daily activities of these people, to which we found a powerful emotional relationship between our necessity to provide a solution and to the clients' will to overcome this problem. Regardless of the potent clarity of the importance of the matter within this small community, it still loomed over our heads as to how relevant is the problem was on a larger scale.

Following the work conducted in PD B, background research had made it clear that nearly 13% of Canadians self-identify as having mobility issues, while 10% of all Canadians self-identify as having some form of disability (Rick Hansen Foundation, 2016). With this information we had established the relevance of the issue on a national scale, it was time to set in motion the production of a relevant solution. A light, portable and inexpensive wheelchair ramp was needed and we were to provide it.

Throughout the course of the semester and as reflected by the contents of this document, various steps were taken in accordance to the guidelines administered by the GNG2101 curriculum and design process to develop an appropriate and unique solution for our clients. This being said, our product, The F.L.I.P. Ramp, became the pride of our efforts and boasts some unique features in its manufacturing process and assembled content functionality. The F.L.I.P. Ramp is unique in that it can be assembled within seconds of unloading, costs less than 300$ to manufacture (see section 8.0) and can be collapsed to less than half of its expanded size. With these specs, we are able to demonstrate the benefits of our product with respect to the competition (see section 2.3).

With this in mind, the events leading up to the current prototype is the result of a multi-step agenda introduced as the GNG2101 iterative design process, which is presented in detail within the first half of this document. Meanwhile, the analysis of the various constraints throughout the development of our solution, along with the hypothetical requirements for establishing a running business were addressed in the later half of this report.

2.0 Needs Identification & Product Specification Process

2.1 Problem Statement

The purpose of the project is to design a lightweight, durable, adaptable and inexpensive ramp to be used by wheelchair bound individuals such that it is portable and easy to assemble by a single person. It is to be collapsable and accommodate various users with a wide range of sizes and masses.

2.2 Needs Identification

This section of the report focuses on taking customer statements from the first meeting turning them into needs. Needs were determined via observation and client statements. Using critical thinking (Who?, Specifics, Positive, Attributes of the Product and Avoid Ranking) we came up with criteria for all the clients needs.

Table 1. Criteria for Needs Statements

1. Functionality	2. Form	3. Usability	4. Cost
Performance Reliability Compatibility Flexibility	Aesthetics Durability Portability Maintainability Uniqueness	Ease of use Complexity	Acquisition Use Disposal

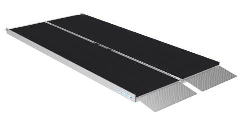
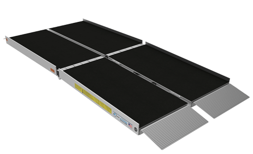
Table 2. Examples of translation and prioritization of statements/observations into needs

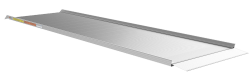
CUSTOMER STATEMENT	EXTRACTED NEED	PRIORITY (1 - LEAST IMPORTANT 5 - MOST IMPORTANT)
"I would like it if I had a ramp so that I could walk up independently"	The ramp is simple to assemble with clear instructions.	5
"I would like railings .. not just me, but everyone else.."	The ramp has a means of leaning on and haptic feedback.	2

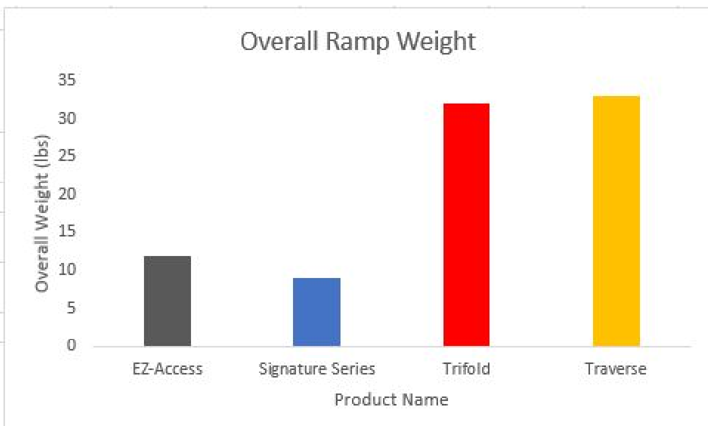
2.3 Benchmarking

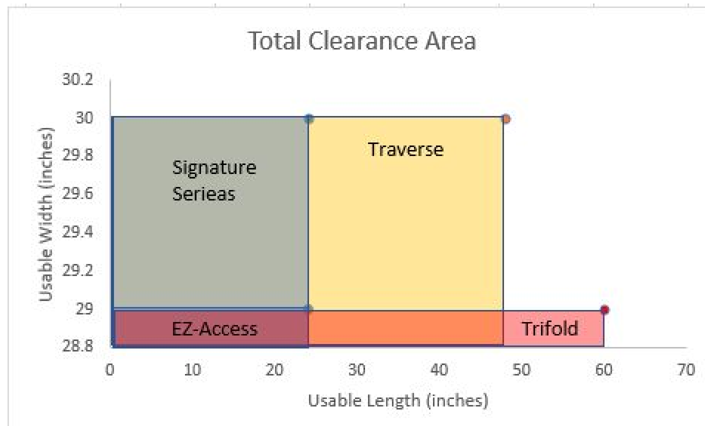
The following competitive products were found online. Each of these products was given a rating by Express Ramps, an American wheelchair ramp installment company, which specializes in standardized commercial and residential wheelchair accessibility product installation.

Table 3. Competitive Final Specs and Customer Ratings

Product Name	Express Ramps Rating	Final Specs	Comments
EZ-Access Suitcase Portable Wheelchair Ramps 	4.5/5	Usable Size: 2' L x 29" W Folded Size: 2' L x 15.5" W Overall Width: 30" Weight Capacity: 800 lbs. Ramp Weight*: 6 lbs. x 2 pieces* * Ramp weight increases by 2 lbs for every 1 ft increase in length	This had the smallest workable area, despite its emphasis on portability and handedness. Regardless, it demonstrated excellent versatility.
Signature Series Suitcase Portable Wheelchair Ramps 	4.5/5	Usable Size: 2' L x 30" W Folded Size: 2' L x 15.5" W Overall Width: 31" Weight Capacity: 800 lbs. Ramp Weight*: 9 lbs.* * Ramp weight increases by 5 lbs for every 1 ft increase in length	With an equivalent loading capacity to that of the EZ-Access model, the Signature series offered a larger usable area, while maintaining a light overall carrying weight.
Trifold Portable Wheelchair Ramps 	5/5	Usable Size: 5' L x 29" W Folded Size: 2.5' L x 15.5" W Overall Width: 30" Weight Capacity: 800 lbs. Ramp Weight*: 16 lbs. x 2 pieces * Ramp weight increases by 3 lbs for every 1 ft increase in	The folded size of this ramp is slightly larger than the EZ-Access Suitcase Portable ramp however, it offers the largest usable area of the

		length	four.
Traverse™ Portable Ramps 	5/5	Usable Size: 4‘ L x 30" W Overall Width: 31" Weight Capacity: 1200 lbs. Ramp Weight*: 33 lbs.* * Ramp weight increases by 11 lbs for every 2 ft increase in length	With the 2nd largest usable area, the Traverse series has the largest weight capacity. In return, the ramp is also the heaviest of all 4 models.





Figures 1 & 2. Visual representation of each of the competitors' final specs.

For all cases, the portable ramp needed to find balance between the *usable area, total carrying weight* and *load capacity*. Where one might excel, the two others will have to pay the price. The image below demonstrates a visual representation of the three factors in effect for each of the given ramps.

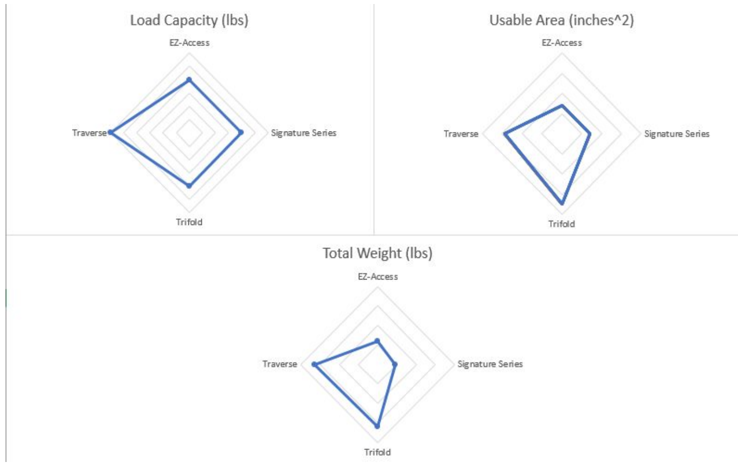


Figure 3. Trade-off sequence of the four products

Given the representations and the quantifications of the various competitive products unveiled through research, it was made evident that the Signature Series boasted a well rounded equilibrium for performance, weight and usable dimensions.

2.4 Metrics and Target Specifications

Following benchmarking we set out to derive our metrics. The metrics found in this project would be based off of the products that were benchmarked. Below is a table of metrics that each both a description of what it is as well as the associated units.

Table 4. Metrics breakdown obtained from competitive products

METRICS DESCRIPTOR	UNIT
Total weight of the collapsed ramp	Kilograms (Kg) or Pounds (lbs)
Total time of assembly	Seconds (s)
Load bearing capacity	Kilograms (Kg) or KiloNewtons (kN) or Pounds (lbs)
The surface friction upon contact of two varying materials at multiple loads and inclines.	Coefficient of Friction ($\boldsymbol{\sigma}$)
	KiloNewtons (kN)
	Degrees (°) or Ratio (height:length) (m or inches)

Acceleration while scaling the ramp	Acceleration (m/s^2)
Reflectiveness of the material	Lux (Lx)
Clearance room per platform	Meters squared (m^2) or Inches squared (in^2)
Ramp width, height and length	Meters (m) or inches (in)
Weatherproof ability	Ingress Protection Rating (IP) See Appendix B

After deriving our metrics from benchmarking, we now had the task of coming up with target specifications of our final product which would be based off what we found during our benchmarking,

Table 5. Benchmarking Metrics and Target specs based on marginal values and ideal values.

METRIC ID NUMBER	METRICS DESCRIPTOR	UNIT	MARGINAL VALUES	IDEAL VALUES
1	Total Weight	Lbs or kg	< 20 lbs * [5]	< 6 lbs
2	Assembly Time	s	< 300 s	< 180 s
3	Load Capacity	Lbs or kg	50 - 350 lbs [2]	> 350 lbs
4	Incline	Degrees or Ratio	1:12 ramp slope ratio which equals 4.8 degrees slope [3]	1:12 ramp slope ratio which equals 4.8 degrees slope [3]
5	Friction Factor	Sigma	>0.98 [6]	1.00
6	Frictional Load	Lbs or Kg	>0.98 x load capacity	1.00 x load Capacity
7	Acceleration	m/s^2	< 1.44 m/s^2 [4]	0.68 m/s^2 [4]
8	Reflectiveness	Lux	To be determined based on material used	To be determined based on material used
9	Clearance Room	Meters squared (m^2) or Inches squared (in^2)	Requirement of a minimum of 60 in X 60 in platform [1]	Minimum of 60 in X 60 in available clearance space **
10	Width	Meters (m) or inches (in)	36 - 48 inches [1]	48 inches

11	Height	Meters (m) or inches (in)	With handrails 34 - 38 inches [1] Without handrails < 5 inches	With handrails 38 inches height. Without handrails 3 inches
12	Length	Meters (m) or inches (in)	30 - 36 inches (as per incline ratio - see above)	36 inches
13	Weatherproof Ability	Ingress Protection Rating (IP) See Appendix B	Solid particle IP: 4 - 6 Liquid Particle IP: >6	Solid particle IP: 6 Liquid Particle IP: 8

3.0 Conceptual Design

This section of the report will focus on the conceptual designs that were theorized by the group. After deriving Design Criteria, we were each given the task of ideating and conceptualizing a design which we thought would solve our client's problem.

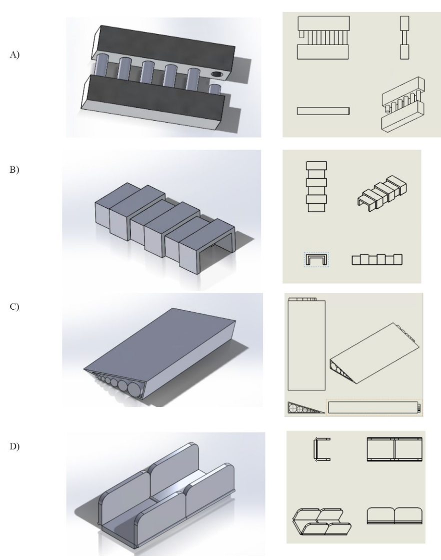
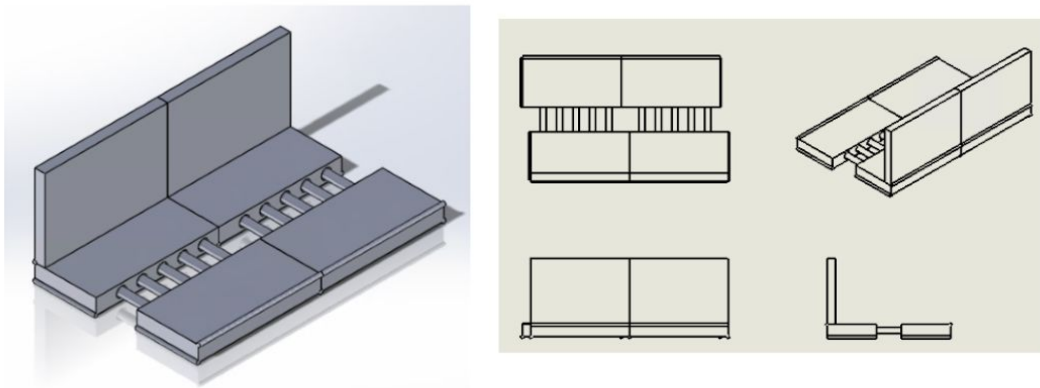


Figure 4. A 3D model of each of the four concept designs that were ideated and presented in Project Deliverable C.

After each design was drawn, the six hat method was used to analyze and critique each design. From the critiques, a final group concept design was conceptualized and presented as a fit solution to the client's problem.



Figures 5 & 6. A promising solution comprised of a combination of elements from previous sketches.

Displayed in figure 5 is a detailed, yet simplified, diagram of a potential solution to the problem statement introduced in previous work. Using the SCAMPER innovative technique, the above design was conceptualized.

4.0 Project Plan and Feasibility Study

4.1 Feasibility Study

Table 6. Feasibility study

Technical	Economic	Legal	Operational
MTC skills (Drill Press, Band Saw)	Aluminum	1:12 rise:run	Physical meetings
MIG/TIG Welding	Bolts & Nuts	Min width 36”	Time spent working
Modelling (3D printing, solidworks)	100 $ limit	Barrier/hand railings	Testing
Sewing	PVC piping		
Sheet Metal folding	Nylon carrying case		

Some of these requirements were not achieved as they were deemed unnecessary or impossible during the given time.

Sewing was not used and therefore was not a technical skill needed. Originally, a carrying case was to be used for the ramp, but it was determined to be unnecessary for the deadline of the project. Sheet metal folding was also not used during the manufacturing process and so was not a necessary technical skill.

The PVC pipes were not used in the final project, but were used during the modelling process. Due to this, it may not have been necessary to include as it was not necessary for manufacturing the final product. The nylon carrying case was never used either but was planned to be used.

The legal requirements used are defined for stationary or permanent ramps and as such do not have to be concrete for a portable ramp, but an effort was still made to meet these requirements. The 1:12 rise:run ratio was not met but the ramp was designed keeping the ratio in mind. Additionally, the railings were not used for the portable ramp as the client expressed that they did not wish for railings. Therefore, the railings were removed from the design and the requirement was not met. The minimum width, however, was maintained. As the ramp is two seperate pieces, the width is adjustable for any size.

5.0 Project Analysis

Throughout our project we had to analyze the project as a whole or its components. This was done to ensure safety as well as ensure that our prototype or model functioned properly. Within this project, stress, force, and deformation was tested and analyzed.

Prototype one did not undergo any testing as the main goal of the prototype was to present our ideas clearly to the client.

Prototype two did undergo testing and it was done it was done with a physical model as well as a analytical model on SOLIDWORKS. The testing done on the physical model was stress and load (of a pine wood design). The testing done on the analytical model was stress, and deformation (of an PVC-Aluminum based design).

$$stress = \sigma = \frac{Force}{Area} = \frac{mg}{LW}$$
$$\sigma = \frac{(56.7kg)(9.81m/s^2)}{(1.82m)(1.21m)}$$
$$\sigma = 252.57\ Pa = 0.00025267\ MPa$$

During this test, the prototype held considering the yield strength of pine wood is 41.4 MPa. However, when load on the pine wood jumped down (to exert more force) it broke the hinge connection in the middle. Despite there being no numbers for this we can assume that the force applied to the hinges was enough to make them buckle. The deformation and stress testing of the analytical model can be seen below.

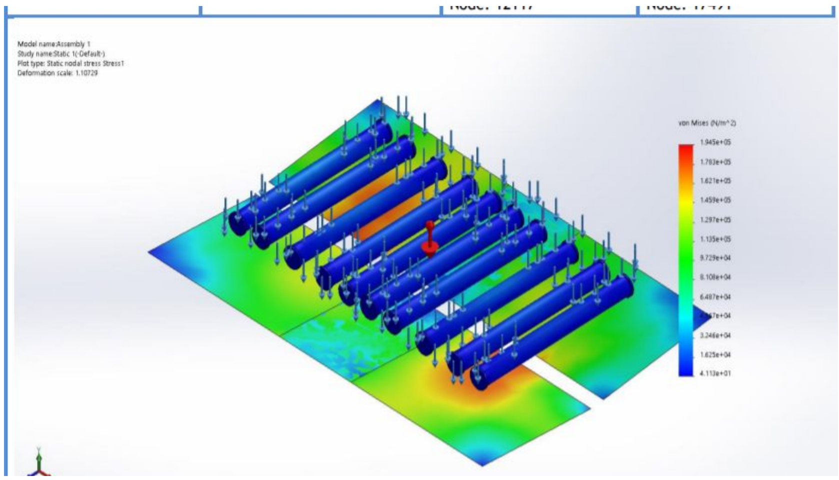


Figure 7. The stress test on the analytical prototype two.

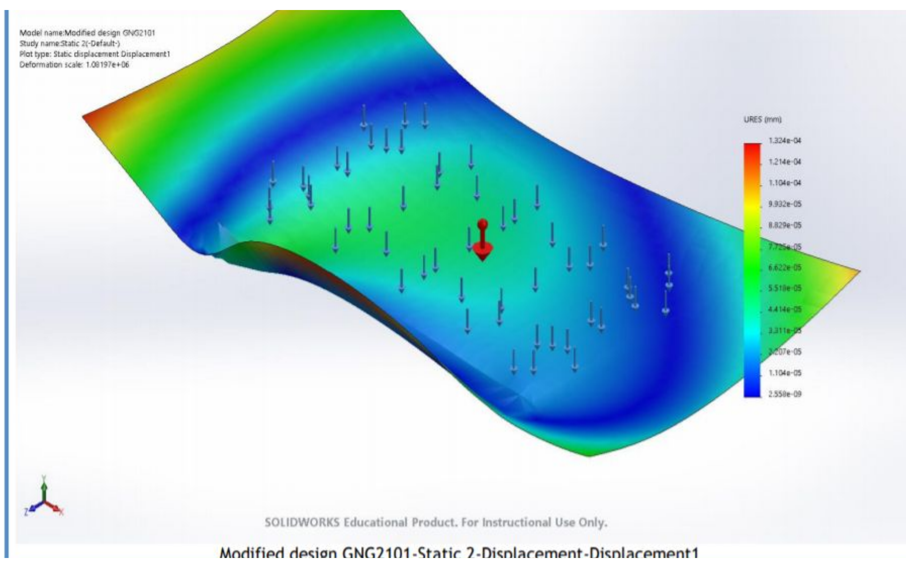


Figure 8. The deformation test on the analytical prototype two.

The equation used in stress testing on SOLIDWORKS was: $stress = \sigma = \frac{Force}{Area}$. The equation used on SOLIDWORKS for deformation testing was: $Elongation = EL = \frac{L_f - L_o}{L_o}$.

Prototype three underwent stress and load testing. This test was performed by a load of a person and wheelchair being applied to the ramp (refer to video attached to brightspace upload).

$$\sigma = \frac{Force}{Area}$$

$$\sigma = \frac{(22.78kg + 72.55kg)(9.81m/s^2)}{(1.82m)(1.21m)}$$

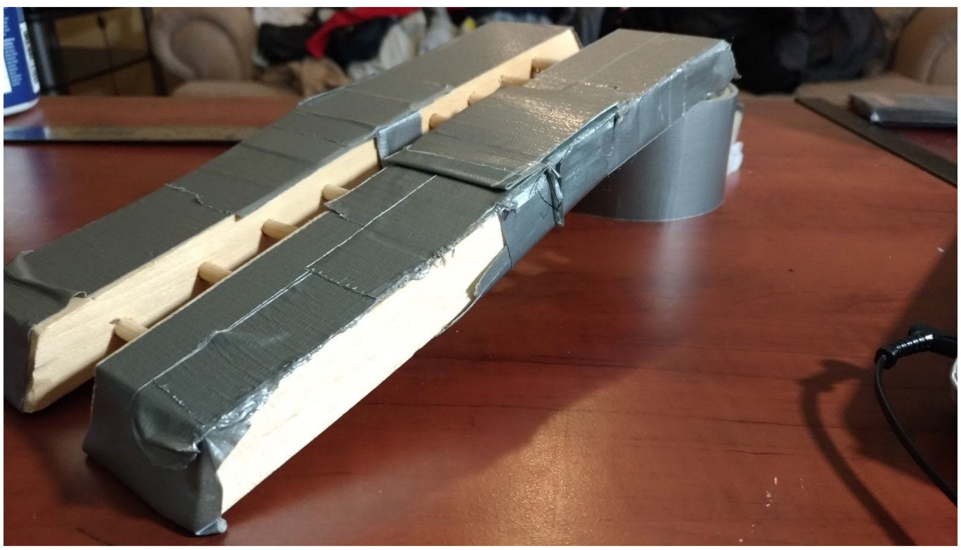
$$\sigma = 424\ Pa\ =\ 0.000424\ MPa$$

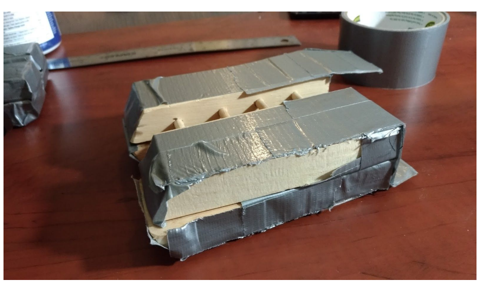
During this test, the prototype easily held considering the yield strength of aluminum 6061-T4 is 110 MPa. This result confirmed that aluminum was a suitable material for the ramp as well affirming our confidence in the new tension-compression hinge system.

6.0 Prototyping

6.1 Prototype One

Prototype one was designed with the goal of communication in mind. We wanted the first prototype to present what our ideas were to the client. We went about this by designing a low fidelity physical prototype one that would be able to effectively communicate our ideas to the client while also being a solid physical representation of the initial design.





Figures 9, 10 & 11. First time alpha prototype presented at the second client meet.

6.1.1 Client Feedback

During our meeting with our client she expressed the following comments towards each of the designs:

Cameron’s Design: One client gave some feedback about this design. They stated that they liked the design and that they were happy it is waterproof. This may be because they had expected a ramp that could be used underwater, however, that is an entirely different application. We restated that it will likely not be used underwater.

Mohammad’s Design: Once again, not too much feedback was given from the clients but one client did say, ”I like that”. The supervisor gave more feedback and said that the design would be perfect for curbs. The design has a quick setup and is only designed for one step. This would provide an easy method to get a wheelchair up a curb which does not provide access, and quickly get the user off the street.

Bryan’s Design: There was no feedback for this design.

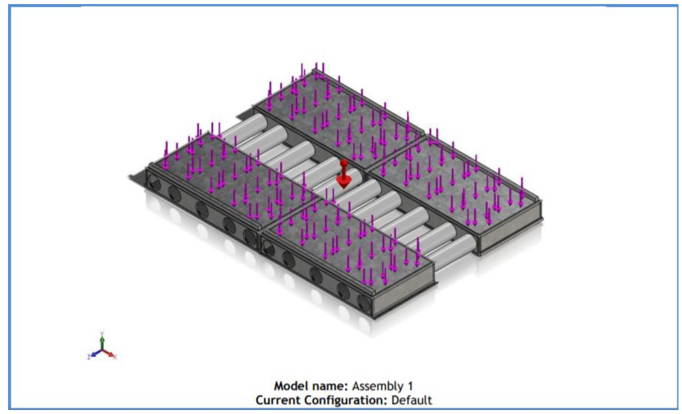
Stephen’s Design: No feedback was given from the clients, but the supervisor did give some feedback. The cylinders that make up the connections should not stick out from the sides of the frames. They might get caught on obstacles or doorways. Additionally, having the cylinders be completely attached to the ramp rather than having assembly required could be beneficial.

Combined Design: The initial impression from the supervisor was that this design is not good. The construction should ideally be one “shake” (unfolding/extending) and then the ramp should be prepared for use. The collapsable idea is still a good idea as well as folding for portability.

Overall: One client said it was pretty well done overall. This client however did not make many comments during the presentation so the client may just be happy with the idea of a portable ramp and just wants one that works. The second client said they liked the first design as well as the second as they seemed sturdier. This client said the first design was preferred due to the higher railings which could help with support and prevention of potential injuries. This is more specific to this client’s particular situation, as they are capable of walking as well. The supervisor gave specific feedback as to features that should be present. The railing would be much better as not detachable. The railing should also be more for wheel guidance than support for the users.

6.2 Prototype Two

Prototype two consisted of two models; an analytical model, and a physical model. The goal of the analytical model was to show the stress loads and results on the system. The goal of the physical model was to show that our design was physically feasible as well as to show the hinge stress test in real life.

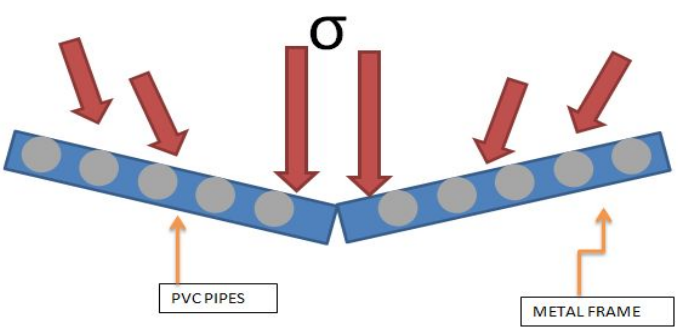


Figures 12 & 13. The physical and analytical model of prototype two.

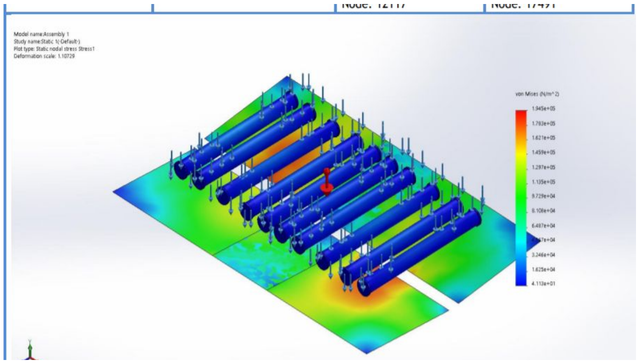
6.2.1 Testing and Results

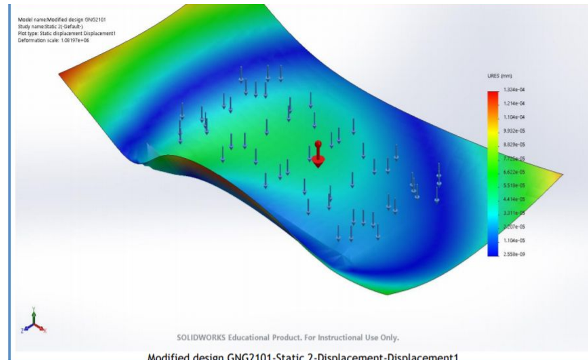
There were tests performed on both the analytical and physical models. On the physical model a simple test of a person standing on the hinges was done. The test resulted in the hinges breaking which meant we had to re-tackle this idea with a different approach in our prototype three design.

On the analytical model there were stress and deformation tests performed. From both tests the results showed that the our current design could withstand the maximum load of stress. However, it also confirmed our physical test results by showing us that the weakest point in our design were the hinges. The hinges were exposed to most of the stress and were the main item to address going into prototype three.



Figures 14 & 15. The test and results hinge stress test of the physical model.





Figures 16 & 17. The results of the stress and deformation tests on the analytical model.

6.2.2 Client Feedback

At the second client meeting we received valuable feedback from our client. We were given many positive remarks as well as a few concerns which we have addressed and will be fixing in prototype II (nearly the final model). Our client was quite satisfied with the time and effort in which the team contributed towards the medium fidelity physical prototype II. She was also very impressed with the acronym that our team had came up with, FLIP (Functional Lightweight Integrated and Portable Ramp).

After showing her the SOLIDWORKS design, the client expressed two primary concerns. The first of which being the difference in height between the lower contact point and the upper surface of the ramp on both ends. The issue was that she was worried it wouldn't be flush with the ground at the top and bottom. This concern stems from the issue that while propelling wheelchair users onto the ramp, the significant change in terrain might prove to be unsettling and rough for both the user and the assistant. We will address this in prototype three by increasing the size of the lip as well as increasing its mobility by adding a movable joint.

6.3 Prototype Three

Prototype three was the final prototype and its goals were to be as close to the final product as possible as well as be a high fidelity functional prototype.

Figures 18 & 19. The high fidelity functional prototype three.

6.3.1 Client Feedback

Unfortunately no client feedback was received from for prototype three. However, on Design Day the prototype received feedback. Most feedback was that people were very impressed with the product overall. People also pointed out the mechanism we used to convert the tension stress in the hinges to compression by using the solid aluminum rods.

Another thing that was stated was how easy the product was to unfold and setup (ie. under 10 seconds). Throughout the day there was no terribly negative feedback besides the fact that design was in two parts and had now bag to carry it around. This is a very minor issue and can be fixed easily by creating a backpack capable of carrying such contraption.

7.0 Final Product and Test Results

The final product that was produced is shown in the figure on the next page.

Figures 20 & 21. The final product.

The final test performed on the product was a simple test of pushing a 160 lb human in a wheelchair up the ramp. The ramp handled the load with no issues; as well as that the hinges withstood the stress and showed no signs of giving in either. A video will be attached to the brightspace upload to show the test.

8.0 Business Model and Economic Analysis

8.1 Business Model

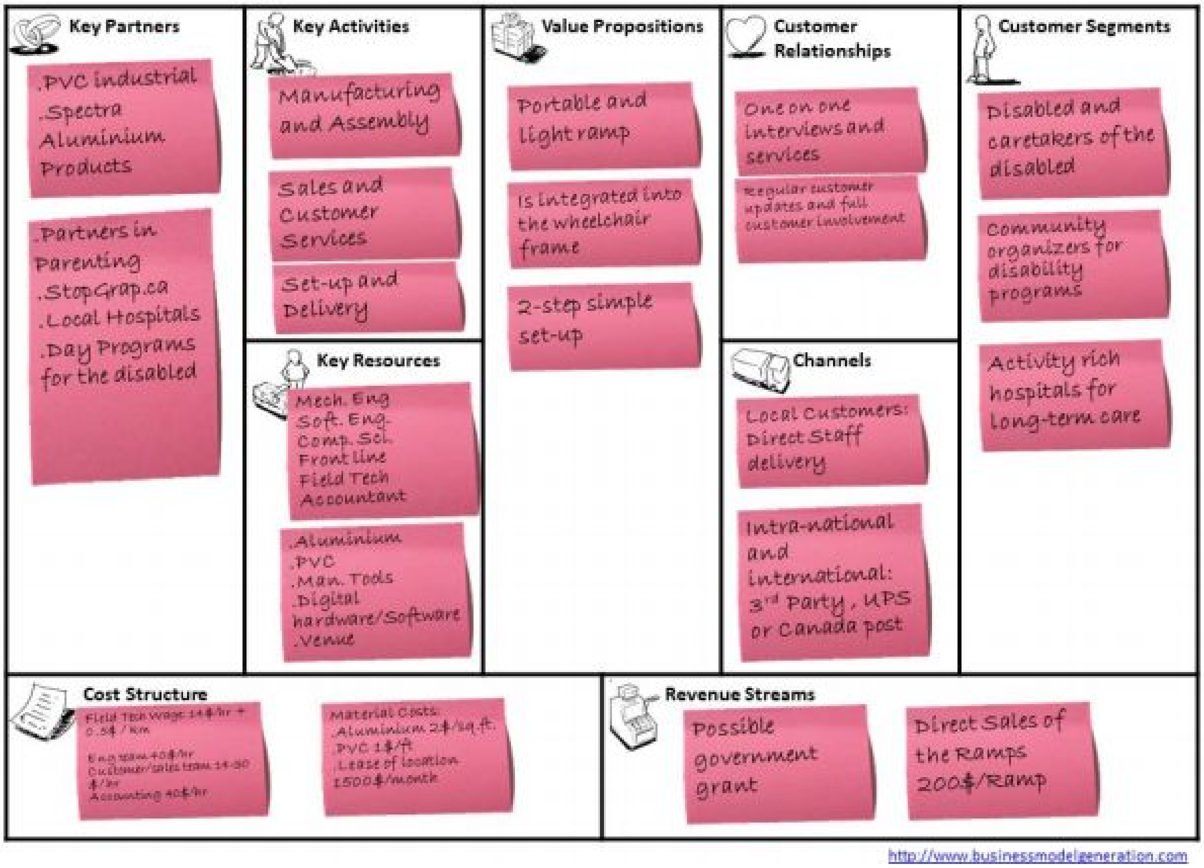


Figure 22. The business model detailing the different key aspects.

The business model that we believe to be most beneficial to our business is the traditional "Brick and Mortar". This model is commonly utilized when one wants to set up a traditional street-side business that interacts with customers face-to-face in an office or store. Local grocery stores and bakeries are excellent examples of businesses that are using the brick-and-mortar business model. The term was later used to differentiate between businesses with storefronts and their online counterparts.

Many consumers prefer to interact with store managers and salespeople directly as they believe questions about products can be dealt with in a more comprehensive and immediate manner in a face-to-face setting. Since our ramp is tangible, well defined and a finite product, we would like for our customers to be able to physically touch, test and take measurements of the ramp before making a final decision. Other business models were viable, however, we believe the brick-and-mortar model will benefit us the most.

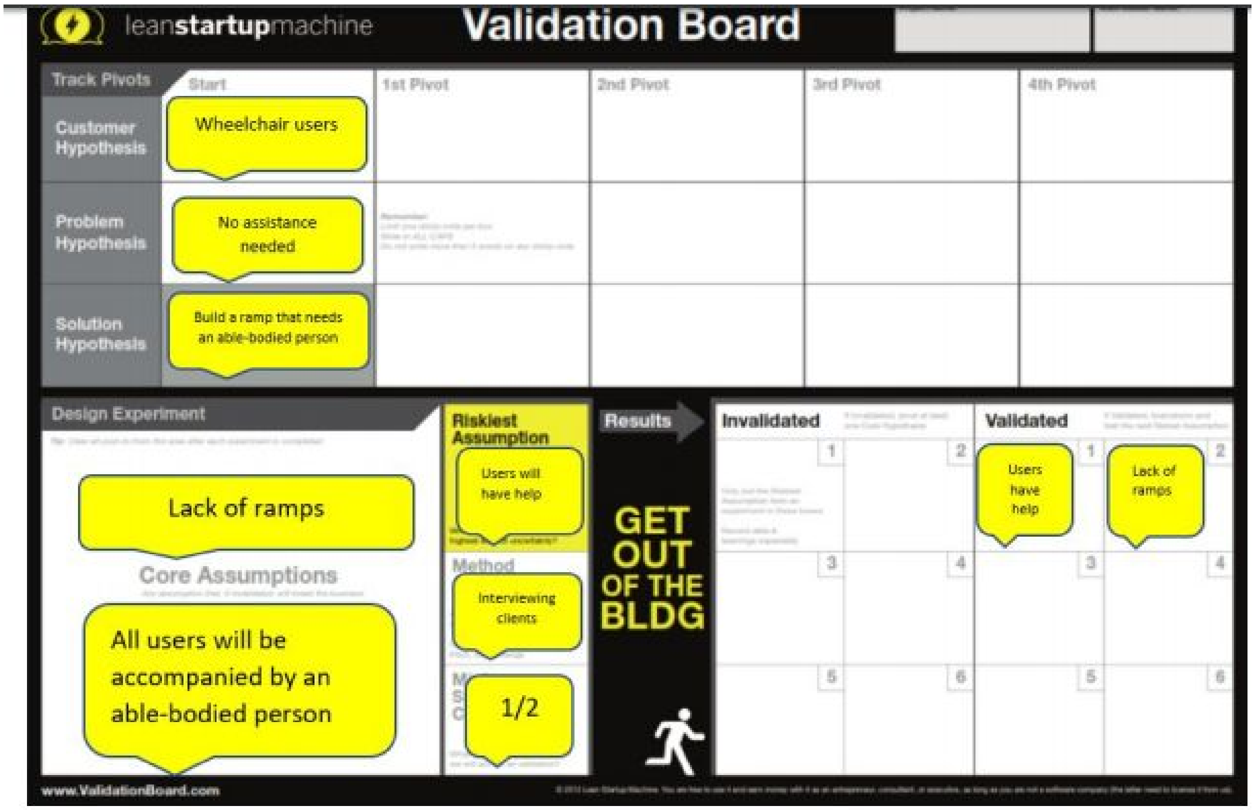


Figure 23. The validation board used to examine the assumptions made.

We validated the assumption that all users will be accompanied by an able-bodied person, by speaking to a representative at the LIFE program. We were told told that no wheelchair bodied person will use the ramp without the help of an able-bodied person. For this validation to be successful we said that at least ½ wheelchair users should be accompanied by an able-bodied person; this assumption was confirmed and we were also told that every person will be accompanied by an able-bodied person. Interviewing the clients and their representative was an easy to confirm our assumption.

8.2 Economics Analysis

Our economics report provides an admirable financial story for the possibility of making a business out of the product, but much like all predictions into the future, nothing is ever certain. Particularly when random variables and events are not taken into account (fluctuations in the market, supplier business status, employee performance status… etc.)

	QUARTER 1	QUARTER 2	QUARTER 3	QUARTER 4
UNITS SOLD	100	300	450	500
MATERIAL COST	31790	95370	143055	158950
REVENUE	38283.5	114850.5	172275.75	191417.5
GROSS PROFIT	6493.5	19480.5	29220.75	32467.5
MANUFACTURING COST	1000	3000	4500	5000
ASSEMBLY COST	500	1500	2250	2500
ADMIN, SALES AND GENERAL	10500	10500	10500	10500
LOCATION RENT	4500	4500	4500	4500
EQUIPEMENT DEPRESSIATION	2000	2000	2000	2000
TOTAL OPERATIONAL COSTS	12000	21500	23750	24500
OPERATION INCOME	-5506.5	-2019.5	5470.75	7967.5
LOAN PAYEMENT	900	900	900	900
INTEREST ON LOAN 6%	3000	2946	2946	2892
EARNINGS BEFORE TAX	-9406.5	-5865.5	1624.75	4175.5
CANADA CORPORATION INCOME TAX (10.5%)	0	0	243.7125	626.325
NET EARNINGS	-9406.5	-5865.5	1381.0375	3549.175

EQUIPEMENT DEPRECIATION RATE	666.67 $ / MONTH
INITIAL PURCHASE PRICE OF EQUIPEMENT	500000
APPROXIMATE SALVAGE VALUE	300000
ESTIMATED USEFULL LIFE OF ASSET	300 MONTHS

Figure 24. The income statement for Year 1.

9.0 User Manual

The instructions written are outlining the setup for an individual piece.

9.1 Folded State

The ramp has many features relating to its portability.
A locking mechanism is attached to the exterior bolts on the open end of the ramp (opposite the hinges). This mechanism keeps the ramp from unfolding while it is being carried. Be aware when removing this locking mechanism that the ramp may unfold if not held with the lock at the bottom.
A shoulder strap can be used to carry the ramp easily between locations. This is the easiest way to carry it as the weight is distributed efficiently. The tension strap underneath the ramp can also be used to carry the ramp short distances, but the weight is distributed inefficiently making it difficult over long distances.
The ramp can also be carried using neither, and simply carried freely. This is the least recommended method however as it may be dropped and damaged.
The edges and corners of the ramp and its parts have been filed down as to not cause cuts when held.

9.2 Setup and Use

9.2.1 Unfolding

Firstly, the locking mechanism is removed. This should be done while the ramp is placed on its side. To remove the lock, simply pull it away from the bolts.
To unfold the ramp when on its side, simply pull the top half up from the open end and fully unfold the ramp. Keep hands away from the area around the hinges while unfolding, as this may pinch skin and cause pain.
If both halves of the ramp are not parallel, this must be fixed. With the bottom of the ramp facing up, push down in the area of the hinges until both halves are flat. This should be done on a flat surface. Avoid placing hands in between the moving parts.
Flip the ramp over and place it near the surface it will be used on.

9.2.2 Placement

With the ramp unfolded and placed top-side up, it can now be placed on the step(s). Firstly, insert both tension bars into the rectangular holders on the top of the ramp. Each bar should pass through the 2 holders on each half. The ramp can now be placed. It is recommended to hold the ramp placing one hand on each

half, but on opposite sides. This avoids placing hands in the foldable area while also keeping the ramp from folding again.
The ramp should be moved onto the step(s) with the hinged lips placed outwards on both ends. The ramp is now prepared for use. The tension bars, tension band, and cylindrical compression pieces all contribute to the ramps sturdiness when in use.

9.3 Folding

After use, the ramp should be refolded for moving longer distances. To do this, remove the tension bars. Hold onto the cylindrical compression pieces on top of the ramp and then simply lift. The ramp will fold on itself or with a small amount of aid. By closing up the open end fully, the lock can be reinserted on the bolts by simply pushing down with the lock. The ramp has now been returned to its folding state.

9.4 Maintenance

If any bolts are discovered to be loose, they can be easily tightened using an appropriate wrench and pliers.

10.0 Design Files

The design files will be attached to the brightspace upload.

11.0 Recommendations

Some lessons we learned are that timelines are very important to be aware of. Some work may take a longer time than expected and should be done early so that deadlines can be met. Binding agents like nuts and bolts ended up using a large part of our budget and welding may have helped with this cost. Organization was also very important as getting all the work done was a team effort. Organizing each team member so that the work was completed efficiently was accomplished using an IM system as well as in-person meetings. This project could not have been achieved without proper efficient time use.
Some suggested avenues of work will now be outlined.
Lots of stress is placed on the bolts, which can cause them to bend or break eventually. Welding would have been preferred as a method to join the aluminum pieces as this is much more

permanent. A better way of joining the pieces is one of the more important improvements that can be made.
A better lock for the ramp can be made. The locks made are prone to falling off and are only temporary. They perform their function but not well. This would be a simple and quick improvement to make for and increase in safety.
Stronger materials could be used for the central folding area of the ramp as much of the stress is placed there. The weight of the ramp would not be affected much and at the same time the strength could be increased.

12.0 Conclusion

Overall, this project was a success. The ramp was able to support a great amount of weight and a wheelchair and person were able to be pushed up without issue. Ideally the ramp would look much more pleasing, but work was focused on the function over the form. This is mostly due to the deadline of completion.

Our group was also satisfied with the final product. It was able to support a surprising amount of weight and succeeded in all of the tests. The ramp was shown during design day and it appeared as though the viewers were quite impressed with the product.

The product met and exceeded our expectations, and although it has not reached the point of true completion, was extremely satisfying to work on and complete.