Final Report

SKED Carrying System

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

Abstract

The Ottawa Volunteer Search and Rescue team is a volunteer organization that provides quality search and search management services to the Ottawa community. To provide services, their main tool is a SKED, used to carry people out of the forest. A sked is a flexible stretcher that is more efficient than a regular one. However, the organization faces a series of difficulties when using the SKED. Our team was requested to design a new carrying system, which had to satisfy various requirements.

The following paper explores different solutions for the carrying system, the steps in the design process and the difficulties faced during the process. Furthermore, it provides information about the product´s advantages and future improvements. Lastly, it examines everything learned throughout the process and how to implement those things in the future.

University of Ottawa

Andrew Squires - 0300026151

Florencia Bigatti – 300042697

Felipe Peselewitz – 300041849

Jordan Lotchuang - 7709483

Zhongjun Huang – 8527016

Table of Contents

List of Tables

Table of Figures

Introduction

The group´s objective is to design and improve a carrying system for the Ottawa Volunteer Search and Rescue team, which will be used to carry injured people using the current sked in a more efficient and comfortable way, both for the rescuers and the patients.

The volunteer team requested various requirements for the solution. Those requirements will be listed later the paper.

Through the design process, the team developed a solution that not only satisfied all the requirements but also stayed within a low budget. In addition, the carrying system can be carried in the same bag as the SKED, giving the team an effective transportation solution. Furthermore, there are no other competitive solutions on the market. The final solution will be presented in this paper, as well as the process to find the solution.

Costumer Description

Throughout the process, the team met up with the client many times to discuss the progress and most importantly get feedback.

The first meeting with the client was very productive. After the meeting, the group was able to understand the costumer´s needs and was ready to start generating ideas. The problem following problems are observed when lifting the sked:

1. Unbalanced distribution of forces, making the Sked tilt, therefore the person that is being carried is not comfortable. This happens because the sked is very flexible, this would not happen if the client was using a common stretcher.
2. There is not enough space for three people to grab the sked from each side. (Because they are carrying backpacks and other equipment).
3. There are problems when there is height and strength difference between the people that carry the sked, it tilts.

The dimensions of the sked are shown in the following picture:

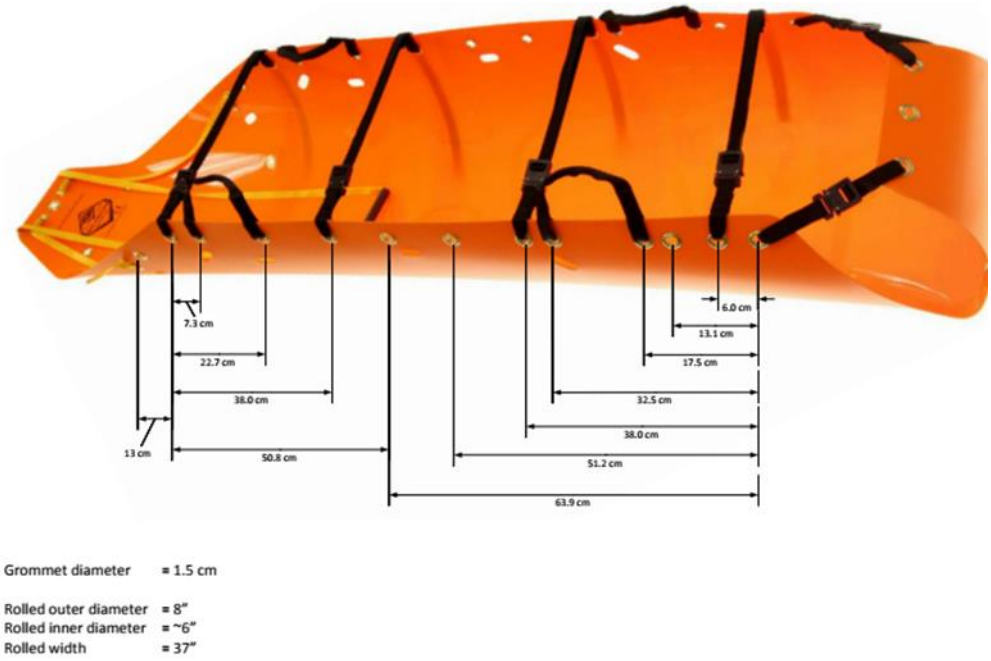

Figure 1 – sked dimensions

In addition, the customer had several requirements for the solution, the requirements are listed below. This was the first step to empathize with the client:

- Able to carry a 450-lb. person with a reasonable safety factor.
- Able to withstand varying loading conditions, meaning where people grab onto it can vary.
- Designed for use in extreme cold temperatures, in terms of both strength/ material properties and functionality.
- Very simple and easy to assemble in stressful situations.
- Compact and collapsible or able to be disassembled.
- Able to lock together when assembled.

- Attached to the sked so it cannot detach accidentally, with optimal spacing of the attachment point along each side of the sked
- Non-slip surfaces on the poles to minimize hand slippage when wet/cold.
- Long enough for three to rescuers to lift the Sked on each side using a proper, safe lifting technique while carrying backpacks.
- Diameter for conformable gripping by hands of rescuers
- Lightweight.

During the first meeting, it was very important to empathize with the customer.

To do so, the team asked open-ended questions, tried to understand the customer´s feelings and struggles.

Then, it was important to translate the client needs into need statements. The following table is used to do so.

Customer Statement	**Need statement**
Able to carry a 450-lb. person with a reasonable safety factor	Sked can carry heavy loads.
Able to withstand varying loading conditions, meaning where people grab onto it can vary.	The Sked can operate with varying amounts of people carrying it.
Designed for use in extreme cold temperatures, in terms of both strength/ material properties and functionality.	The sked can operate normally in any weather.
Very simple and easy to assemble in stressful situations.	The sked can be assembled quickly and easily.
Compact and collapsible or able to be disassembled.	The sked can be transported easily.
Able to lock together when assembled.	The assembled sked is sturdy
Attached to the sked so it cannot detach accidentally, with optimal spacing of the attachment point along each side of the SKED	The handles cannot detach accidentally and are spaced well.
Non-slip surfaces on the poles to minimize hand slippage when wet/cold.	The handles grip well in all weather.
Long enough for three to rescuers to lift the Sked on each side using a proper, safe lifting technique while carrying backpacks.	The sked is long enough for three people to carry on either side with lots of room.
Diameter for conformable gripping by hands of rescuers	The handles are comfortable.
Lightweight	The sked is easily moved

Table 1 – Costumer Needs into Need Statement

The team continued by assigning the costumer need a priority. Not all the needs had the same importance, therefore it is important to focus in the most important ones. The following table gives puts each requirement in a priority scale.

1 – Most important

5 - Least important

Customer Need #	Costumer Need	Importance
1	Able to carry a 450-lb. person with a reasonable safety factor	1
2	Able to withstand varying loading conditions, meaning where people grab onto it can vary.	5
3	Designed for use in extreme cold temperatures, in terms of both strength/ material properties and functionality.	2
4	Very simple and easy to assemble in stressful situations.	3
5	Compact and collapsible or able to be disassembled.	4
6	Able to lock together when assembled.	3
7	Attached to the sked so it cannot detach accidentally, with optimal spacing of the attachment point along each side of the SKED	2
8	Non-slip surfaces on the poles to minimize hand slippage when wet/cold.	2
9	Long enough for three to rescuers to lift the Sked on each side using a proper, safe lifting technique while carrying backpacks.	2
10	Comfortable gripping diameter	1
11	Lightweight	3

Table 2- Priority of Customer Needs

Benchmarking

To continue the process, it was important to do benchmarking and research of similar things in the market. The research is shown on this section.

Rigid stretcher

The team currently has another stretcher, which has several advantages: it is rigid and steady, it is made of metal (a strong material) and can be disassembled in two parts, and it has two rods on both sides to distribute the load evenly. The main problem of this stretcher is that it cannot be packed in a small bag and carried into the woods. Besides, it is heavy to be carried by the rescuers for long distances. The picture below shows the union between the two halves of this stretcher.

Figure 2 - Rigid stretcher owned by the rescue team

Pole Stretcher

A company called Sure-line sells a product called Pole Stretcher. According to the company's website, the pole stretcher is available in a choice of two sizes: 206 cm and 229 cm. They are made from lightweight aluminum for easy lifting, they have spreader bars to provide additional support, the vinyl fabric (where the person lays) is made from an impervious material and they have non-slip plastic carrying handles. There are two versions for the pole stretcher: the unifold and the duo-fold.

The unifold version can be folded in width to a slim shape for storage. The duo-fold version can be folded in length and width to a compact size.

The technical specifications for these versions were taken from the company's website and are listed below:

Length: Unifold -206cm (overall); Duo-fold -206cm (overall) – 103cm (folded)

Width: (both) 55cm

Weight: Unifold 5kg – Duo-fold 6kg

Load Capacity (both): 159kg

The pictures below show the two versions mentioned above.

Figure 3 - Unifold Pole Rescue Stretcher

Figure 4 -Duo-fold Rescue Stretcher

Figure 5 - Duo-fold Rescue Stretcher folded

The advantages of this stretcher are the following:

- The duo-fold version is collapsible, so it can be packaged and carried easily.
- It is light enough to be carried amongst the woods.
- It includes bars that distribute the weight.
- It includes non-slip handles.

The disadvantages of this stretcher are the following:

- The patient can slip down, since the surface where the patient lays is a flat rectangle.
- The load capacity is smaller than the load capacity set by the client in the design requirements.

Basket Stretcher

The Ferno Model 71 Basket Stretcher is also offered by Sure-line. It was designed for being used in muddy terrain without the patient being affected. It is like basket, with enough interior space to accommodate the patient, blankets, and other objects. It has handle holes all around for easy transporting. The technical specifications of this stretcher are listed below:

- Length 2180 mm

- Width 610mm
- Depth 190mm
- Weight 10Kg standard – 11Kg split

This stretcher can be folded in two for storage.

The basket stretcher is shown in the picture below.

Figure 6 -Basket Stretcher

The main advantage of the basket model is its shape. It prevents the patient from slipping down and it provides a good degree of comfort for the patient. Also, the rigid handles give even distribution of weight.

The Multi-Purpose Carrier (MPC)

This stretcher is also offered by Sure-line. It was made for being used in wet, muddy, snowy and icy conditions. By using some accessories, it can be adapted for flotation. It has rigid handles all around.

The technical specifications are listed below:

- Load capacity:454kg / 1000lb. single patient weight capacity
- Weight: 19kg / 42 lbs.
- Size: 217 x 71 x 22.5cm
- 12 x 15 x 5cm hand holes

The MPC can be seen in the picture below:

Figure 7 - The Multi-Purpose Stretcher Carrier

The main advantages of this stretcher are: rigid handles all around, high load capacity and a shape which prevents the patient from slipping down.

However, it has some disadvantages: it cannot be packed, and it is quite heavy.

Stretcher with wheels

This stretcher has a pair of wheels at the bottom. When not in use, the stretcher can be folded from the middle. When carrying a person, the carriers lift the handles up, leaving the wheels on the ground and push the stretcher forward. This stretcher usually requires only two people to carry. The person on the stretcher would not feel uncomfortable since his or her upper body is lifted and there is no unbalanced load distribution. The major problem of this design is that when the stretcher is tilted, the person on it would easily slip, which is unsafe. Also, the wheels are not suitable for the wilderness, and it doesn´t have appropriate handles for carrying. This stretcher can be seen in the picture below.

Figure 8- Stretcher with wheels

After thorough research, the team concluded that there are different types of sked and stretchers used for different situations. However, there is no product in the market that provides a similar carrying system to the one requested by the rescue team.

Problem Statement

Design an improved carrying system for the Ottawa Volunteer Search and Rescue team, which will be used to carry injured people using the current sked in a more efficient and comfortable way, both for the rescuers and the patients.

Design criteria

Design criteria was proposed to comply with the customer needs and the target specifications.

The following table contains the design criteria developed by the team:

Requirements	**Criteria**	**Justification**
Load capacity	• The carrying system should be able to hold the weight of the injured person plus certain belongings/elements to be carried, with a reasonable safety factor. • The sked should hold a load of 450 lb. with an approximate safety factor of 4. A load capacity of 1800 lb is required.	• The client required such load capacity, for the patient to be safe.
Usability – Weather conditions	• The carrying system should be able to work appropriately under rain and snow, and should resist winter and summer weather conditions. • The carrying system should be able to work in a temperature range from -50 to 50 Celsius degrees.	• The client needs to be able to use the sked in any weather condition.

Usability – Assembly	• The carrying system should be assembled by two volunteers (at most) in a short time, given that the injured person must receive treatment immediately. • Ideally, the carrying system should be assembled in 30 seconds. • The individual poles of the carrying system should have a maximum length of 0.75 meters.	• The client required a system which can be easily assembled in very stressful conditions.
Volume	• When collapsed, the carrying system should occupy a volume that can be easily carried by one of the rescuers. • Ideally, the carrying system should occupy 17,000 cm^3.	• The client commented the importance of carrying the sked and the bars in a compact size package.
Usability - Number of users	• The carrying system should be held by 3 volunteers on each side if necessary. Volunteers may also carry backpacks. • The distance between handles should be at least 0.75 meters.	• The client wanted to be able to have more volunteers carry the sked at one time.
Strength of the material	• The material should be strong enough to support the load capacity stated above. • The carrying system should be able to resist a distributed load of 2000 N in the vertical axis with no	• The team calculated this value to accomplish the load capacity.

	significant deformation. • The carrying system should break when a distributed load of 8000 N is applied in the vertical axis.	
Surface characteristic	• The poles should have a non-slip surface, so both handles and rescuers' hands do not slip during the carrying process. • A friction coefficient of 1.15 is an ideal value for the poles.	• The team estimated this value based on non-slip requirement set by the client.
Gripping diameter	• The poles should be comfortably carried by the hands of the rescuers. • A diameter of approximately 3 cm is an ideal value for the poles.	• After discussing with the client, they had prior experience with pole handles, and found this worked well.
Weight	• The system should be easy to pack and carry by a single rescuer. • A maximum weight of 10 lb. is an ideal value for the whole carrying system (sked not included).	• The client required a lightweight carrying system.

Table 3- Design Criteria

Even though some metrics were changed during the design process, most of the goals related to measurable attributes remained the same during the process. In fact, the final solution complies with the design criteria shown above.

Generated solutions

Some of the solutions that have been generated during the design process will be shown in this section.

Solution 1

This solution consists of using a metal bar to provide reasonable load capacity.

Each metal bar is separated in four parts. Each separated part has a thread on each extreme, letting each part screw into each other. A sketch of this solution can be seen in the image below.

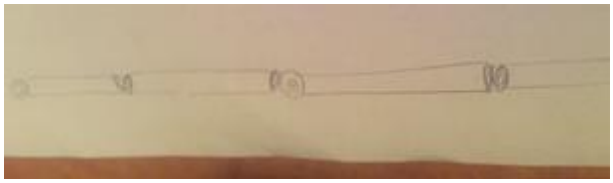

Figure 9- Solution 1

Advantages: The main advantage of this solution is that the load is going to be well distributed, making the structure more rigid. Therefore, the problem of tilting will be resolved. Another issued address here is the space; the bar is long enough for three people to grab it comfortably. In addition, the metal is strong enough to carry 450lb. This solution is easy to transport given that the poles are collapsible.

Disadvantages: Probably not very easy to assemble. Might be heavy to transport. The handles do not hang safe from the bar. If it is not properly designed, the system can collapse.

Some characteristics of this solution were adopted for the concept design: use of steel to provide load capacity, collapsible carrying system.

Solution 2

Adding rubber handles to solve the problem of unsafe grabbing and to provide more comfort for carrying, especially in bad weather conditions.

An example of the added rubber handles can be seen in the image below.

Figure 10 - Solution 2

Even though this solution was not accepted by the client as it is described above, rubber material in form of tape is going to be used in the final product. This tape is going to be placed along the poles and will prevent the slip between the sked handles and the poles, and between the rescuers' hands and the poles.

Solution 3

This solution consists of:

· A metal piece attached to the bar

· A metal ring attached to the metal piece

· A metal hook which links the metal piece with an adjustable belt, which will be placed around the waist of the rescue

· An adjustable belt which will be linked to the previous belt, and will be hung in one of the rescuer's shoulder.

The main objective of this solution is to allow the rest of the body to carry part of the weight.

A sketch for this solution is shown in the image below.

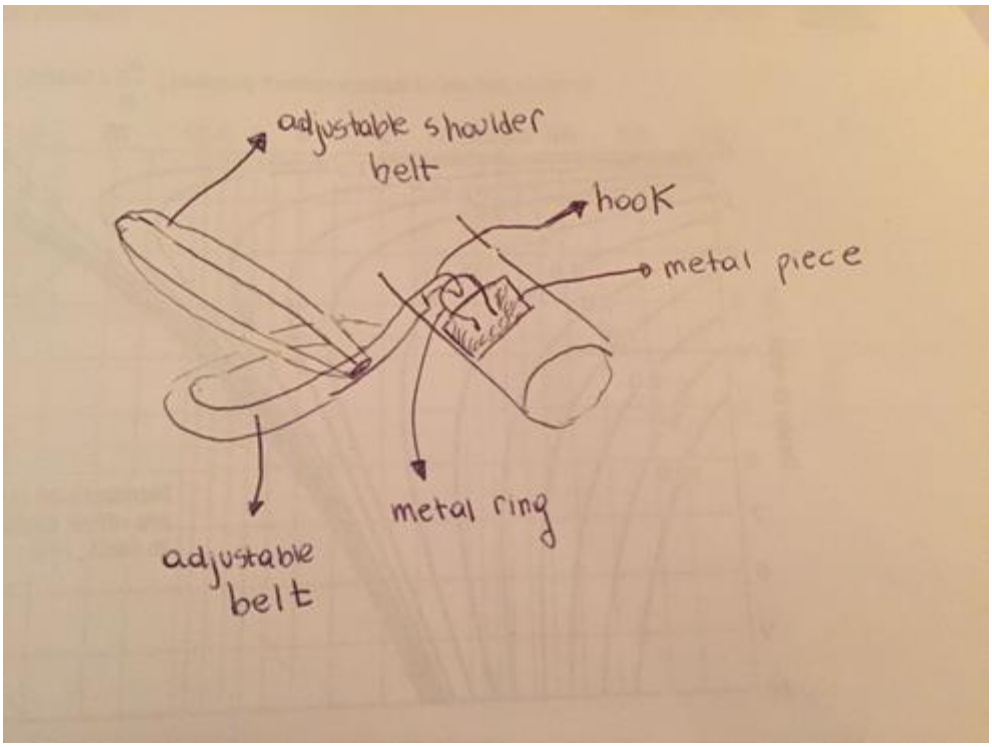

Figure 11 - Solution 3

Advantages: The rescuers' hands will be freer, and the carrying process will be more comfortable. Given that the belt is adjustable, the difference in height between the rescuers can be balanced.

Disadvantages: The solution adds complex components to the carrying system. The new components can make the assembling process more complicated, and may not be easy to pack and transport. Adding a belt may make walking through rough terrain even more difficult

This solution was not accepted by the client due to its complexity. It was difficult to assemble and pack. However, the client recognized that it could be applied in another context, since it ensures a very comfortable carrying process for the rescuers.

Solution 4

The solution proposed below comprises a combination of different solutions generated during the ideation step

It can be described as: a long metal pole that is broken into small chunks via a connection system (using buttons). The pole will go through all the rubber handles on the current sked and will have its own handles that will be screwed or attached to each segment of the larger pole.

A picture of this solution is shown below.

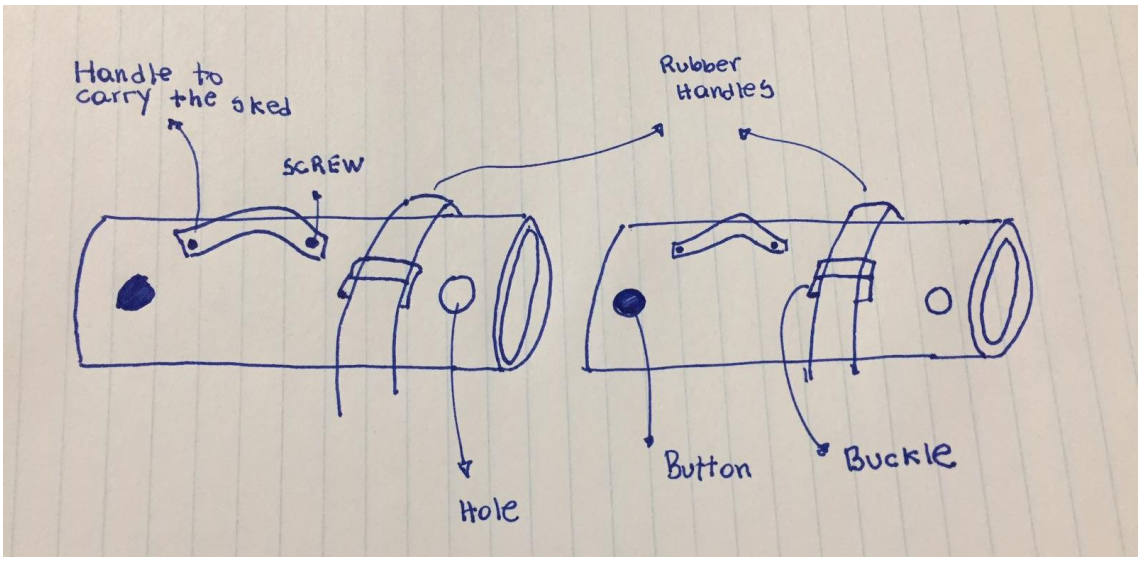

Figure 12 - Solution 4

In the picture, two chunks are shown. The individual chunks are embedded to form the long pole.

Solution 5

The idea proposed for solution 4 was a conceptual design established by the team in early steps. However, by getting feedback from the customer and by discussing several characteristics of the product, the solution was changed to a simpler model.

The new approach consisted of long poles which could be joined by using a safe connection system, with no handles and no buckles. This approach was an initial step for changing the solution. It was still uncertain which connection system would be applied, which material would be used, and which dimensions the pole would have. Solution 5 was still in its early steps, and the generation of a new conceptual design would lead to a final solution.

Design solution

First to approach to a design solution

After having a meeting with the client in which Solution 4 was shown, some changes had to be done to fully meet the client's needs and requirements. As mentioned in Solution 5, the overall shape and functionality of the design was approved by the client, but some elements were removed or changed, given that the client stated they were adding complexity to the solution, rather than improving the carrying system.

The rubber handles for carrying the sked were eliminated. The client mentioned that the rescuers need to be able to carry the sked by grabbing the poles all along the lateral distance, and not specifically where the handles are placed.

On the other hand, the system for joining the poles was changed. The button system was too sensitive in terms of a long-term solution and extreme weather conditions. Therefore, a thread system will be adopted, which had been previously

discussed when sharing individual solutions. Also, a metal coating will be placed around the threads, to make the joints steadier and enhance the load distribution.

Finally, the rubber handles and bulks to attach the sked to the poles will be replaced by rubber sleeves all along the poles (except on the joints). This will provide a better gripping and will prevent the slip between the current handles (the handles the sked currently has will be kept) and the poles. When discussing this point with the client, the team was concerned about how to eliminate the problem of tilt due to height difference, which was supposed to be solved by using buckles. The client answered that this problem cannot be solved, given that the rescuers switch positions all the time when carrying the injured person.

All in all, the updated solution will consist of long poles which can be broken into small chunks, keeping the properties and metrics stated in the previous reports, but including the changes mentioned above. A general sketch of the updated solution is shown in the picture below.

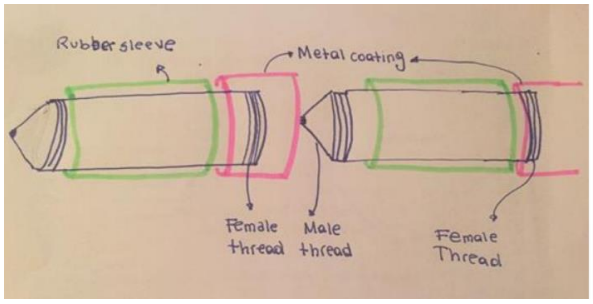

Figure 13 - Sketch of updated solution – Two chunks are shown

Final approach to a design solution

Proceeding with the design process, the team started considering different materials, connection systems, economic factors, time factors, among others. The first approach described in the previous section was still vague. It did not clarify the technical functionality of the solution, and it was still uncertain the material to be used, how to ensure durability. The team decided to perform research on materials, and focus mainly on load capacity, weight of the proposed carrying system assembly time, and other characteristics mentioned in the design criteria.

The team managed to find a suitable design solution, and presented this solution to the customer during the last meeting. Even though the client decided to add some refinement to the solution, the overall functionality was accepted. At this point, the team was all set to start building the final product. A description of this solution is given below.

Steel rods which can be screwed into metal couplings. Each rod represents one chunk, and the metal coupling will connect two chunks. For simplicity, only two chunks will be on each pole (each side of the SKED). These inner elements will provide the whole load capacity. It is the steel who will support the required load. Therefore, there will be two rods and one coupling on each side, and the poles will consist of two chunks per pole.

PVC pipes, which will surround the steel components. This element will provide comfortable diameter for grabbing, and will prevent the steel bars from deterioration.

Nylon spacers which will fill the space between the PVC pipes and the steel components. The spacers will transfer the load from the PVC pipes to the threaded rod.

Plastic end caps which will be placed on each end of the poles. These plastic elements will close the poles and prevent the entrance of dust and other small particles.

Adhesives which will stick the elements inside the PVC pipes between each other, which will add even more rigidity and prevent sliding and movement of elements.

Gripping tape which will be placed around the PVC pipes to provide comfortable gripping for the rescuers.

The second prototype included the steel rods, metal couplings, PVC pipe, nylon spacers and plastic caps. Based on the client decision, the team will be not applying the hockey tape, since the client wants to be the one applying the tape.

The steel rods, metal couplings and nylon spacers were shipped from the US to build the final prototype. The PVC pipes and plastic cups were bought in the city of Ottawa. The adhesives were provided by one of the team members, so it did not have any cost for the prototype.

The PVC pipes were cut using the machines at Brunsfield Center to achieve the desired length. The nylon spacers were lathed using the machines at Brunsfield Center as well, to achieve the necessary outer diameter so the spacers could tightly fit in the PVC pipes.

Diagram of the proposed final solution

A diagram including all the components mentioned in the previous section is shown below. The second and last physical prototype was done in views of reflecting as more accurate as possible all the mentioned characteristics.

The two diagrams shown below are cross-sectional diagrams. The first one represents the section with the rod, spacer, and PVC pipe. The second one represents the rod, the coupling and the PVC pipe. Between these elements the adhesive was applied.

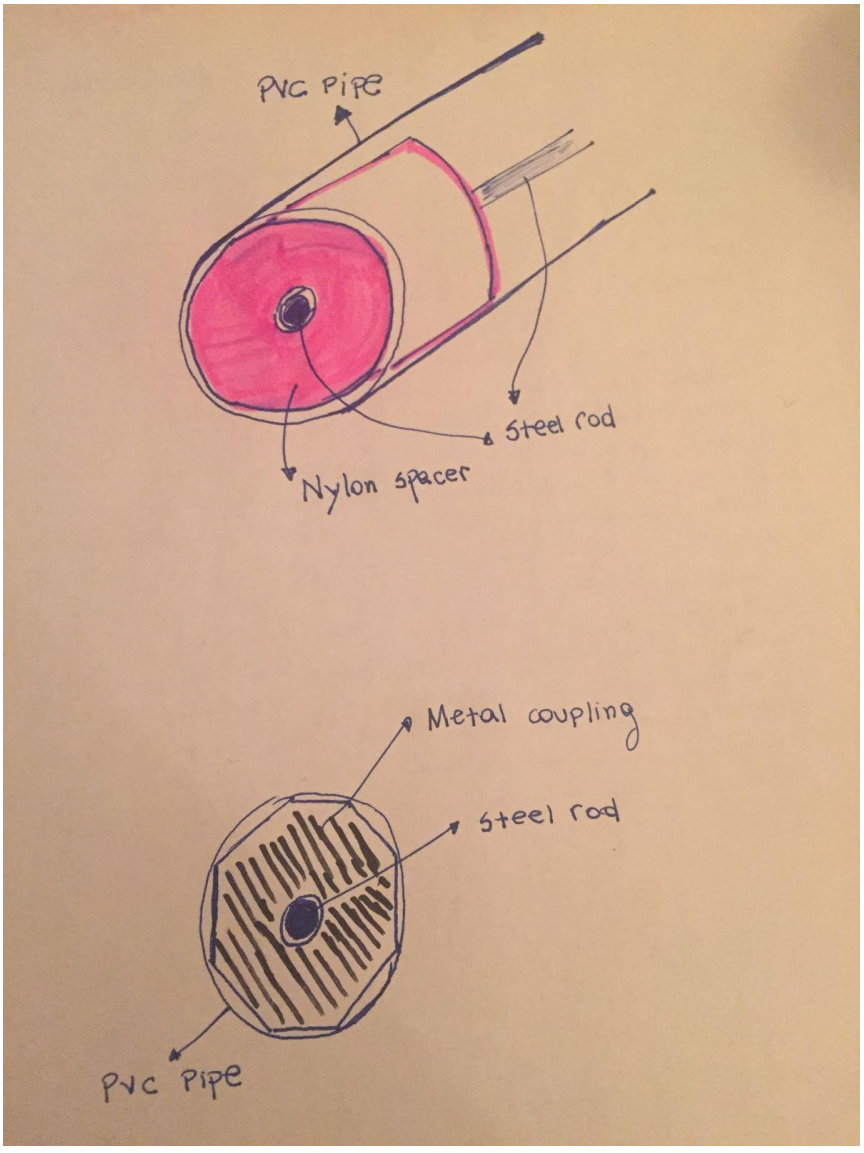

Figure 14 – Final solution Sketch

Documentation of the final prototype

Figure 15 – Steel rods and metal couplings

Figure 16 – PVC pipes

Figure 17 – Plastic end cups

Figure 18 – Nylons spacers

Figure 19 – PVC pipe with nylon spacer inside

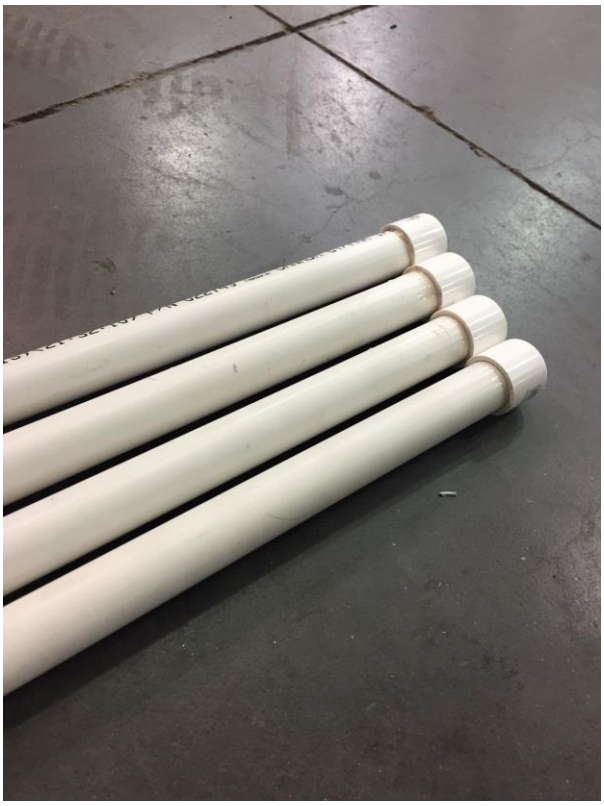

Figure 20 – PVC pipes with plastic end cups

Figure 21 – PVC pipes containing steel components inside

The pictures below show the finished prototype, including all the components. The four chunks were built, which are joined to form two poles.

Figure 22 – Section view final prototype

Figure 23 – Final product

The picture below shows the poles in the SKED, which was displayed by the team during Design Day.

Figure 24 – Final product displayed during Design Day

Testing Objectives and Results

First prototype

Two things were tested on the first prototype, on one hand, the joining system for the bars and second the gripping diameter. It is the most adequate for the client and considering the client´s feedback, we decided to continue with this joining system. As for the gripping diameter, a 3-cm gripping diameter was chosen to be the best one.

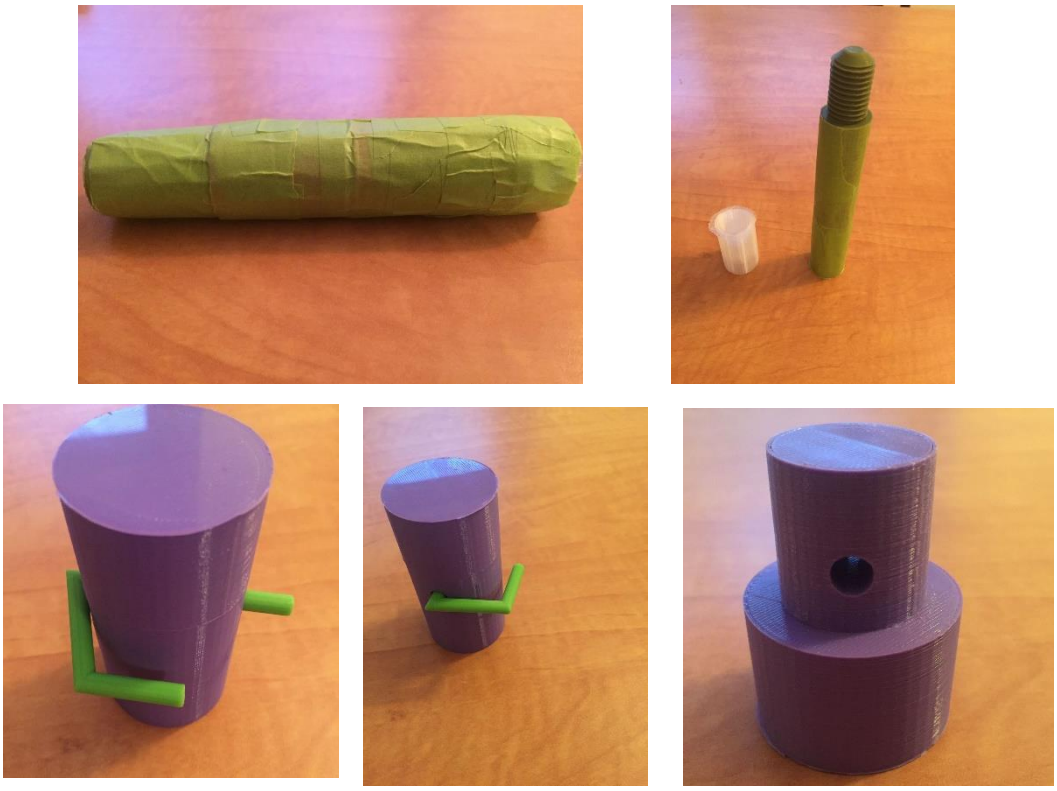

Figure 25- First prototype testing

Final prototype

Three tests were conducted to verify if the prototype met the specifications.

Test 1 – Loading Capacity:

The objective of this test was to verify if the prototype could carry the proposed load. For this, a container with water was hanged from the bars. The worst scenario was tested, where the bar was only supported at the ends and the load was applied in the middle. A second case was testes, this time; the supports were not the end, closer to the middle. The following table shows the results.

Length	Weight	Deflection
0.95	6.27	3.81
0.95	10.55	7.62
0.95	15.8	9.52
0.45	15.8	1.27
Meters	Kg	Cm

Table 4- Final Prototype test results

Although these values are not close to the load specified, the results were satisfying, as the bar did not show permanent deformation.

Test 2 – Assembly Time:

The assembly time was tested, representing some different conditions. First, we tried in good weather conditions, around 5°C. The assembly was done was done very quickly in 10 second each bar. This does not include putting the bars though the handles, as we did not have the sked available for testing. A second rest was performed, this time with very thick gloves on to simulate a very cold weather condition. The assembly time for each bar was of 20 seconds each, taking the same scenario. Then, we estimated that the total assembly time considering passing bars through handles will be around 1.30min total, in an extreme scenario.

Test 3 – Durability:

We wanted to give the product an estimated usage time. For this, we threw bars around, dropped on the floor. The bars did not show any damage signs. Therefore, we conclude that such cases will not be an issue for the bar. The estimated product life is 5-10 years, depending on the frequency on their use as well as the conditions they will be exposed too.

Technical specifications of the final product

Some technical considerations relevant to the final product are listed below:

- The achieved product can be assembled in a period of one minute (maximum).
- The system is composed of material which can be exposed to temperatures in a range from -50 to 50 Celsius degrees, which implies the whole system can be used under extreme weather condition.
- The total weight of the product is 10.5 kilograms, which complies with guidelines for packing for a 65-kilogram rescuer.
    - From the Geneva Labour Laws, for men and women older than 15, an admissible load to be carried frequently is 10 kg.

    - Most backpackers recommend carrying no more than 15% of your body weight.
- The system is collapsible, and is made of simple products that can be easily replaced in case of deterioration or breaking.
- The lifetime for the product is governed by the PVC pipes, and it is estimated to be from 5 to 10 years.
- The load capacity was analyzed by load testing, and will be explained separately in Testing section.

Conclusion and Recommendations

Next Step

The customer will include to the bars a non-slip tape, to have a better gripping. The specific tape will be selected by the client, so they can choose one that fits their needs best.

Lessons learned and future

We had an issue with the budget. When we looked at the product and made our BOM we had estimated the cost of our final prototype of $105. Most of the materials were bought from the United States. We called the company and were told that the shipping cost was around $20 dollars and no taxes would be added. After the purchase was made, we were charged with a higher shipping fee and Canadian taxes. Because of this, the total amount we paid for the materials purchased from the United States was $140. Then, with the purchase of the rest of the materials, the final amount of money spent was $163. This was much greater than the estimated price. We learned to be very careful when shipping from another country and that probably with more research, we could have found similar materials in Canada, and this would have not been a problem.

On another hand, working in teams is not easy. Sometimes it is difficult to have a good communication and to manage to meet at times that are good for everyone. As a team, we did not have a team leader, which we should have had. This gave us some difficulty when having to do a derivable, team members did not know what was their part. For the future, more communication and organization are required for a more successful team success.

In addition, the team struggled with time. The final product was finished last minute because of this, not many tests were conducted. We would have liked to do more tests to show more accurate results. Doing tasks earlier would a more good way to solve this.

Final comments

Something that really is interesting about the process is working with real customer in real problems. We were able to really emphasize with the customer and find a good solution for them. We are very happy to know that the solution will probably be used by the team.

Bibliography

Sure-line Evacuation & Rescue. Stretchers. Retrieved from http://www.sure-line.com/stretchers/ on September 29th, 2017.

Maximum weights in load lifting and carrying, 1988, 38 pp. (English, French, Spanish), ISBN 92-2-106271-6, Sw.fr.10.