Marshall Playground – Team F4

Final Proposal

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Abdalaziz Alazmi

Mohammad Alsewaji

Khaled Alenezi

Abdullatif Alenezy

Saad Aldawsari

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Project Sponsor: Gore

Clients: Eva Herberger, Krista Branch

Instructor: Dr. Sarah Oman

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Executive Summary

Purpose of this report is to find the design for the project of building fun apparatus such that it is useful for disabled children of age 5 to 8. Furthermore it will be useful in all weather conditions and play outside. It must be safe and easy to use and easy to set up as well. With all these requirements few designs have generated from which one final design has selected on using Pugh chart and decision matrix. The final result is a design of moving cart over the rail track with the display board holding over the cart, the cart will have a board of features that the children will play with and get educated also, the chair that the kids will be placed on will have a seat belt to secure the children from any injuries.

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1. Background

1.1 Introduction

This project relates to the children in which children will get a source to play around with fun apparatuses and tools. Disabled children faces lot of difficulties specifically to move around and try to enjoy at different times. Disabled children need to have something for play in spare time.

Our purpose is to support the children with disabilities and varying needs that require them to be in a classroom that accommodates those specific needs. The majority of students use walkers, gait trainers, and strollers to help them get from place to place in their daily routine. Students are working on academics that are modified to their specific learning needs, as well functional skills and life skills. Some students use a communication device to say their wants and needs, others use sign language, and some have verbal communication skills. So this project will build something that will help those children for fun playing and hanging out.

1.2 Project Description

Purpose of this project is to build such a toy that will help children with disabilities to play around with, and through the toy they will be able to spend time all around. This project calls for a fun apparatus for children to play on outside. Basic need is that such a toy or a device that has to be a learning module for them and it must withstand in various weather conditions as it's going to be used in an outdoor areas. It has to be portable, easy to set up and be safe for children to use with little supervision.

1.3 Original System

This is an original system and we are not going to extend any already built system and neither are improving any old system which has already existed. The design of this project will also be the new one and didn't copied neither amended any existed design.

"This project involved the design of a completely new fun playing apparatus for children. There is no original system when this project begin."

2 Requirements

In this section we are going to discuss about the customer requirements, engineering requirements, testing procedures and house of quality (HoQ)

2.1 Customer Requirements (CRs)

Our design requirements were generated from the given project description in Bblearn. However, all the customer requirements were taken from the meeting with our clients as shown in table 1. We have listed the most important customer requirements that we received from the client so we start building our design. All the customer requirements have helped is a lot in achieving our goals.

Table 1: Design and CRs requirements

Customer Requirements
Portable
Fun Apparatus
Long life
Less cost
Safe
No sharp edges
Material needs to be rubber and soft
Consider different sizes
Sound motivations
Nontoxic material

2.2 Engineering Requirements

The engineering requirements have to be generated from whatever the client gave us in terms of the customer requirements. Therefore, table 2 shows a list of our engineering requirements after evaluating the customer requirements.

Table 2: Engineering Requirements

Engineering Requirements
Device shouldn't weigh more than 30 kg.
Size of the straight track will be 7 x 4 meters
Round all sharp edges to 1.375 mm.
Children ages range between 4 to 7 years
Device needs to at least lasts for 2 years
Size of the crat body will be 1.7 m in length by 1.2 m in width by 0.95 m in height
Motivation board has the size of 0.4 in length by 0.2 in width

2.3 Testing Procedures

Weight of the cart: The weight of the cart will be tested on the choice of materials that it will be made of. The team will test it by doing a research of different materials to see how much each would weight, and therefore, we'll choose the material with the lightest weight found. In that way, we will be able to satisfy this engineering requirements.

Track: Because the team visited the playground area in Marshall Elementary School, we could test and see that a size of a 7 x 4 m for the track is going to work. No other tests are needed for the size of the track because it will not need any other tests in regards to the size.

Sharp edges: We will test all sharp edges by using Solidworks because this program will help us in seeing how exactly rounding sharp edges would look like. Also, the assumed round off dimension is 1.375 mm for all sharp corners in the body of the cart, however, we'll need to test whether or not this assumed dimension will work or fail.

Age ranges: Age ranges of children will simply be tested by asking the teachers in the classroom, what is the age ranges of children in their classroom. Which was done at the first meeting with the client, and it was found that the ages will range between 4 to 7 years old.

Body of the cart: All what we need to test for the body of the cart is to know what normally the size of the waists of our stakeholders are. Because testing the body of the cart is dependent on what size will we need to satisfy this engineering requirements.

Motivation board: The team will test this part by looking at how the children will get attracted and motivated. So we'll test many ideas found in industries that might be relative to our ideas and design. The client have also provided us with some information that will help the team in doing a research as a part of testing, such as, said by the physical therapist Krista, "Most children with disabilities get attracted by touching different textures".

2.4 House of Quality (HoQ)

House of quality is a chart which creates the link between engineering requirements, customer requirements and targeted values. House of Quality chart has obtained using the engineering requirements and customer requirements. These requirements have interacted with each other on the basis of client requirements. HOQ tells which engineering requirement is most important for the project and that requirement will be assign the highest weightage. Whereas the one which shows the lowest value of grade got lowest weightage. Table 3 shows the HoQ of our project.

Table 3: HoQ

House of Quality (HoQ)

Customer Requirement	Customer Weight	Device shouldn't weigh more than 30 lbs	Rubber platform needs to be 6X6 ft	Round sharp edges to 1/8"	Sounds at 5 DB	Children ages range between 4 to 9 years	Device size 50X50 inches	9 inches tire radius			
1- Portable	4	5	5					3			
2- Soft Material	3			5							
3- Safety	5	3	9	9				5			
4- No sharp Edges	4	3	9	9							
5- Sound Motivations	3				9						
7- Consider different sizes	3					5					
8- Device size	3	3					3				
9- Picture icons	3										
Total	33	56	74	96	27	15	9	37			
Absolute Technical Importance (ATI)		56	74	96	27	15	9	37			
Relative Technical Importance (RTI)		3	2	1	5	6	7	4			

The percentage of importance from this HOQ tells that which is important for this project in maximum and which has least important. From the importance we can determine which engineering requirements we have to focus more. So from the HOQ we can see that device shouldn't weight more is quite important for this project also rubber platform is also most important for this project and round shape is also most important for the project. So now we will focus more on these points while building the project.

3 Existing Designs

In chapter 3, it has discussed about how the research has to be done and how the existing designs can find out, and doing the literature review for any project with the references.

3.1 Design Research

Design research is process of searching out the related data as the project. As our project is to build such fun apparatus which will help disable children to play around with in the outside environment. For this purpose, we have searched on internet, and tried to find out different sort of journals, articles, and different websites to see if there have been any similar projects done on the same requirements or not. And from the search, we have found out different designs available with the same requirement and those are different ideas then the one we will going to implement in this project. From those design problems we have found some issues which will be relevant to our project as well and those issues are:

1. Size of a project must be enough that children can play around easily
2. Portable with easy to set up

These two issues are the problem that we will face while building our own project. And there are few opportunities we have identified after research which are:

1. Sound motivation can easily get by putting small speakers
2. Pictures can use for toy shaped icons

So with these opportunities we will able to fulfill our engineering and customer requirements. So from searching around we have found that things can get easy and lot of help can get from internet. As the issues have mentioned now we will focus on our design and finalize such design from which issue of size will not appear. Furthermore, portability and easy to set up is our main course as well, and now we will keep focusing on our design to make such design which will not have any portability issue as well.

3.2 System level

Here are the few design ideas we have found which have been built before but these are not similar to the one we are building in this project but their requirements are the same as given to us for this project.

3.2.1 Existing Design # 1: A game to Play with the small board with holes

This is a toy formed apparatus which is portable and will not affect by the weather conditions. Also it is long lasting as all of the material used in it is plastic. There are pictures of fruits of large size made on the board and their mouths have cut. So children can play by putting things in their mouths [1].

Figure 1: Board with holes [1]

3.2.2 Existing Design # 2: A baby's laptop

A laptop in small size with the keyboard which play around with sound and some alphabets so this design is useful for disabled children as well because they will have the capability to listen it. So they can use this apparatus for fun time [1].

Figure 2: Baby's laptop [2]

3.2.3 Existing Design # 3: A small running Train

This is also a fun playing apparatus. It is a train which moves around with the battery backup and it don't need the track as well so with such design with no track this design is good for playing disable children [2].

Figure 3: Small running train [3]

3.3 Functional Decomposition

Functional decomposition is basically a way to describe the project in details. First of all, there is black box model which describe the top level of the system by just telling the inputs and outputs of the system. Then there is hypothesized model which is also known as hierarchy model in which the detailed functions of inside the product explain in details. Here is the black box model section. It is very significant that we do our black box and functional decomposed models because they help us in examining the design we'll consider. As the subsystem of our project contains tracking train, track, cart and displaying board.

3.3.1 Black Box Model

Black Box model is quite important for any project because it tells the input and output of the system. It doesn't depend on the working on inside model, it just tells what inputs will take by the system and what outputs generates by the system. Black Box model of this system is showing below as

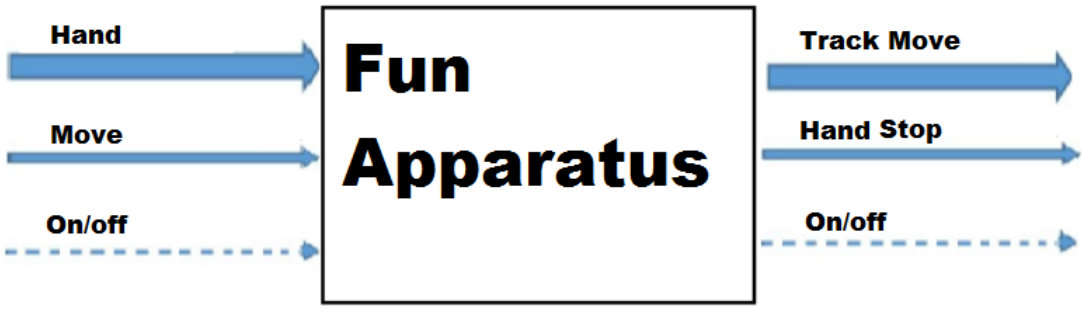

Figure 4: Black Box Model

3.3.2 Functional Model

Functional model is basically tells the steps uses by the system from input to output. It actually tells what are the things happening inside the system for generate the output. All the processes though which the input goes, shows in functional model and then it shows the output so interlink between inputs and outputs shows through functional model. Here is the functional model for our project.

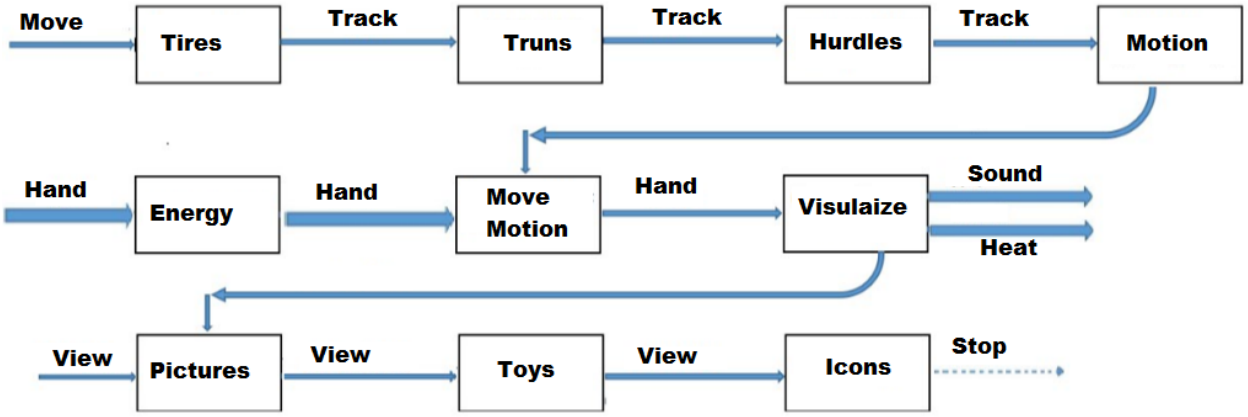

Figure 5: Functional Model

This functional model will help us in building the project as we now knows what are the processes we have to perform in the project in order to develop the project. So it gave us the basic knowledge about our project so we got to know about project in details for the processing.

3.4 Subsystem Level

In this section we are going to discuss our three sub system for the project.

3.4.1 Subsystem # 1: Track

For our project the product will move on some sort of track that could be either ground or any track like a train system. So the apparatus will easily move over the track. This is really important for our project as it will provide a moving platform so it will be easy a good fun for the children and easy to move over the surface. Now see the existing designs for this this subsystem.

3.4.1.1 Existing Design # 1: Tracking System

Tracking system is a track similar to the train on which trains moves only in the direction where the tracks heading. Train cannot move other than the track system that's why this design could be useful for our project. For children when they want to move the apparatus, it will move only

in a specific direction and it will be easy for them. And this track can place at any location and move the apparatus

3.4.1.2 Existing Design # 2: Ground level

This is an option of ground level, means the simple ground with small grass or no grass can use for the track to move the apparatus. This is very common as everything with tires can move over the ground. In the same way we can use this system in our design and use the simple ground as a track so the children will not need to put any defined track and can move towards each side.

3.4.1.3 Existing Design # 3: Carpet road

This design is basically the roads we have available in our surrounding. This is a good track as well and useful for the plan ride and movement. .This track is not available then have to build such track. This option is also useful for design because we can move our apparatus over the carpeted surface.

3.4.2 Subsystem # 2: Tires

This subsystem will play an important role in our project for moving the apparatus all around. Tries is the only best way to move things around without carrying them. That's why it plays an important role children apparatus with which they are playing and can take it around without any problem.

3.4.2.1 Existing Design # 1: Plastic Tires

Plastic is good material to use and there are hundreds of tires available in plastic materials. These are smooth, don't have any hard edge, and long life as well. We can use this type of tires in our project and that's why this existing design is useful for our project.

Figure 6: Plastic Tires [3]

3.4.2.2 Existing Design # 2: Iron Tires

These tires are also available in different sort of materials. Irons tires is an existing design and we can use this design for our project because for any tracking method iron tires can work and move all around.

Figure 7: Iron tires [4]

3.4.2.3 Existing Design # 3: Rubber Tires

Rubber tires design is available and this type of tires are soft and have the capability to cover up some sort of jerks because of their elastic nature. This design is useful for our project especially if we use ground track or carpet road track.

Figure 8: Rubber Tires [5]

3.4.3 Subsystem # 3: Visualizing Board

This is another important part of our project, as visual boards will use for fun and children will enjoy such boards if they want to play they can play with it and if they just want to watch they can just watch it,

3.4.3.1 Existing Design # 1: Wooden Board

Wooden board is an existing design and useful for holding kneels in them and placing pictures, toys, icons etc. on the board. This is useful for our project because if we use wooden board we can place any sort of item over it and it can hold easily because it is strong.

Figure 9: Wooden Board [6]

3.4.3.2 Existing Design # 2: Iron Board

Iron boards are not very common but it is an existing design. It is useful for our project in a way that we can put the icons over the board and put the displaying pictures.

Figure 10: Iron Board

3.4.3.3 Existing Design # 2: Plastic Board

Plastic boards is another existing design useful for displaying the things. Over the plastic board different sort of things can write as well. So this is a good option to use for our project as children can write over it as well.

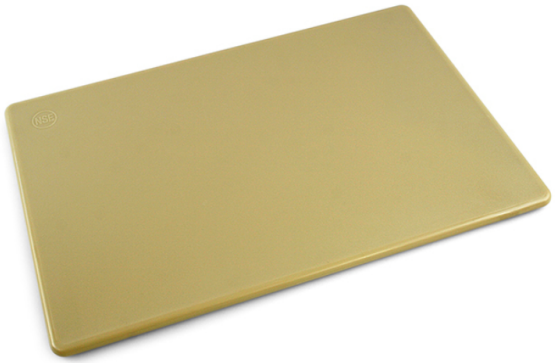

Figure 11: Plastic Board

4 Designs Considered

As the purpose of this project is to build fun apparatus for disabled children and therefore multiple designs have considered for it and these designs have presented below as well.

4.1 Design # 1: Cart moving on rail track with display board

This is the design in which a there is cart with 4 tires and that cart moves over the rail track. Cart has a holding board which uses for display items, holding pictures, icons and placing toys. Design is showing below

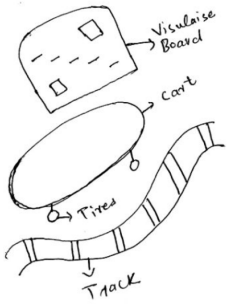

Figure 12: Rail track cart system

Advantages	Disadvantages
• No sharp edges of cart and board • Sound Motivations • Picture Icons • Safe • No toxic Material • Portable • Easy to Set Up	• May be little longer in size • Track could be difficult to manage

4.2 Design # 2: Moveable and portable Wall

This is a portable wall with the tires and holding platform which is safe is as well. Wall is useful for displaying items like pictures, icons and toys and there are speakers over the wall which produce sound for enjoyment for children. Wall is portable as it can fold around and easily carry to some other place. There are tires which moves the wall and there is black slit showing on the right side of design which is holding the wall straight and the wall can easily detach from the slit. Following figure is showing the design idea.

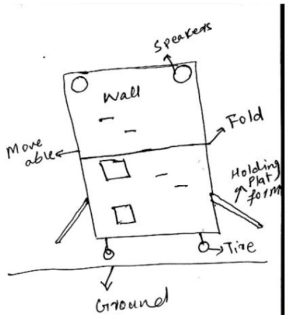

Figure 13: Moveable Wall

Advantages	Disadvantages
• Safe • No sharp cuts • Sound • Moveable • Portable • Easy to set up	• Big in size • Difficult to stand up the big wall with tires and slit

4.3 Design # 3: Moving Stairs

This is a design of moving stairs. A stairs made up of wood with the tires under them. These stair can move around and two children can play with it. One children can sit over the stairs and second children will push the stairs. Other than this, it has a displaying part on which pictures and icons can use for display. Another option is that a child can put the ball over the top and it will flow down towards the end where the ball catcher will catch it. Following figure is showing the design.

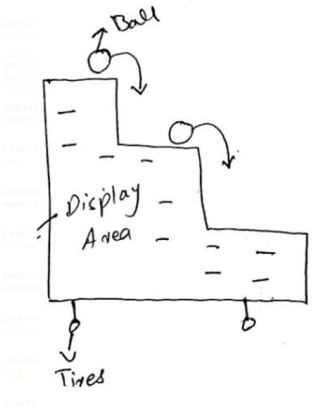

Figure 14: Moving Stairs

Advantages	Disadvantages
• Easy to use • Moveable • Portable	• Sharp edges • Difficult to control because of weight Disadvantages

4.4 Design # 4: Motor car with play cards

This design is consist of motor car which has play cards in it. Play cards will move up and down and keep changing their logo. And there is a color ball attached at the back side which has multi colors light in it. As the car move those lights starts blinking in different colors. This is a motor car so it operates on battery and move with any push. Idea is showing in the following figure.

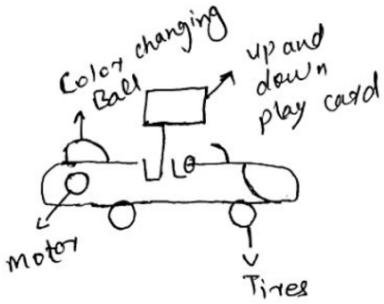

Figure 15: Motor Car

Advantages	Disadvantages
• Moveable • Safe • No toxic material	• Motor can cause trouble for running the car by children • Battery need to replace after some time of interval

4.5 Design # 5: Sliding Mobile

This is a sliding mobile design which a mobile screen with the keypad over it as well. It have tires and a stand over which the mobile will move and children will press the button and different pictures and themes will appear on the screen. It has a sound motivation as well. Following figure is showing below

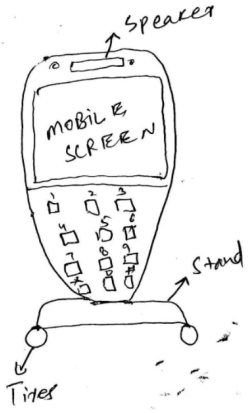

Figure 16: Sliding Mobile

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Mobile holder is a sensitive thing • Mobile can drop

4.6 Design # 6: Bubble Ball

This is like a gun machine in which a ball through from the top and ball moves in different directions and come out of the gun from three different points and the gun has the capability to move around with the help of tires so any disabled child can move the gun and the design is showing in the following figure.

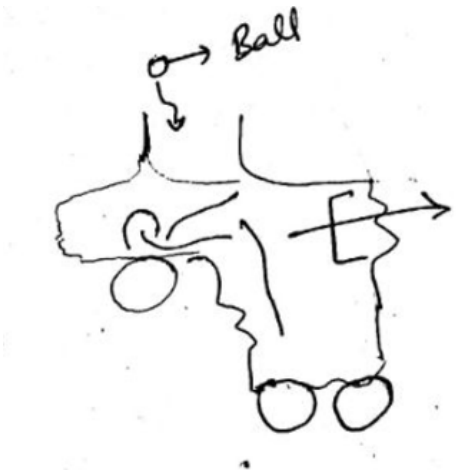

Figure 17: Bubble Ball

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Ball is sensitive to hit

4.7 Design # 7: Push wall with baby walker

A disabled child can sit in the walker and then push the wall in a way that it feels like some door moving out of the way and it is showing in the figure.

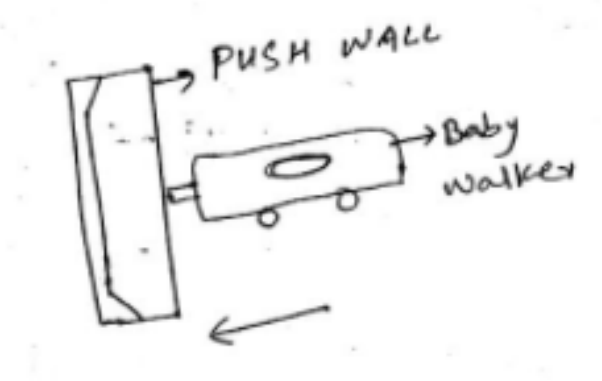

Figure 18: Push Wall with Baby Walker

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Not Safe

4.8 Design # 8: Baby Car

Disabled child who cannot walk around have a good apparatus that they will drive the car and they can travel as well to some other locations with the help of this car. This is an electric car which has all the controls and children can move as the following figure has the design.

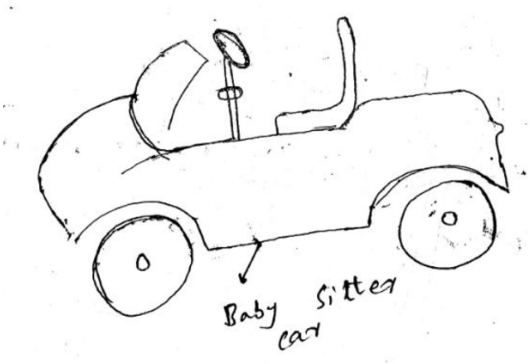

Figure 19: Baby Car

Advantages	Disadvantages
• Easy to use • Sound motivations	• Need to put baby in it • Control is difficult for child

- Portable

4.9 Design # 9: Electro Mechanical Hand

This is a hand with electro mechanical movement in it and it can control the hand whereas it has a pencil at the end and disabled children can write through it. Being a fun apparatus the main thing is to handle the hand and write correctly as showing below.

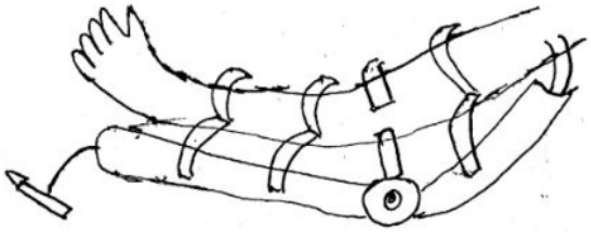

Figure 20: Electro Mechanical Hand

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Pencil control is difficult

4.10 Design # 10: Moving baby cart over the railroad

A specific track will carry the child sitting in the cart to some other place and it will be a fun travelling in the cart as showing below

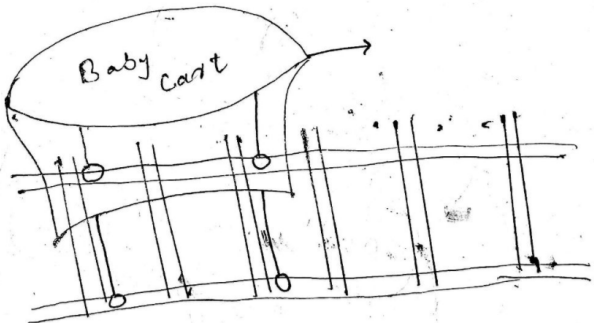

Figure 21: Moving Baby Cart

Advantages	Disadvantages
• Easy to use • Sound motivations	• Not safe

5 Design Selected

In this chapter planning of developing the designs has presented. Different types of project plans have discussed like stage-gate or water fall plan and the deliverables for the plans. Furthermore building the plans have also discussed in this chapter. Like proof of concept or building a prototype model for any design before implementing it in real. Different sort of communications have discussed in the plan like following the task we can use bar graph or Gantt chart which will help in keeping the things on track and some design examples have provided as well to elaborate the design process and completing the design plans.

5.1 Rationale for Design Selection

Purpose of this project is to build such an apparatus which provides fun to the disabled children and therefore few designs have presented for it. In this section we are going to finalize our design using two different methods. One is Pugh chart and second one is decision matrix. Following is the Pugh Chart in which sliding mobile is our datum design.

Table 4: Pugh chart

5 Designs for Fun Apparatus	Weightage	Moving Stairs	Moving Wall	Moving Cart	Motor Car	Sliding Mobile	Bubble Ball	Push Wall Baby Walker	Baby Car	Electro Mechanical Hand	Moving Baby Cart
Fun Apparatus	8	+	+	+	+	D	-	-	+	+	-
Play on outside	7	S	S	+	-	D	S	+	+	+	+
Withstand in weather conditions	6	-	+	+	+	D	-	S	+	-	-
Portable	5	+	+	+	+	D	S	-	-	-	S
Easy to set up	4	+	S	+	S	D	+	-	-	S	S
Safe	3	+	+	+	-	D	-	S	S	-	+
Easy to use	2	-	+	+	+	D	-	-	S	S	-
Pluses		4	6	7	4	D	1	2	3	2	2
Minus		3	0	1	3	D	5	4	3	4	3

Now we have two final designs from Pugh chart now move on to decision matrix and finalize the single design.

Table 5: Decision matrix

	Weightage	Moving Cart	Moving Wall
Fun apparatus	8	5x8=40	4x8=32
Play on outside	7	6x7=42	5x7=35
Withstand in weather condition	6	2x6=12	3x6=18
Portable	5	7x5=35	1x5=5
Easy to set up	4	7x4=28	2x4=8
Safe	3	5x3=15	4x3=12
Ease to use	2	5x2=10	2x2=4
Economical	1	1x1=1	2x1=2
Total		183	87

From decision matrix the result we have found is the moving cart. Moving cart has got the maximum numbers and if we see the advantages of moving cart, it has all the plus points which are looking by customer requirements. So on the basis of these results we are going forward to use the moving cart design.

5.2 Design Description

Moving cart is the design which has been finalized on the basis of selection methods results. In this cart we will build a cart and a track and a display board. The cart will move over the track and the display board will hold over the cart as well as different types of pictures and icons on display. A simple basic view of our project model is shown in figure 22.

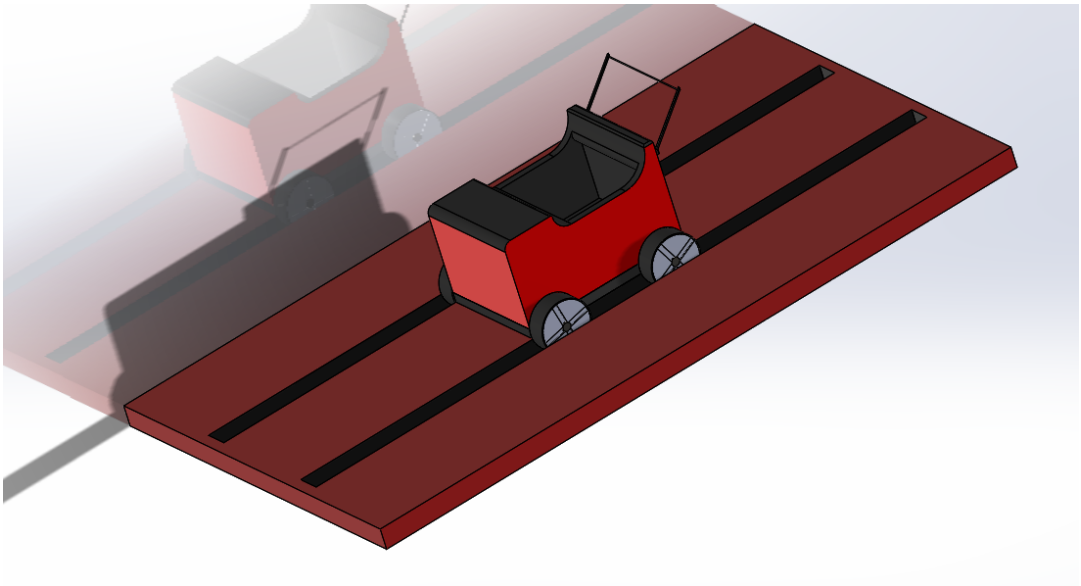

Figure 22: Design Model

5.2.1 Track

The track design is shown in appendix B. The track will be placed permanently outside in the playground, it's a straight track that have to block of woods at the end of each side, the tire will be fitting exactly on the track so that the children will be safe from injuries meaning the children foot will not stick on the gap of the track.

5.2.2 Cart

The cart design is shown in appendix C, and basically the cart will have four tires and a handle that will be used by the teacher to move the cart by exerting mechanical power. The seating would be wide enough so that it will fit different waists of children whose age ranges between four to 7 years old.

5.2.3 Motivation board

The motivation board now is including with the cart. The board will be in front of the child seat. As the previous idea the board will have a few features such as, hands with different materials like, plastic, wood and iron. Second, the board will have a pictures for animals. The purpose from these features as team we required to have something educational, so we searched what is the best entertainments educational toys that could be placed on board.

5.2.4 Individual Analysis done by the team

The project is aimed at availing fun activities to children who have disabilities. Most of these children utilize walkers, strollers and gait trainers for their utility needs. So as to fit the needs of these children, the project is required to be portable, and be able to withstand harsh weather for improved durability. It also has to be safe enough for use by the children under minimal supervision. The analyses that was done by the team was mostly focused on the customer requirements. Below were the most important aspects that were analyzed, and they were:

Portability:

Where the team has been analyzing how the design will be portable as portability was one of the most important aspects of the design because the clients wanted to have the ability to move the device from a place to another. Therefore, we needed to analyze the movement for the apparatus is really important and also the rotational for the cart depend on the tires that we install so for example a triangle shape with three tires in the front, and the same on the back so we can control the movement of the cart easily so we will have total of six tires on the cart.

Weight trade off analysis:

We agreed that it would be very important and nice to have one of the team members analyze the weight trade off. It will clarify, and show us how much each of the designs we came up with would weigh as a final weight. This will involve a lot of calculations, so it's determined.

Analyzing the aspect of heat transfer analysis:

In order to perform a technical analysis on heat transfer in moving wall, it is also significant to consider the heat and thermal energy that the wall will experience at the outer surface as that will

be directly proportional to the increase in temperature of the wall. According to CSA Z412-00 (R2106) Guideline [14] on Office Ergonomics, a general recommendation of temperature for human comfort in summers in the US is approx. 23-26°C and in winters is 20-23.5°C at 50% humidity levels. Keeping in consideration these limits of temperature, the wall temperature should also be limited to these ranges. However, looking at the climatic conditions in Flagstaff, AZ, it can be observed that the temperature is quite lower in both winters and summers so the design has to follow specific limitations such as color and wall material. The material greatly influences the temperature as well as the color of the wall. The associated equations will include heat transfers based on the three basic phenomena of heat transfer i.e. conduction, convection and radiation

6 PROPOSED DESIGN

Our design has been finalized and the final design selected is the cart and track with a display board. As the design will have the car which will move on a specific track. There will be a display board which will stand over the cart and that display board will have multiple icons. Figure 23 shows the body of the cart.

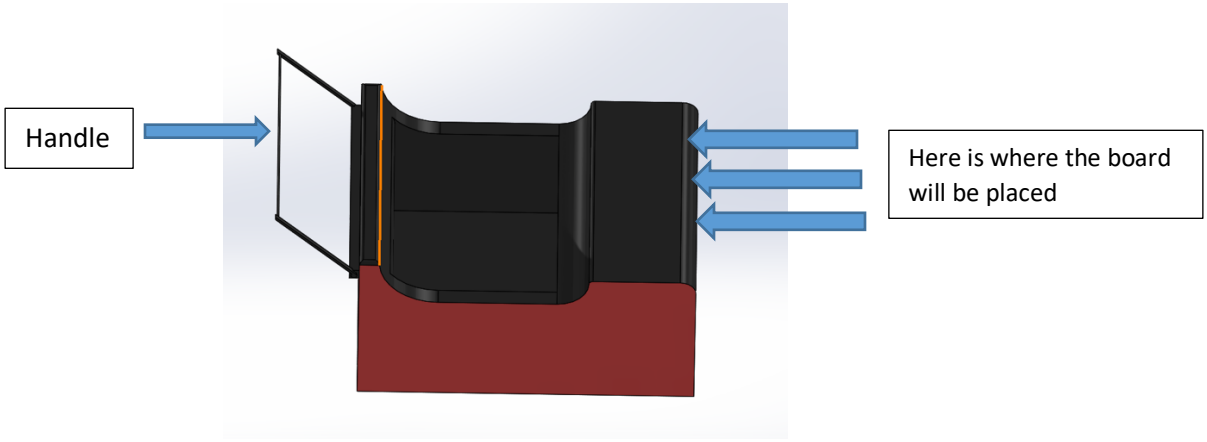

Figure 23: Top view of the cart

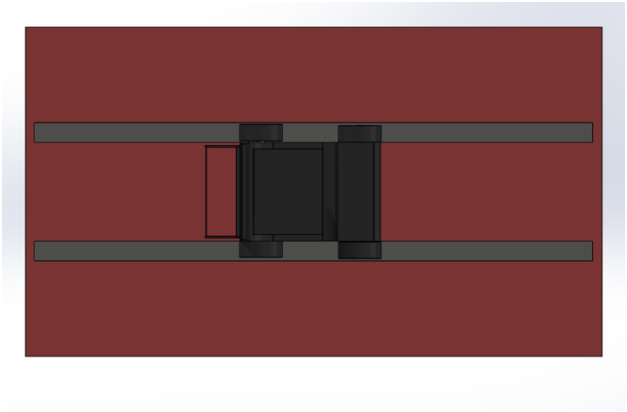

Figure 24: Track with the cart placed up top of it.

There are two sides in the track and those two railing sides will capture the wheels and wheels will move only inside those railing. As railings have the boundary which will keep the wheels in the straight path and on the track.

6.1 Manufacturing Plans

At the beginning of the spring 2018 semester, we will start manufacturing process on our project, and we will work on the track and the cart which will be done at the machine shop (98C). Because our design is consisted from more than one part, and the manufacturing for those part need to be manufactured by our hands and many other useful tools that we looked at when the team has visited the machine shop area.

Implementation is a very big step to the team. As we know, first semester has no implementation of any parts of our design, as we have to start implementing it next semester. However, we have made our prototypes so it help us know how our design would be implemented, would the design be hard to create, what difficulties we might face, and will it meet the requirements of our clients or not. Those factors and thoughts have helped the team a lot in seeing what changes we need to make and how important these changes will be. After we have created our auto CAD and prototypes we have definitely faced issues and decided to go with some changes in the design.

Many parts in our design need to be manufactured. The design of the cart and track has many parts that we'll need to manufacture. The body of the cart will be manufactured and created by polyurethane and maybe a mix of some other materials with polyurethane. The track also needs to be manufactured. All individual analyses that were done by the team have helped us to ensure that engineering requirements have and will be met. The team have faced many iterations that we considered as a failing iterations of the design. A failed iteration of the design of the track occurred when we did our auto CAD where we went creating a track that shaped with a quadrilateral shape as shown in figure 25.

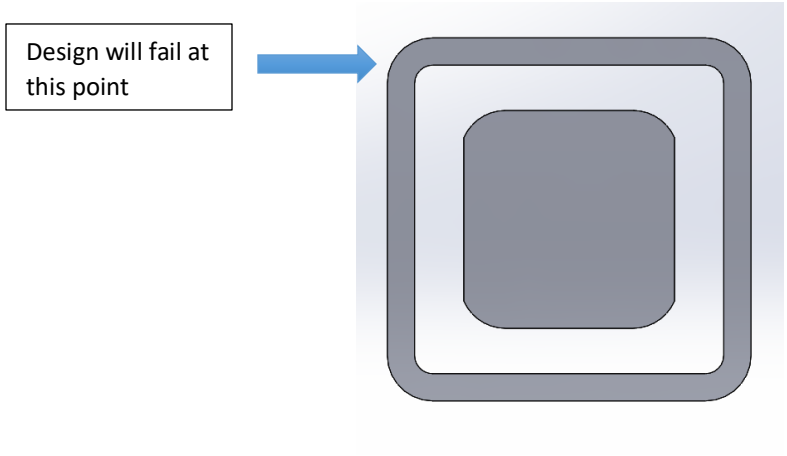

Figure 25: A failing design of the track

An iteration of the design was needed at this point because it is impossible that the cart moves in a quadrilateral shaped track around the corner.

The team also had a continuous iterations for the choice of the tires. Meaning, we were not sure whether or not we'll use casters or rubber tires. This iteration was considered as a continuous

iteration because it's very dependent on the shape of the track. Since the team have decided to go with a straight track as shown in figure 26

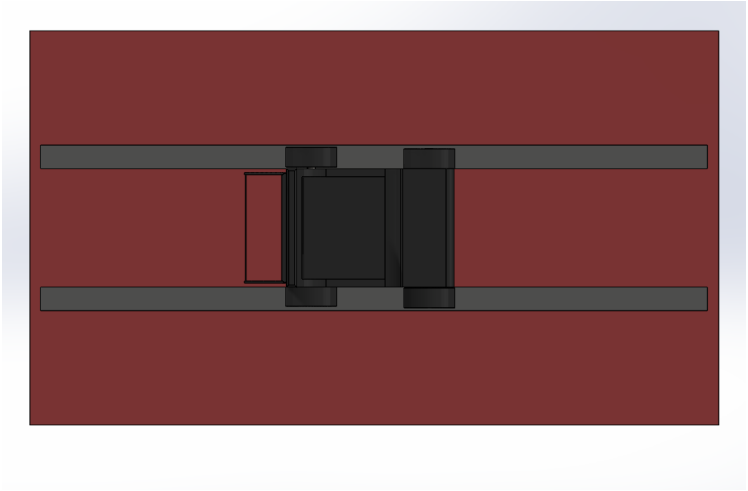

Figure 26: Final design of the track

Thus, it won't be that important to actually be worried about the choice of the tires. Also, any sharp edges in the body of the cart will be manufactured by rounding edges by 3.175 mm and cushion rolls will be attached to edges. In table 6 is a detailed explanation of how engineering requirements have met based on the manufacturing process of the design.

Table 6: How will manufacturing process meet our ER's

Engineering Requirements	Manufacturing Process
Body of the cart should be less than 13 kg	The manufacturing process will be met by the choice of the material that the cart will be made of.
The cost of the design must not exceed $2000	The current cost breakdown of the design is less by much than the provided budget as shown in our bill of materials in appendix A.
Round all sharp edges by 3.175 mm	Sharp edges will be manufactured by rounding all edges by 3.175 mm and cushion rolls will be attached.
Children ages ranges between 4 to 7 years	The seating of the cart will be manufactured by how much will the waists of those children is.

6.2 Some Design Changes

As this is only the first semester. The team have not yet started implementing the design. However, we have faced some problems when we assumed how the implementation process would go. Some of those problems are:

- The track is to be placed in an outside area permanently, and the problem of implementing this track is not in our clients' hands to ensure us an access so we go and implement whatever we want in regards of the track. Will the team change the design because of this implementation problem? The client contact of the team have met client Eva to discuss this issue, and she responses, "The people who are responsible of giving us an access to allow you to place the track outside are the people who work for the school which I will need some time to contact them regarding this issue, and therefore, we'll let you know whether or not you'll be able to implement your design. But I feel that 75 percent they will let you guys have access to do what you needed to do." Because the client have set a good percentage of saying that they will probably let us implement the design, the team will not change the design and the idea of having a track.

No other implementation problems that we faced unless the ones mentioned that we'll have in our design. The design of the track has changed due to its wrong shape not to how it will be implemented. Appendix B will show some CAD model of how the design of the track have been changed because of its wrong shape.

6.3 Testing

Our testing plan have helped us to specifically know what are we looking, and how will we meet all the design and customer requirements for our project. The team did not face any issue or problems during testing the requirements of the design which was great.

Portability: Portability is one of the very significant customer and design requirements of the project. It was tested mostly by looking at how much will the cart weight? All what we need is that we need the cart to be portable so it can be taken back inside the classroom when children are done using it. That was actually done by forcing ourselves to not exceed a weight of ~ 35 kg so a human can lift it up. Thus, this was tested and approached by testing each material and how much can it affect the weight of our device, and it was found by the team that the polyurethane is a very good choice for the outside body of the cart.

Withstand various weather conditions: The team have chosen a heat transfer analytical analysis to analyze different materials. This is how this design requirement got tested. Many calculations and researches have been done by the team to see how we can satisfy this design requirements. Calculations done regarding the heat transfer analysis is shown in appendix D

Long-life: Since it was required from the client that the device should stand for at least two years. We have tested the material of the track since it's going to be placed in an outdoor areas, and we found that the track should be made of steel so it doesn't get ruined when time passes.

No sharp edges: Round off sharp edges have been tested using Solidworks. We have created the body of the cart with the dimensions we chose, therefore, we tested more than one fillet on all sharp edges of the cart's body.

Choices of materials: Our design is a set of more than one part. Which means that not all parts will have the same material. So this design requirement have been tested by the team by looking at first what part of the design are we trying to choose a material for? How big this part is? And will this part be left outside permanently or not? In this way, we have been able to satisfy the requirement and chose the best material that this part needs to be made of.

Different sizes: As the children's ages ranges between 4 to 7 years old in the classroom. This means the size of the seating needs to satisfy all children's waists sizes. That's why the team have made the size of the cart's body and the seating place wide enough so it fits all children waists.

Motivation boards: This board is considered as one of our features of the design. Many thoughts from the team members have been changed regarding how this board should be tested. We have finally looked at many ideas on what could be the most interesting board for children with disabilities, and we found that a simple board with a set of different materials to be considered as a touching textures have been tested and approved to satisfy this design requirement, and similar boards are shown in figures 27 A – B.

Figure 27 A: Board with different materials

Figure 27 B: Board with different materials

7 IMPLEMENTATION – Second Semester

7.1 Manufacturing

Manufacturing was one of the important steps that the team had consider and have had a lot of plans before we actually start manufacturing our project. As you were going through the above sections, you must have realized that our project is a combination of two sets. Which are the cart and track. We first have chosen a plan in our minds in terms of building the cart and track.

7.2 Cart Manufacturing

The cart's manufacturing plan was that we wanted to mold and cast our own intended shape of the cart. Why did we choose to go with casting? We felt that it is going to be better for us if we mold our own part because we could have instead bought a body cart in the market and simply make changes to it, however, it will not be easy for us to find a cart that is going to be similar to the shape that we intended to have as our exterior design of the cart. The team therefore moved on with the idea of casting and have actually bought the necessary tools and kit for the procedure of molding. The team then realized that we lacked a bit of experience with molding, and that we did not actually have a good area to mold, thus, we got a contract with one of the companies to only mold the exterior body of the cart. It was easy and not that expensive to take this step because we have actually made the plug first, and then we delivered the plug, the kit and tools that we bought along with the plug which actually turned out that the money we paid for the company was only for molding excluding everything else.

Pictures of the plug that we created with wood before it got delivered to the company.

Figure 28: This is the top of the plug which has a hole cut out, so the child torso, head, and arms will be outside of the cart.

Figure 29: Those would be the side walls from wood to get the part ready for molding. Everything is lined with plastic, but it's hard to see. Basically, a plastic sheet is wrapped around every piece of wood.

Figure 30: That's an outside look of how the plastic sheets works on one side, and then secured on the other side. Noting that will prevent it from getting contacted with the fiberglass resin.

Figures 31: Round corner molds that are typically used in drywall applications, and we used it and taped it in the corners to have a molding part with no sharp edges.

Figure 32: This figure shows the three-way intersection. It will come out of the mold rough, and it will be sanded to a smooth round corner.

We waited 4 days for our molded part to be ready. Figure 33 shows the finished molded part that we picked up. Before delivering the plug, team F4 have had everything ready and set so we go right away and continue manufacturing the cart as soon as we pick it up. What we ended up having as problem is that when we had the molded body placed and secured in one of our teammates' garage as shown in figure 33, wrinkles in the body occurred when the molded part was left for one day which had put us in a problem that we needed to fix. Figure 34 will show you how those wrinkles looked like. The fiberglass resin should have pushed those wrinkles down, but it happened because probably the resin was not enough or wasn't molded correctly. Therefore, we went again to buy more fiberglass resin to cast those wrinkles and make them look

better. An iterative procedure for molding happened when we used fiberglass resin to cover those wrinkles. We actually did molding three times to make sure those wouldn't occur again.

Figure 33: The molded exterior body of the cart.

Figure 34: Wrinkles occurred when the molded part was left in the garage.

After we did molding again three times, the casted body was thereafter ready, so we continued on manufacturing. The next step after a very long process of molding was painting and attaching the caster wheels. We used one color for the paintings which was red. In the sake of having the cart look professional we used stain, as well as clear coats. The only body work or body filler that we needed to do before painting would be in all the corners, so they're blended. We then painted, stained, and clear coated the cart. The idea of staining and using clear coats turned out to have the cart be in a very good quality in terms of paintings as shown in figure 35. After painting was done, we have attached wood panels to the bottom outside body for the caster wheels which would add some structural stability. After we attached the wood panels, we then put the wheels, and tested whether or not they're were stable enough, and it was actually very stable and had a smooth movement. Figure 36 shows the wood panels with the caster wheels attached to the body of the cart. We are not 100% finished with manufacturing the cart, thus, this section will be updated as we move forward with manufacturing.

Figure 35: The cart after it got painted with attaching the clear coats

Figure 36: The wood panels and the caster wheels

7.3 Track Manufacturing

The manufacturing of the tack has been dependent on the authorization from the school at which our client is an employee at. Getting an authorization and an approval from the school so we place the track outside in the playground area have had the team be behind the schedule because we have not yet started manufacturing the track, and that was because we need to speak with whomever is responsible of that in the school. Our client suggested that we should come by the school with the design of the track that we have and find out who is exactly the person responsible of reviewing our design and telling us whether or not we could have an approval to move forward with manufacturing. All the materials needed to manufacture the track were purchased and ready which would ease out manufacturing to us until we receive the authorization. This section will be updated when we finish manufacturing the track.

7.4 Design Changes

Some changes occurred when we started manufacturing our project. One of those changes that we felt are worth of mentioning was when we first started doing the plug of the cart body, we used foam, so we create the plug as the intended design. The team encountered many problems while creating the plug out of foam. Cutting the foam was hard and we needed to be very careful because if we screw small things in the foam plug which can easily happens, we would end up with a funny shape. We tried cutting the foam with a foam cutter, but it did not work well at all. We wasted a lot of foam for the plug after the sixth try, and thereafter we decided to change the material of the plug to be wood. When we tried wood, it turned out to be very good and much easier than the foam.

Moreover, the possibility of changing the design of the track is high. The track design that we currently have might not be approved by the school which might put us in the risk of changing the design. Thus, the team have made another two designs for the track as a plan B if somehow the current one will not be approved. Those two designs are shown in figures 37 and 38.

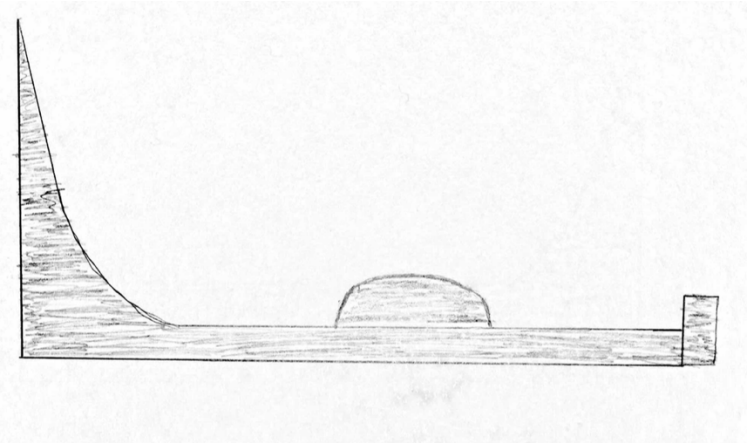

Figure 37: New idea for the design of track which is a one drop with one or two humps allowing the cart to go only in one direction.

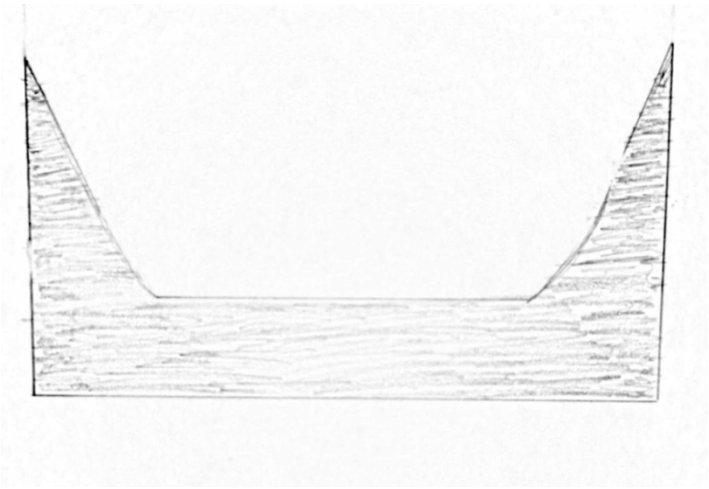

Figure 38: The second new design of track which is the half pipe design allowing the cart to travel either direction.

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APPENDECIES

APPENDIX A: Bill of materials

Bill of Materials

Item No.	Title	Desc.	Qty.	Seller	Price per unit (pre-tax)	Unit of Price
1	Nordstrand Fiberglass Chopped Strand Mat Cloth 50" x 360" 1.5 oz	E-Glass Fiber Roll CSM GRP for Molding Roofing Boat Marine Repair - Resin & Epoxy Compatible	1	Smart Parts US	55.99	USD $
2	2x3-96" Stud	1.5in x2.5in-96in Select Stud	2	Home Depot	2.25	USD $
3	92-5/8 Stud	1.5in x2.5in-92.625in KD Prime Stud	4	Home Depot	3.27	USD $
4	FIBGL Resin	Bondo 404 Fiberglass Resin 1 Gal	1	Home Depot	37.97	USD $
5	9" ADHCOVER	Better 9in Adhesive and Epoxy Roller	2	Home Depot	4.97	USD $
6	4" FMBRSHWDN	Chip 4.0 Flat Brush	1	Home Depot	3.97	USD $
7	10x25 3.5mil	10'x25' 3.5 MIL CLR Plastic Sheeting	1	Home Depot	10.98	USD $
8	Tray Liner	Linzer 9 in pet tray liner white 1pk	1	Home Depot	0.98	USD $
9	1" Drywall	1" Coarse Drywall Screw 1LB	1	Home Depot	6.28	USD $
10	3/8 PART BD	0.369 in 3/8 cat pb 48in x 96in	1	Home Depot	9.98	USD $
11	PRECONCGRY	1-Kote 80lb gray premium concentrate	1	Home Depot	16.45	USD $
12	Rust Stripper	N/A	1	Walmart	7.47	USD $
13	Filler Gallon	NA	1	Walmart	15.44	USD $
14	Lag Screw	5/16"X4"HEX HD LAG SCR HDG	8	Home Depot	1.26	USD $
15	Lag Screw	5/16"X3" HEX HD LAG SCR HDG	7	Home Depot	0.94	USD $
16	Liquid Nail	LN Heavy Duty 10 oz	4	Home Depot	2.57	USD $
17	Stanley 3/16" Long Alum Rivets 50 pk	Polyacrglsqt	1	Home Depot	15.97	USD $
18	Minwax Polycrylic GLS Qt 275V	Varabarnrdqt	1	Home Depot	8.48	USD $
19	Vara 3x Stain Oil Barn Red Qt	Wodglumax8	1	Home Depot	4.67	USD $
20	Wodglumax8	Elmers Carpenters Wood Glue Max	1	Home Depot	7.98	USD $
21	2436 Bk PDB	.118 24x36 Black PVC Project Board	1	Home Depot	8	USD $
22	2X4-10 GDF	1.5in x 3.5in-10ft STD/BTR Prime DF	1	Home Depot	6.2	USD $
23	Caster	Caster non-mark rubber 5" rigid	4	Home Depot	43.88	USD $
24	2.7MM Lauan	0.106inX48inX96in;Utility Panel	1	Home Depot	10.98	USD $
25	Pro Aerosol	Pro Safety Red 1.5oz	2	Home Depot	5.27	USD $
26	2X Redprmr	Painters Touch 2X Red Primer	2	Home Depot	3.87	USD $
27	Fibgl Resin	Bondo 404 Fiberglass Resin 1 Gal	1	Home Depot	37.97	USD $
28	ACTNSTTHNRGL	KS Acetone Gal	1	Home Depot	15.27	USD $
29	HRDNR 74oz	Bondo 20216 Liquid Hardner	2	Home Depot	5.77	USD $
30	Corner PI	GenPRP 3/4 CRNR Guard PineP266	5	Home Depot	0.77	USD $
				Total	355.85	

APPENDIX B: Track design changes

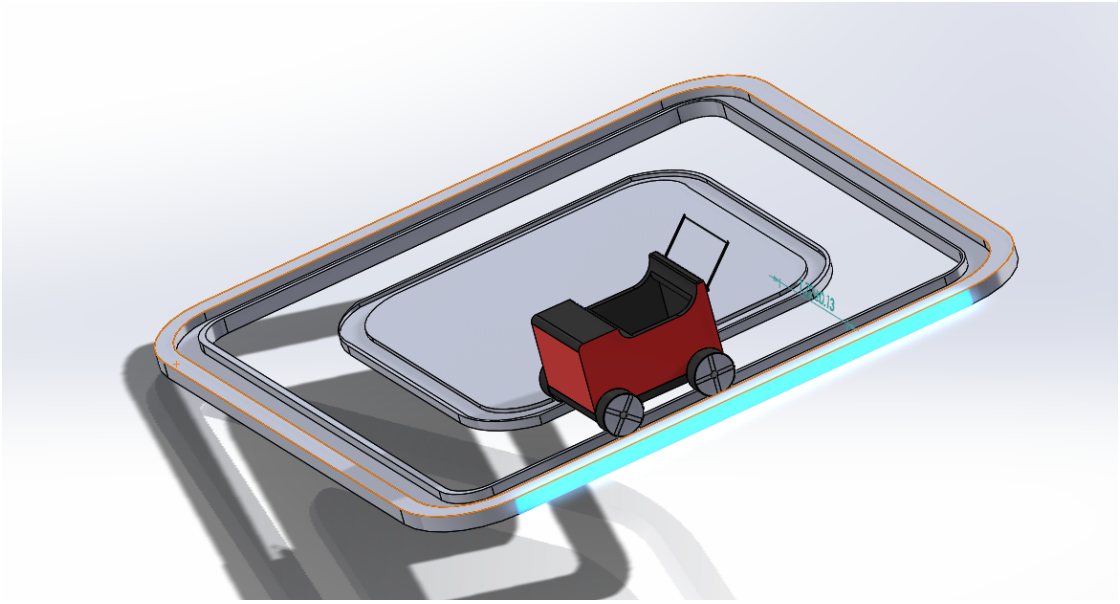


Figure: The old failing design of the track

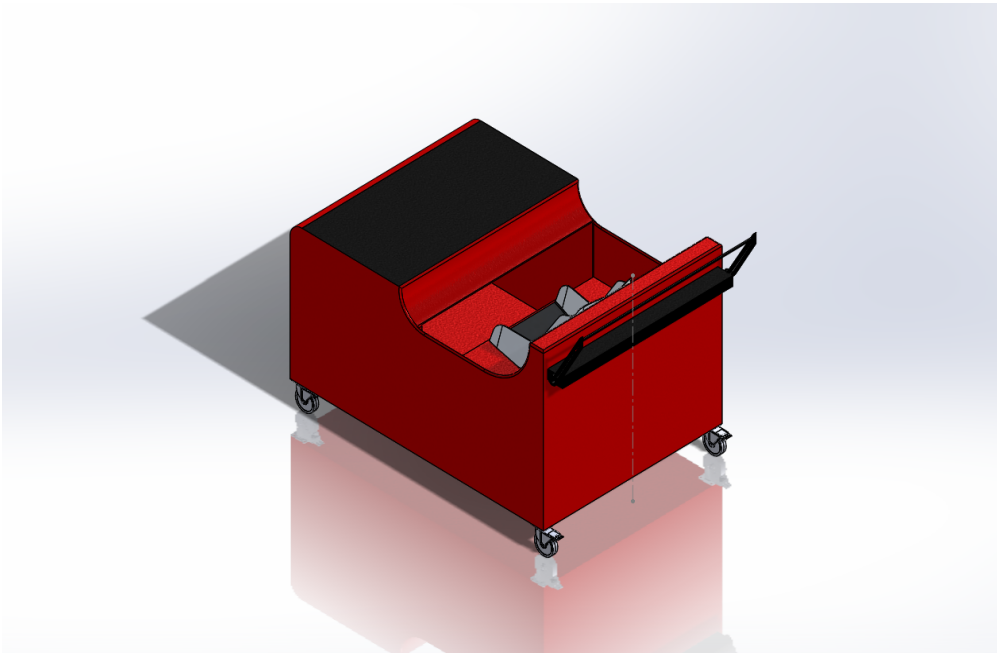
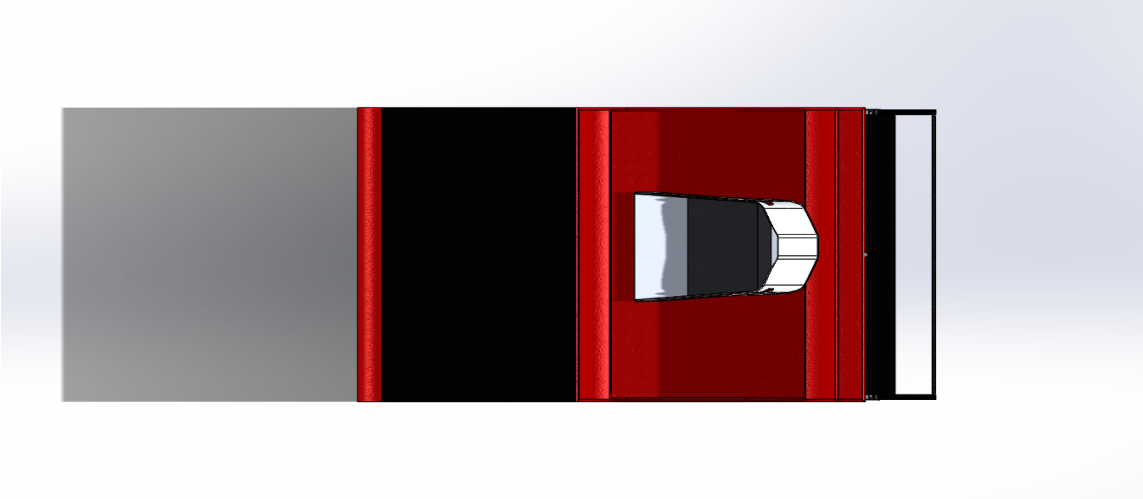
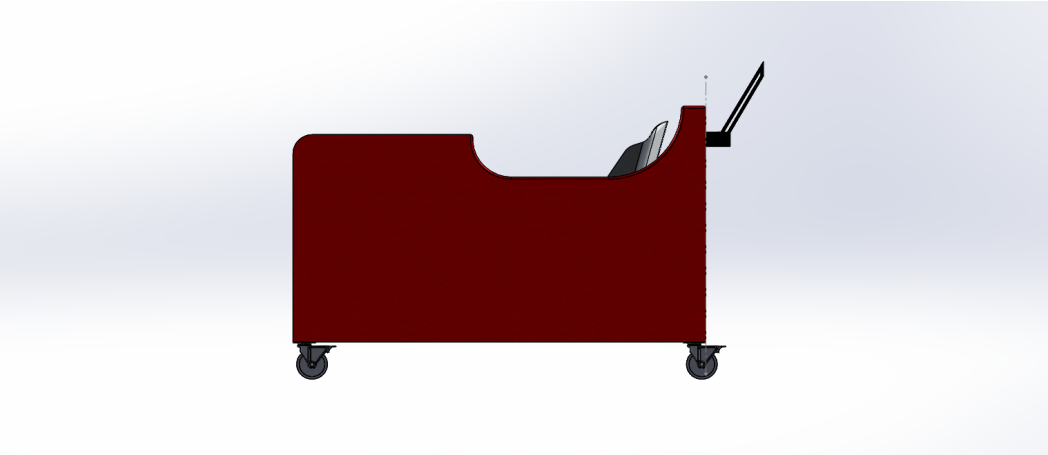


Figure: The new and final design of the cart

APPENDIX C: CAD model the design





APPENDIX D: Calculations

3.6 Additional Calculations

If we consider a wall of the following parameters, we can also analyze the heat transfer behavior in case of conduction for a better understanding. Will use winter case because the summer on flagstaff are cool. By Fourier's Eq: $Q = \frac{KA(T_{surface} - T)}{d}$

d = 0.15 m

Height of wall = 2 m and width of wall = 2 m

T = -8°C and $T_{surface}$ = 20°C

Case 1: Material -> Iron

k =79.5 W/m K [4]

Q = 59360 W

Case II: Material -> Wood/Composite

k = 0.12W/m K [4]

Q = 89.6 W

Case III: Material -> Aluminum

k = 205 W/m K [4]

Q = 153066.6 W

As we can see from the values of heat transfer for iron, wood and aluminum, wood seems to be a better option as it does not conduct heat at a high rate.