MECH 4240 Preliminary Design Review: Disabled Child Mobility Project

Corp #8

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Abstract

A better system is needed for transporting a special-needs three-year-old child and all his medical equipment. Due to the large amount of equipment that he requires, this transportation device must have increased storage capacity and be further customized to fit the child's needs. The client currently uses a two-seat model with a relatively small amount of storage space, causing most of the equipment to be stacked precariously in the seats. This report elaborates the systems engineering approach to solve this design problem. The mission of Corp 8 is "to provide a comfortable means of transportation for a special needs three-year-old child and an effective and convenient means of storage for all the necessary medical equipment."

It was determined early on that it would be best for the client if a commercial two-seat stroller were purchased and modified. Through the use of trade studies and decision matrices, the Chicco Cortina Together stroller was chosen as the base model for these modifications through the removal of the rear seat and the addition of five subsystems: an IV pole, removable tray, extended footrest, storage shelf, and oxygen tank storage. Alternative arrangements of these subsystems were investigated to produce a recommended system design.

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1.0 Introduction

Ryan Duke, seen in Figure 1, is a three-year-old child with special needs who was born prematurely. He has a tracheotomy which necessitates the regular use of a vent, suction bag, and food pump wherever he goes. He also needs a large and a small oxygen tank, a diaper bag, and an emergency bag. Due to these special requirements, off-the-shelf designs of most commercial strollers are not suitable for Ryan and his needs. The engineering need is for a new mobility device with sufficient storage and strength to hold Ryan and all his equipment, and reliability to last through two years of use.

The stroller currently being used by the client (Christina Duke, Ryan's mother) is the Graco Ready2Grow Classic Connect, a two-seat model with a relatively small amount of storage space. Because of this lack of room, most of the equipment must be stacked precariously in the seats or on top of other things while Ryan rides in the seat closest to the driver.

Figure 1: Ryan Duke

This report will review the requirements for the stroller design, and the decision-making process and architectural design for a commercial stroller, from preliminary research to final selection. The concept of operations, requirements verification, environment, and risks will be investigated. Then, the design and interfacing of additions and modifications will be reviewed and detailed. Finally, the project's organization will be covered, including budgets, documentation, and other general management. Finally, the conclusions of the report will be summarized.

2.0 Mission Objective

The objective is to provide a comfortable means of transportation for a special-needs three-year-old child and an effective and convenient means of storage for all the necessary medical equipment.

3.0 Mission Environment

The stroller is used in various out-of-home environments. Christina often takes trips to doctors' offices, which have narrow doorways that the modified stroller would need to fit through. Also, this on-the-go nature means that the storage must always be accessible to the operator for any emergency or other situation that may arise.

Another major part of the design is its storage. The folded, compacted device must fit in the trunk of Christina's car, a 2007 Honda Odyssey. As previously mentioned, any additions should not lengthen the stroller in this dimension by more than about six inches.

4.0 System Requirements

I. The device shall include a storage system with sufficient space for all equipment.
   a. Storage space shall be unobstructed for easy access to bags and objects, which may include the vent, suction bag, emergency bag, feeding bag and pump, diaper bag, and personal accessories.
   b. Holders shall be provided to store and support both oxygen tanks.
   c. An IV pole shall be attached for use of the feeding bag and pump.

II. The device shall be easily maneuverable in rooms, hallways, and doorways.

III. The device shall collapse to fit in the trunk of Christina's car, a 2007 Honda Odyssey.
   a. Folded frame dimensions shall not be significantly larger than the current model.
   b. Any additions or modifications shall not significantly increase these dimensions.

IV. The device shall provide safety, stability, and comfort for the child.
   a. The seat belt system shall keep the child safe without constricting his movement.
   b. The frame shall fully support the weight of the child and his equipment.
   c. The wheels shall have a locking system to stabilize against rocking.

V. The device shall provide sun protection for the child when necessary.

VI. The device shall accommodate two years of growth from the child.

VII. The device shall allow the child to face forward.

VIII. The device shall meet existing standards and requirements for both strollers and disability equipment.

5.0 Architectural Design

The first design problem addressed for the stroller was whether to build a new device from the ground up or to customize and modify an existing stroller model. After meeting with Christina and discussing her current stroller and its problems, it was concluded that an existing model could easily be adapted to fix Christina's issues.

5.1 Trade Studies

Following this decision, extensive research was done on both medical and commercial strollers. Medical strollers were quickly ruled out because they generally lack the needed storage space and are difficult to modify, both of which are crucial needs for this project. Commercial strollers; however, provided several good options. Many two-seat strollers had spacious storage compartments. Other models were more adaptable, even if they did not come with much storage. After researching many stroller brands and models, four viable options were selected: the Chicco Cortina Together, Contours Options Elite, Baby Trend Sit 'n' Stand, and Graco DuoGlider, as shown in Figure 2a, 2b, 2c, and 2d respectively.

(a) Chicco Cortina (b) Contours Options Elite (c) Sit 'n' Stand (d) Graco DuoGlider

Figure 2 (a, b, c, d): Stroller Options

For each stroller model, several different characteristics were considered for use in a weighted decision matrix. These are described in Table 1.

Table 1: Stroller Characteristics

Category	Chicco Cortina Together	Contours Options Elite	Baby Trend Sit ‘n’ Stand	Graco DuoGlider
Ease of additional installation	Back seat is firmly attached	Back seat is easily removed	No extra seat, so adapting is easier	Back seat is firmly attached
Weight	34 lb	38 lb	27 lb	29 lb
Size	47.25” x 23.5” x 45.5”	49.5” x 26” x 39.8”	45.3” x 21.7” x 45.3”	35.5” x 20” x 40”
Folding Ease	Folds with grip on handle and a kicking force on the basket	Collapses with handle and a kick lever	Easy folding mechanism trigger on handle	Folds with grip on handle and a kicking force on the basket
Storage Space	Large basket under seats	Large basket under seats and attachable basket	Very small storage area under seat	Very large storage basket
Additional Accessories Available	Quick-connects at front of stroller allow other accessories to be attached	Additional basket and other devices that may attach in place of the rear seat	None available, would need to be made or manufactured	None available, would need to be made or manufactured
Seat Size	Suitable size for Ryan	Possibly not big enough for Ryan; the footrest is too high	Suitable size	Suitable size
Base Cost	$299.99	$299.99	$139.99	$134.99
Cost of Modifications	Low cost	Low cost	Higher cost (more modifications needed)	Higher cost
Versatility	Versatile in many ways, but the second seat is attached	Very versatile; easy to modify and reconfigure	Highly adaptable	Less versatile due to difficulty of removing or reconfiguring components

For the decision matrix, weighted scores were tabulated and results calculated with an Excel spreadsheet, for each team member. Table 2 shows the manager’s table as an example and Table 3 shows each team member’s total score for each stroller.

Table 2: Example Decision Matrix

Characteristic	Weighting Factor	Chicco Cortina	Total	Options Elite	Total	Sit 'n' Stand	Total	Graco DuoGlider	Total
Ease of additional installation	4	3	12	3	12	3	12	2	8
Weight	2	3	6	2	4	4	8	3	6
Size	2	2	4	2	4	3	6	4	8
Folding ease	2	4	8	3	6	3	6	4	8
Storage space	5	4	20	4	20	3	15	5	25
Additional accessories	3	4	12	3	9	3	9	3	9
Seat size	4	3	12	2	8	3	12	3	12
Base cost	3	2	6	2	6	4	12	5	15
Additional cost	3	3	9	2	6	2	6	3	9
Versatility	3	5	15	4	12	4	12	3	9
Total weighted score:			**104**		**87**		**98**		**109**

Table 3: Members' Decision Matrix Scores

Team Member	Chicco Cortina Score	Options Elite Score	Sit 'n' Stand Score	Graco DuoGlider Score
Neil	104	87	98	109
Nathan	121	96	121	92
Callie	125	94	117	106
Daniel	120	119	114	107
Jaron	119	100	106	101
Jay	118	105	116	109
Average Score:	**117.8**	**100.2**	**112**	**104**

The average weighted score from the decision matrix above clearly indicated the Chicco Cortina Together as the best choice. However, the final selection was not made until after meeting and discussing all options and results with Christina and Dr. Renner. Christina preferred the design of the Chicco Cortina for its versatility and maneuverability, and Dr. Renner agreed.

After this, the team contacted Chicco to ask about the potential for getting a free or discounted stroller. The company was able to provide a new Chicco Cortina stroller at no charge for the project. This stroller was measured and a model was built in SolidWorks to allow for different architectural designs and modifications of the stroller assembly.

5.2 Product Hierarchy

Five main subsystems will be added to the Chicco Cortina base model to satisfy all the system requirements and meet Ryan and Christina's specific needs:

1. IV pole
2. Extended footrest
3. Removable tray
4. Storage shelf
5. Oxygen tank storage

The IV pole is needed to support the feeding bag whenever it needs to be used. The pole needs to be lightweight and must not hinder the device's folding. The extended footrest is needed to accommodate Ryan's growth over the next two years. The footrest will also provide better support for Ryan's feet, as well as protection from the wheels. The removable tray is necessary for Ryan's rehabilitation activities, which require plenty of space. The tray will also allow the stroller to be used like a high chair when traveling.

The additions of a storage shelf and oxygen tank holders are modifications with multiple alternative arrangements. The shelf may consist of a folding, static, or sliding design. The tank storage may be located under the front seat, or within the basket horizontally or vertically.

These alternatives and their layouts will be fully detailed in sections 5.4 through 5.8.

5.3 Subsystems Design Engineering

A standard engineering design process was followed for the design of subsystems. For the elements that need to be added to the stroller, the first step was to identify the form-driving attributes. These are: stability against rocking, expanded storage space, seat restraints, support for the feeding bag, cup holders, tray space, a forward facing seat, wheel locks, sun protection, oxygen tank holders, and collapsing the stroller. As an exercise to generate alternatives, team members were split into two subgroups each assigned to their own half of the characteristics. Each member independently came up with a morphological matrix of multiple possibilities to accomplish the desired functions. An example is shown in Figure 3 below.

	Function	Option 1	Option 2	Option 3
1.	Stability against rocking	Keep heavy bags in the very bottom to lower c.g.	widen base or add supports (high chair) lock wheels	lower seat or tighten restraints
2.	Storage for medical equipment	Existing compartment in bottom of stroller	Choose another stroller with more storage space	Add custom storage (e.g. sleeve for O_2 tank) "umbrella holder"
3.	restraints	simple lap belt with center clip	seat belt clip	full car seat harness
4.	Support feeding bag	Buy IV pole accessory to clip on (combine with tank holder)	Attach actual IV pole to stroller frame	Simply clip IV bag to stroller frame
5.	hold cups, drinks, or accessories	Clip-on cupholder and other attachments for stroller bar	hooks to hang things from	use existing cupholders + storage
6.	desk space	Replace small front-facing tray with larger one	custom folding tray	high-chair type tray (maybe Graco compatible)

Figure 3: Example Morphological Matrix

Some of these form driving characteristics are already adequately provided in the Chicco Cortina. Stability, seat restraints, cup holders, a forward facing seat, locking wheels, sun protection, and collapsibility are already inherent in the model. As long as no additions hinder the operation of these included subsystems, they are suitable as-is.

However, the included restraint system will need to be modified to accommodate Ryan's expected growth over the next two years. This can be done by either extending the straps or by changing the position of the straps on the seat. The location of where the thong passes through the seat will be shifted toward the front of the stroller.

In the following sections, design concepts for each subsystem and modification are provided. Alternative designs are provided separately for the shelf subsystems and the oxygen tank storage; however, these are closely interdependent in the system architecture.

5.4 IV Pole

The IV pole attachment is needed to hang a feeding bag, which needs to be located close to Ryan's head height. A small IV pole will be built, as shown in Figure 4.

Figure 4: IV Pole

This pole will be attached to the vertical bar of the stroller's frame, just behind the front seat, shown in Figure 5. This IV pole concept is the same for all design alternatives.

Figure 5: IV Pole Positioning

The IV pole will be attached to the frame of the stroller by either bolting through it, or creating a system that will wrap around the frame. The pole will not interfere with the folding if attached at the location shown in the figure. The angle of the pole may be adjusted by loosening the wing nut, moving the pole to the desired position, and re-tightening the wing nut. For the stroller to be folded, the pole must be rotated parallel to the vertical bar to which it is attached.

Rudimentary calculations for the maximum bending stress and the necessary diameter are provided below. The forces and moments involved are detailed below in Figure 6.

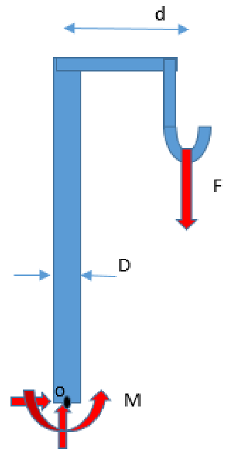

Figure 6: IV Pole Free Body Diagram

$$\sum M_o = M - Fd = 0 \quad \rightarrow \quad M = Fd \tag{1}$$

$$I = \frac{\pi}{64} D^4 \tag{2}$$

$$\sigma_{max} = \frac{M \cdot y}{I}, \text{ where } y = \frac{D}{2} \tag{3}$$

$$Factor\ of\ Safety = n = \frac{\sigma_{yield}}{\sigma_{max}} \tag{4}$$

Equations 1-4 can be combined to form Equation 5 below, which is used for finding the minimum diameter for the IV pole.

$$D \geq \left(\frac{32\, F \cdot d \cdot n}{\pi \cdot \sigma_{yield}} \right)^{\frac{1}{3}} \tag{5}$$

Assuming a 5 pound load, a factor of safety of 2, stainless steel 304 (with a yield stress of 31.2 kpsi), and d=3 inches, the minimum diameter for the IV pole is 0.214 inches. Therefore the recommended design will have a 0.25 inch diameter.

5.5 Removable Tray

Another element which needs to be added to the front seat is a tray, shown in Figure 7. Many stroller models come with a tray that is set in front of the child; however, the Chicco Cortina does not. Additionally, most stroller tables are too small to facilitate Ryan's rehabilitation activities.

The two quick-connect attachment options included with the Chicco Cortina are either a bar that extends across the seat, or two cup holders. These attach into the ends of the two top bars of the stroller frame. Because the cup holders will not be needed, the connecting pieces from them may be adapted and attached to the tray. The tray will be at least nine inches long to provide adequate space for Ryan's rehabilitation exercises. It will also have a lip around the edge to prevent things from slipping off. It is likely that the tray will be 3D printed.

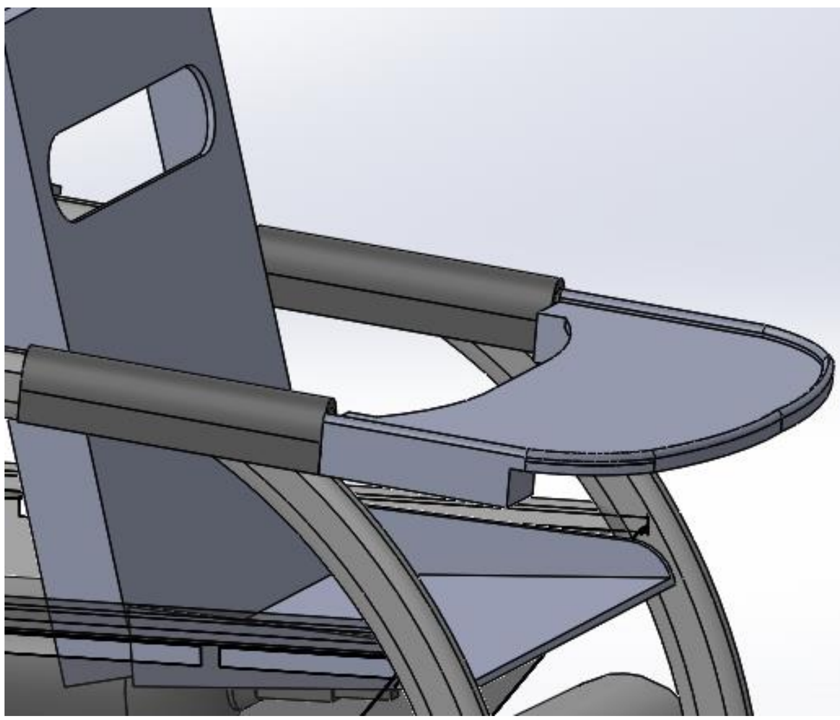

Figure 7: Removable Tray

5.6 Extended Footrest

In order to account for the growth of Ryan's legs over two years of stroller use, the footrest of the stroller needs to be adapted. In order to provide support for his feet and protect them from hitting the wheels, an extended footrest is necessary. It will sit on top of the current footrest and fold up on a hinge for storage. The current footrest, shown in Figure 8a, and its modification, shown in Figure 8b, are presented below.

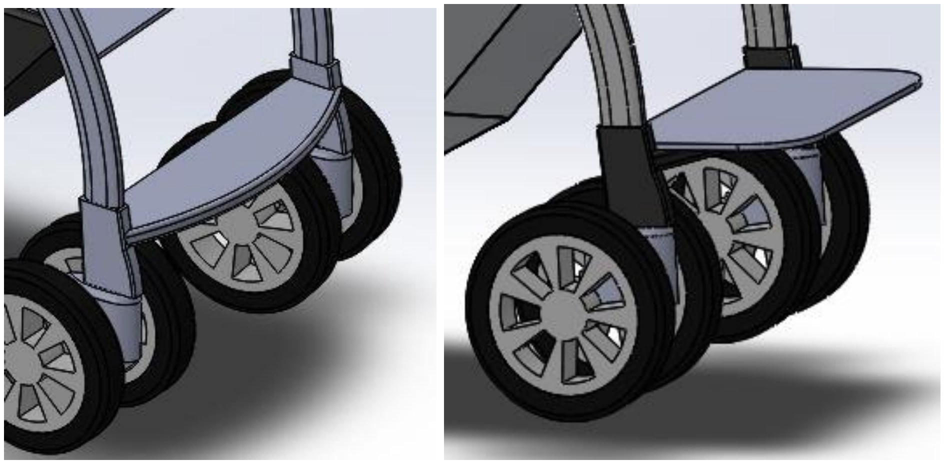

Figure 8 (a, b): Current and Extended Footrest

5.7 Shelf Alternatives

The alternatives described in the next three subsections call for adding a shelf to support the most important medical equipment.

5.7.1 Alternative 1: Folding Shelf

The shelf configuration shown in Figure 9a would be foldable so that storage space can be accessed underneath. The main benefits of this design are that it would effectively double the storage space and allow for important medical equipment to be easily accessed. The shelf would not interfere with the folding of the stroller in any way, and all of the frame components, specifically the top cross bar, would remain intact. This alternative would require side support on the shelf to secure the equipment when turning the stroller. This support could easily be provided by a simple netting system, as shown in Figure 9b. However, the net could possibly get stuck when the stroller is folded.

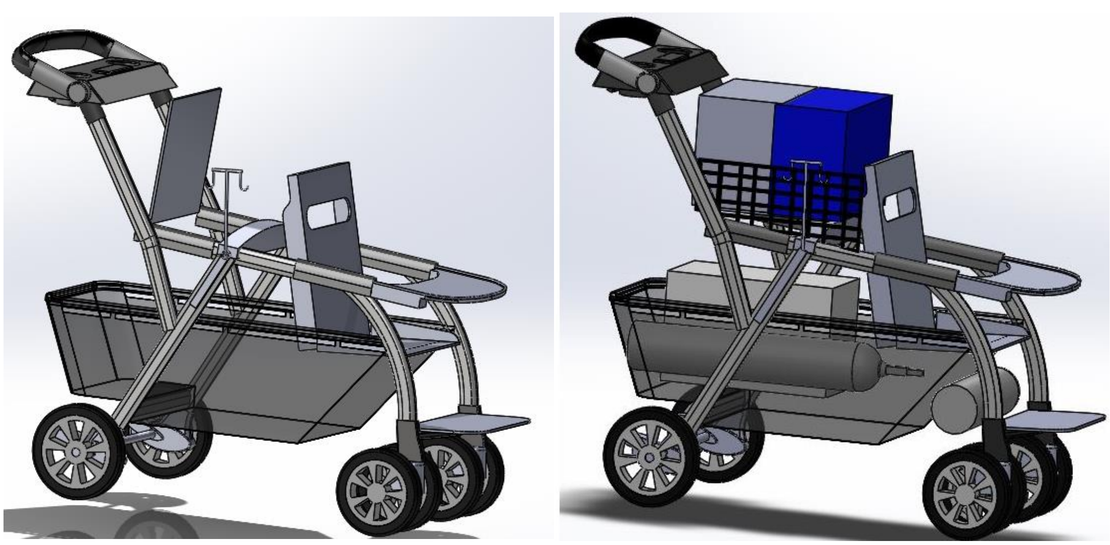

Figure 9 (a, b): Folding Shelf Alternative

5.7.2 Alternative 2: Static Shelf

The second concept shown in Figure 10a includes a rigid shelf either on top of or in between the top horizontal bars. This would keep the frame intact and maintain torsional support, while providing additional vertical storage space for all the components in Figure 10b. However, the front of the basket would only be accessible by folding the front seat forward. This would cause a problem if the user needs to quickly retrieve an item in the front portion of the basket.

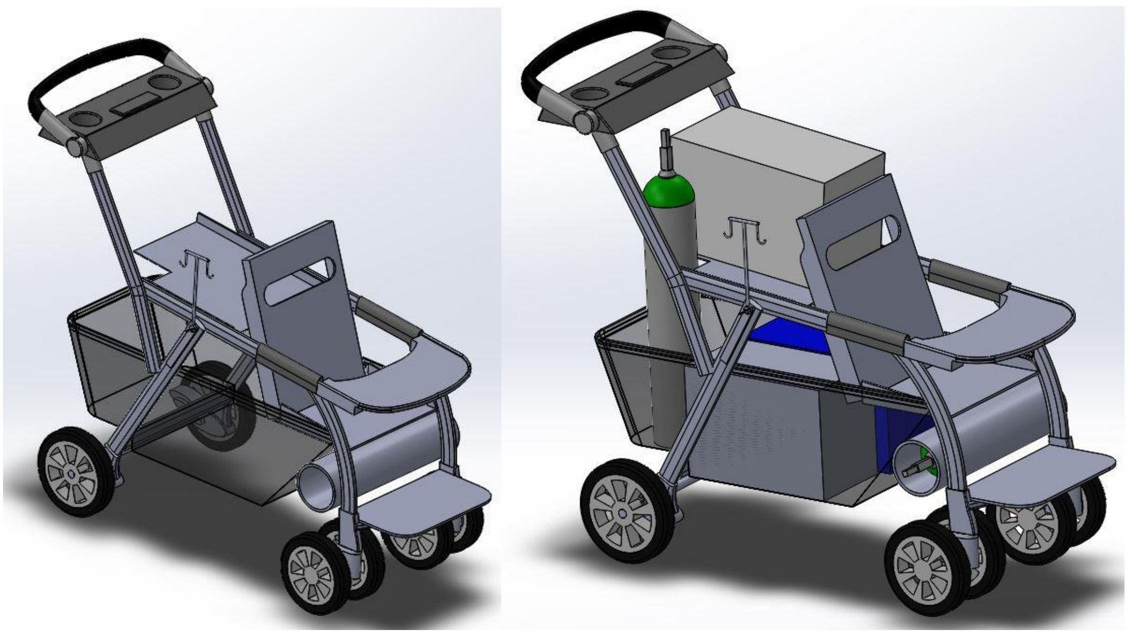

Figure 10 (a, b): Static Shelf Alternative

5.7.3 Recommended Alternative: Stackable Sliding Shelf

The recommended concept in Figure 11 consists of a stackable sliding shelf system that can be modified or adjusted for different uses. The sliding shelf sits on a rail system that lies on the basket frame. The entire system is made up of a rail or slotted channel, and two shelves that support the load and support the medical equipment. The shelves are designed to be stackable or entirely removable, as shown in Figures 12 and 13, so that the operator can access the storage basket underneath. The shelves can also be arranged while stacked to provide easy and seamless access to the storage basket, or vertical space for storing taller objects.

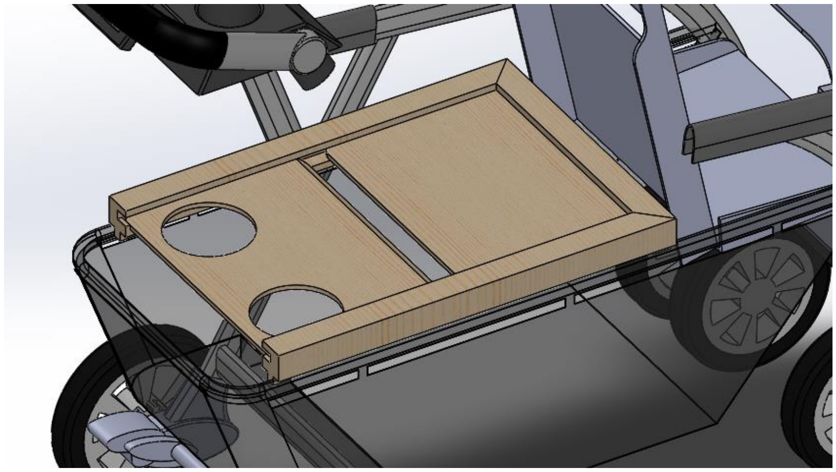

Figure 11: Stackable Sliding Shelf - Extended

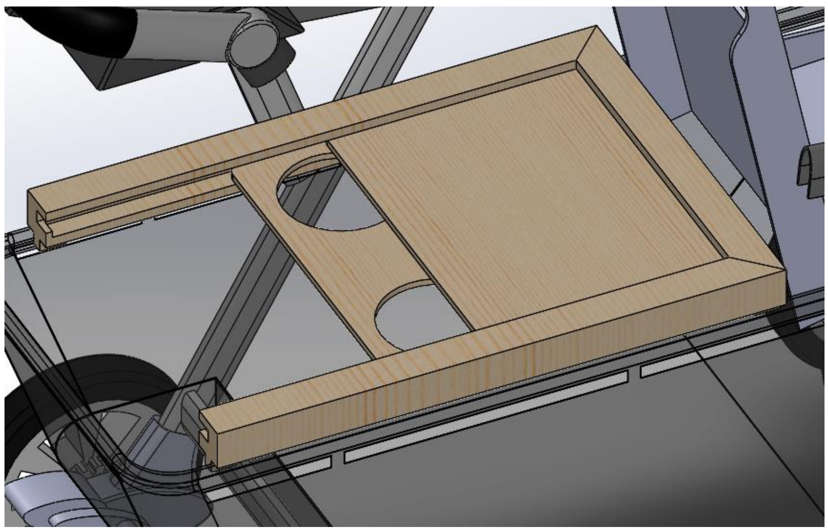

Figure 12: Stackable Sliding Shelf - Partially Stacked

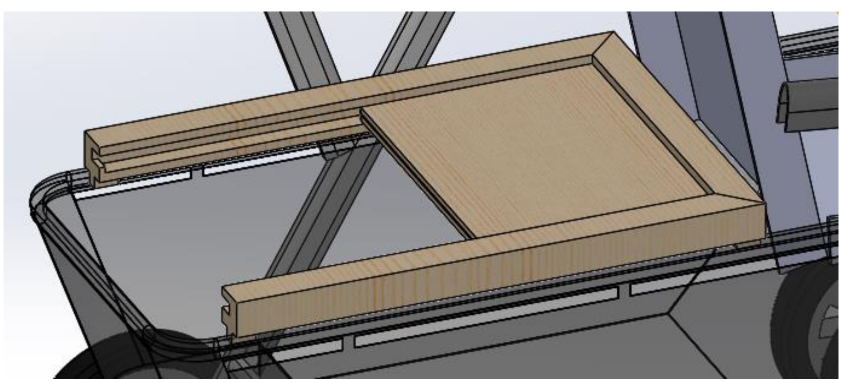

Figure 13: Stackable Sliding Shelf - Fully Stacked

5.8 Oxygen Tank Storage Alternatives

The following two subsections describe two alternative arrangements for the oxygen tank storage subsystem.

5.8.1 Alternative 1: Under-seat Tank Storage

A tank storage system under the seat would correspond to either the folding shelf or static shelf alternative. A tough cloth tube with one end closed would be attached to the front legs to contain the small oxygen tank underneath the front seat, as shown in Figure 14a. Plastic or metal guards (not pictured) would be added to the sides of the front frame to protect both ends of the oxygen tank, because it does extend beyond stroller's main frame as shown in Figure 14b. When needed, the large oxygen tank could be contained within the storage basket in either a vertical or horizontal position, depending on the shelf alternative selected.

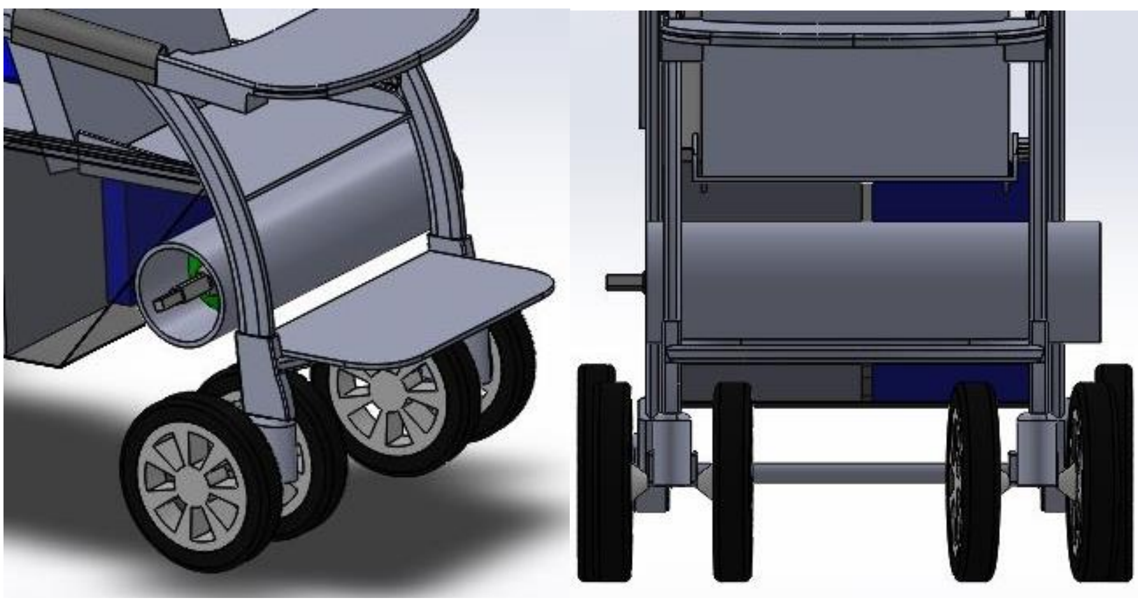

Figure 14 (a, b): Under-seat Tank Storage Layout

5.8.2 Recommended Alternative: Tank Cup Holders

The rear shelf is designed with two circular cutouts for the two oxygen tanks, which can be stored as shown in Figure 15. The weight of the tanks will be supported by two "cup holder" devices (not pictured) attached to the frame. For both, the shelf and the cup holders, the weight of the medical equipment is supported by the stroller frame rather than the basket fabric, which will promote fatigue longevity of the basket.

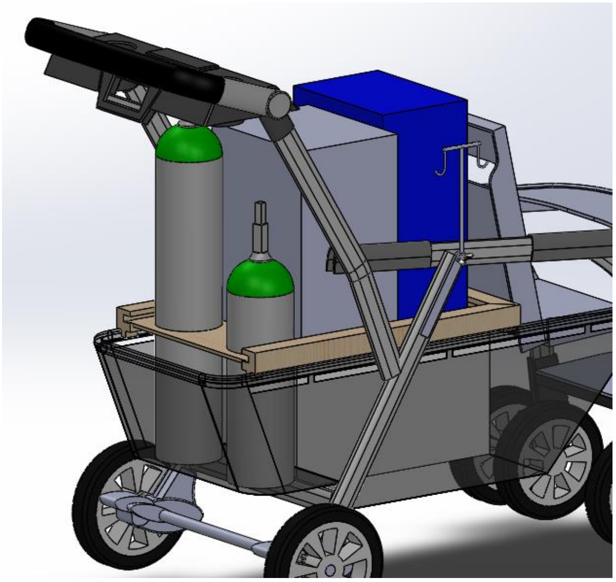

Figure 15: Proposed Tank Storage Layout

5.9 Preliminary Bill of Materials

The project's preliminary Bill of Materials is shown in Table 4. This is a basic cost estimate of the main parts and materials that will be required in the stroller modifications.

Table 4: Preliminary Bill of Materials

IV Pole						
Item	**Description**	**Use**	**Quantity**	**Source**	**Price/unit**	**Total Cost**
1/4" Shaft	stainless steel 440C, 18"	raw material for pole	2	McMaster	29.95	59.90
1/4" bar	.25"x.75"x24" Stainless steel 304	raw material for base	1	McMaster	12.48	12.48
1/4"-20 Wing Nut	5 pack 316 Stainless steel	raw material for base	1	McMaster	6.76	6.76
					Subtotal	79.14
Foot Rest						
Item	**Description**	**Use**	**Quantity**	**Source**	**Price/unit**	**Total Cost**
Tee Hinge	2" width, steel		2	Grainger	2.97	5.94
					Subtotal	5.94
Shelving						
Item	**Description**	**Use**	**Quantity**	**Source**	**Price/unit**	**Total Cost**
Drawer sliders	18", pack of 2	rail for removable shelves	2	Home depot	6.48	12.96
					Subtotal	12.96
Oxygen Tank						
Item	**Description**	**Use**	**Quantity**	**Source**	**Price/unit**	**Total Cost**
Aluminum Plate	1' x 6' 6061 Aluminum	Oxygen tank base	1	McMaster	12.28	12.28
PVC Pipe	6" x 5' White PVC Pipe	Oxygen tank tube	1	McMaster	47.43	47.43
					Subtotal	59.71
Modelling/Prototyping						
Item	**Description**	**Use**	**Quantity**	**Source**	**Price/unit**	**Total Cost**
Cable Ties	11", 40 lb tensile, .14" width	temporary fastening	2	Grainger	7.92	15.84
1/4 Plywood	4' x 8' Sandcastle	shelf, footrest, tray	2	Home depot	19.92	39.84
1/4"-20 Thin Hex Nuts	100 pack Low Carbon Zinc Plated	Fastener for attachments	1	Grainger	4.82	4.82
1/4"-20 Hex Head Screws	25 pack 7/8" 316 Stainless Steel	Fastener for attachments	1	Grainger	7.66	7.66
Flat Washer	25 pack fits 1/4"	Fastener for attachments	1	Grainger	4.10	4.10
					Subtotal	72.26
					Overall Total	230.01

6.0 Interfaces

The interface of each subsystem to the stroller is essential to meeting the overall system requirements. These operational boundaries are generally known, but specifics have not yet been fully determined. The IV pole will be attached to the frame in a secure position that does not hinder folding. The extended footrest will be added atop the current footrest, attached by hinges to be folded up for travel. The removable tray will be added by using the quick-connect feature built into the stroller. The connectors from either the bar or the cup holders may be used, allowing the tray to attach to the ends of the top frame bars. The recommended shelf may slide back and forth as needed on rails along the basket frame, where the back seat will have been removed. The oxygen tank storage will be accomplished by either sturdy cloth sacks or some sort of cup holder-like addition attached to the shelf or frame.

7.0 Concept of Operations

I. Preparation
   a. The stroller is removed from the trunk of Christina's car.
   b. The stroller is unfolded and expanded.
   c. The oxygen tank(s) are stored. (Whether one or both tanks are stored depends on the duration that the stroller will be used.)
   d. Ryan is strapped into his seat.
   e. The vent, suction, and emergency bags are stored.
   f. If needed, the feeding bag and pump are stored.

II. Routine usage
   a. The stroller is pushed across flat surfaces like sidewalks and indoor floors.
   b. The stroller is pushed up and down ramps, like handicapped-accessible ramps outside buildings.
   c. The stroller is pushed through narrow hallways, doorways, and around tight corners.
   d. The stroller is stopped and locked into place when Ryan needs to be cared for.
   e. Stored items are accessed at a moment's notice to care for Ryan.

III. Wrap-up
   a. If used, the feeding bag and pump are removed first.
   b. The vent, suction, and emergency bags are removed.
   c. Ryan is removed from his restraints and the seat.
   d. The oxygen tank(s) are removed.
   e. The stroller is folded and compacted down.
   f. The stroller is stored in the trunk of Christina's car.

The new model will operate in similar ways and environments. It will most likely be loaded with all the equipment first, both into the main storage basket and the designed storage elements that will be added. Then Ryan will be loaded into his seat. Routine usage for the new model will be the same as the current model: rolling across flat surfaces and ramps, braking in place, fitting through small doors and halls, and containing all the materials for easy access. After use, like the original model, it will be folded and stored in Christina's car. The added subsystems must not add too many additional steps to the stroller's operation, or hinder its ease of folding or storage.

8.0 Validate and Verify

In order to test the storage capacity (System Requirement I) of the stroller, cardboard and poster board mock-ups of all the equipment were created to test if the storage areas were sufficient. These mock-ups are imperfect since they are rigid box representations of bags, which are in reality more pliable. After adding an additional cardboard mock-up of the shelf, there was more space created atop the shelf, plus ample space in the basket to fit all the equipment.

The stroller has been tested for maneuverability (System Requirement II) simply by the group's day-to-day use. It has been taken from the workroom locker to various meeting places and moved through small areas, through doors of varying sizes, and in other situations representative of its everyday use by Christina and Ryan.

During a visit to Christina's house, the unmodified Chicco stroller was folded and put into the trunk of her Honda Odyssey, pictured in Figure 16a. The stroller fit easily, with extra room in the trunk (System Requirement III). We will also design all additions and modifications such that they will not exceed the trunk space. The stability and comfort (System Requirement IV) of the new stroller were also tested during this visit. After fastening Ryan into his seat as shown in Figure 16b, it was found that the stroller generally met these requirements.

Figure 16 (a, b): Cortina Stroller in trunk and with Ryan

However, to allow for two more years of growth, the seat belt thong will need to be moved forward and the footrest further extended. Once these modifications have been made, the final stroller design will undergo both software-based and physical stress tests for stability, making sure it will be able to support Ryan's predicted weight in two years.

Other requirements, including sun protection, cup holders, and forward-facing seats, are already met by the stroller's initial design and will not need to be tested.

9.0 Risk Management

This project has a certain amount of risk involved, primarily safety concerns associated with making modifications. Because the stroller is being made for a child, there is a safety risk. Removing or modifying certain components of the device could lead to compromised structural integrity and possibly failure. However, with careful analysis of the structure, and well-designed and implemented modifications, these risks will be effectively managed. Before the final review, we will also make sure that our design satisfies existing ADA and CPSC standards for strollers. Personal liability forms and institutional review boards may also be pursued. Table 5 shows the most probable risks and corresponding mitigation measures.

Table 5: Risk Management

Risk	Level	Risk Expectation	Risk Type	Mitigation
Extremity pinching	1	Likelihood: Low Consequence: Low	Safety	Proper operation training
Frame torsion	2	Likelihood: Low Consequence: High	Structural	Stress tests, FEA
Occupant falling out	3	Likelihood: Moderate Consequence: High	Safety	Child restraints
Basket failure	4	Likelihood: Moderate Consequence: High	Structural	Load distribution to the frame

Risk Level 1: Non-critical- If this risk occurs, the primary design goal can still be achieved, with minimal or temporary discomfort.
Risk Level 2: Moderate- If this risk occurs, the primary design goal is still upheld, but the occupant and/or user may have temporary injury.
Risk Level 3: Semi-critical- If this risk occurs, the primary design goal has primarily failed, but may be partly recoverable. The user and/or occupant may have sustained injuries.
Risk Level 4: Critical- If this risk occurs, the primary design goal has failed and/or the user/occupant may have sustained severe injuries.

10.0 Technical Resource Budget Tracking

This project includes few limitations on technical resources. No parts of the stroller are powered or fueled, nor are there any electrical or memory requirements involved. The primary limitations are on the weight and volume of the device. Its weight budget should not be much greater than the base weight of the current stroller model (Graco Ready2Grow) at 33 pounds. For comparison, the base weight of the Chicco Cortina is 29.5 pounds. The final weight of this stroller will be decreased by the removal of the back seat, but increased by any subsystems and other components added.

To satisfy the volume requirements, the device must ultimately fit into the trunk of Christina's car when folded. During a trip to Christina's house, it was found that the Chicco Cortina Together left about five (when measured from the wheel's edge) or ten inches of space in the trunk. As long as any additions do not exceed this space, the volume requirement will be satisfied.

11.0 Configuration Management and Documentation

Photos of equipment, bags, the house, and their dimensions were taken at meetings with Christina and shared with the team through the organization website Basecamp. This site was also used to divide up the work and assign various tasks to group members throughout the design process. The SolidWorks CAD files were managed using a shared Google Drive folder, so that all group members could check out and modify shared assembly files. Files for the report and presentation (Google Docs and Google Slides) were also managed through the shared folder, where all members could simultaneously modify and collaborate on the documents.

12.0 Project Management

The total financial budget of this project was initially estimated to be around one thousand dollars. However, since Chicco sent a stroller at no charge, this substantially reduced the expected cost of the project. Now more of the budget can be dedicated to the other expected costs, which may include the purchase of a new high chair (Appendix A), and also materials and manufacturing costs for the new stroller parts.

The group still has many milestones to reach by the end-of-semester design review. In order to allow the required space for additional storage, the stroller's back seat and footrest will be removed. A full, comprehensive design and dimensioned CAD drawings will be completed for all added components and parts. The product hierarchy, bill of materials, and detailed budget will be finalized. And of course, the requirements and standards for strollers and handicapped devices will be fully investigated and applied to the final design. These steps follow a systems engineering design process according to the vee chart model. Figure 17 shows the Gantt chart, a project management timeline for completed and upcoming phases of the design process.

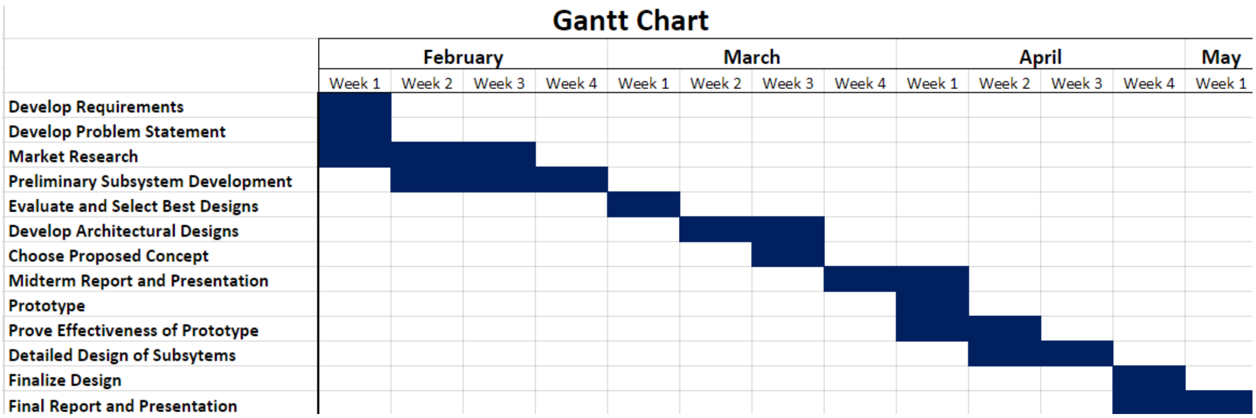

Figure 17: Gantt Chart

13.0 Conclusions

The team has concluded that the recommended architectural design will satisfy all system requirements while staying within budget. Most notably, this design will easily maneuver through rooms, hallways, and doorways, accommodate two years of Ryan's growth, and provide ample space for medical equipment while maintaining unobstructed, easy access to bags and other equipment in the basket. The IV pole will provide a designated location for Ryan's feeding bag. The removable tray and extended footrest will provide extra benefit, safety, and comfort for Ryan. With all its modifications, the stroller will still fold easily to fit within Christina's car. All of the client's needs shall be met or exceeded with the final system design.

The next step in the team's design process is creating accurately-sized prototypes of all subsystems and visiting Christina's house again to test the prototyped stroller for fit and functionality. Once this is complete, subsystems-level requirements, architectures, and concepts of operation, including interfacing, will be verified, and a plan made for final system verification and validation. According to the vee chart, these steps will complete the preliminary design phase and progress to final detailed design for each subsystem. With fully dimensioned SolidWorks drawings for each part and component, the team's system design will be finalized, verified and validated, and presented in a Critical Design Review (CDR) at the end of this semester. Fabrication will begin next semester.

Appendix A: High Chair

In addition to the stroller, Christina may be in need of a better, more stable high chair. Her current setup at home consists of either a booster seat on top of a regular chair or a smaller stroller with its wheels locked. The booster seat is at risk of tipping over when Ryan rocks backward, and the stroller is far too bulky and cumbersome. The new high chair would also require a table large enough to accommodate Ryan's rehabilitation activities. The high chair is currently a small side project that is much more basic than the stroller.

For the high chair, the mission objective is to provide a chair that is stable against rocking, mobile, and provides adequate table space for rehabilitation activities.

System Requirements

I. The device shall eliminate the risk of the child rocking or tipping over.
   a. The wheels shall have a locking system for stabilization.
II. The device shall accommodate two years of growth from the child.
   a. The device shall support the child's weight for two years of growth.
   b. The device's height shall be adjustable.
III. The device shall include a large removable tray for rehabilitation and other activities.
IV. The device's dimensions shall be compatible with the house dimensions and kitchen counter height.
V. The device shall be easily foldable for storage.
VI. The device shall be easily transportable by rolling, while in use or folded.

Like the stroller, for the high chair portion of the project, the first question asked was whether to build and design a brand new device or to modify an existing model. Different kinds of chairs were researched including: wooden restaurant chairs, plastic molded chairs, and the more commonly used folding frame chairs. Like the stroller, the decision was made to modify an existing model.

The main modification that might be needed for the high chair is additional stabilization against Ryan rocking in the seat. Multiple concept designs were made for stabilization attachments. One of the concepts, an added plate for stabilization, is shown below in Figure 18.

Figure 18: High Chair Stabilization Concept

However, since most commercial high chairs are already designed to be very stable, additional devices may not be needed. Calculations were done that solved for the force needed to tip the chair about point O for a restaurant-style highchair. Those values were used to determine the factor of safety. It was found it to be 1.42. The free body diagram associated with these calculations is shown below in Figure 19.

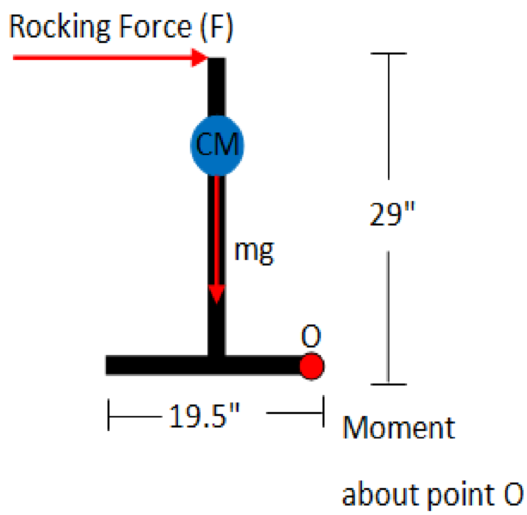

Figure 19: High Chair Proof of Safety