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The Design and Fabrication of an Upright Collapsible Transport System for Pushing Children

Collapsible Kid Cruiser™

Zachary Boorman, Richard Freitas, Kristie Kordana, Adam Stanley
School of Engineering Computing & Construction Management
Roger Williams University
Bristol, RI
zboorman086@g.rwu.edu, rfreitas115@g.rwu.edu, kkordana842@g.rwu.edu, astanley745@g.rwu.edu

Abstract— **There are currently no products on the consumer market that allow a parent or guardian to push a child between the ages of 4 to 10 in an upright or standing position. The ideal design for such a product would be a device that is collapsible for easy transport, can support a load of at least 250 lbs., weigh less than 8 lbs., have a low manufacturing cost of less than $25 per unit at full scale manufacturing, have adjustable settings to accommodate a wide age range of riders, and be both visually and ergonomically appealing for the rider and user. When collapsed, the device should fit in a backpack style carrying case. Therefore, the ultimate goal of this multidisciplinary capstone engineering project is to acquire a patent for a device that meets the aforementioned requirements and develop a fully functional prototype. Numerous design options were explored and conceptualized with the preliminary design emerging from a hand cart concept that was chosen specifically for its collapsing wheel system. This project was undertaken as a requirement of a six credit, multidisciplinary senior design project in engineering at Roger Williams University.**

Keywords—upright; child; transportation; collapsible; kid; cruiser

I. Introduction

The upright child transportation system is a device for children ages of four to ten. By conducting research, the task was to build a device that is inexpensive, safe and visually appealing to both children and their parents. Design requirements included the ability for the device to collapse and fit into a carrying case that is lightweight and comfortable. The device should hold 250 pounds and assemble in less than 30 seconds; manufacturing cost should be less than 25 dollars, and the device has to be safe and ergonomic for both the user and children riding on the device. The motivation for this product was to provide older children an alternative to walking during travel at amusement parks, outdoor outings and family trips.

As a first step in the design process, a patent search for devices that were similar to the product was undertaken. Products such as scooters, strollers, handcarts, wagons, wheel chairs and skateboards were investigated. Following the patent search, a brainstorm session was completed for the design of the new product. After evaluating the strengths and weaknesses of each alternative, each was analyzed and contributed to the final design. While building and re-engineering the preliminary concept for the prototype, more research was undertaken to identify an appropriate name for the device. Safety regulations were researched, a schedule was constructed for milestones and deliverables as well as when focus groups would be conducted for testing the product. A carrying case was designed and manufactured using the chosen colors of blue and yellow.

The product called "Collapsible Kid Cruiser™," consists of five different subsystems. The subsystems include the standing area for the child (base and wheels), the steering system for the adult, child safety, pushing system for the adult and containment.

As a multidisciplinary team of engineers, the team has worked together to accomplish the ultimate goal of developing an upright collapsible child transport system for pushing children. The team is somewhat different from most multidisciplinary teams, in that each member has a technical background in mechanical engineering but has interests and experiences in divergent areas of the field. The team's design philosophy involves working collectively suggesting ideas that could be implemented into the design instead of having each member work exclusively on a separate subsystem. Furthermore, one member has responsibility for project management and planning to keep the team organized and on track while another brings his experience with fabrication to construction and device development. The final two members contribute an ability to conceptualize subsystem integration while the last brings her experience with computer-aided design to the optimization and analysis of the design.

II. Research

A. Literature Search

The primary consideration driving design for the child transportation system is safety. ASTM F833-13 "Standard Consumer Safety Performance Specification for Carriages and Strollers" defines a stroller as a wheeled vehicle used to transport children usually from infancy to 36 months of age. The product is designed for children from ages 4 to 10 and many of the safety specifications for strollers are implemented in the design of the system. For example, ASTM F833 states, "latching mechanisms must resist unintentional folding when a 45 pound force is applied five times in an attempt to fold the product without the releasing a latch [1]." It is important to assure that none of the components collapse unexpectedly and potentially injure the child or adult pushing the Cruiser. Another concern is the weight of the system because the adult will be carrying the system on his/her back when not in use. Studies show that most physicians suggest that a backpack weigh no more than 15-20% [2] of a person's body weight.

B. Patent Search

The following table consists of the patent name and number of the patents researched.

Table 1: Patent name and number of the patents researched

Patent Title	Patent Number
Backpack Convertible to a Baby Stroller	US 8, 020,879
Carriage Device	4,659,096
Cart for Children	EP 1122148 A1
Collapsible Child's Carrier and Seat	2,587,688
Collapsible Luggage Carrier	3,400,942
Collapsible Stroller Backpack	US 2008/0042379
Collapsible Stroller Frame	US 8,172,254 B2
Collapsible Stroller	US 6,533,310 B2
Collapsible Stroller	US 7,163,228 B2
Collapsible Stroller	US 8,500,152 B2
Convertible Stroller and Backpack Infant Carrier	Des. 357,438
Flat Platform Cart With Collapsible Casters	US 7,784,816 B2
Foldable Handcart	US 8,465,029 B2
Foldable Stroller Frame With an Auto-Extending Wheel Distance Adjustment	US 8,496,263 B2
Foldable Stroller	US 6,814,368
Foldable Stroller	US 8,360,461 B2
Folding Baby Stroller	US 8,308,391 B2
Folding Child Stroller and Frame Carrier	6,155,579
Folding Wagon With Seats	US 8,388,015 B2
Four Wheeled Hand Truck	4,274,644
Tricycle With Geared Auxiliary Steering Mechanism	US 6,840,527 B1

C. Evaluation of Competition

The Collapsible Kid Cruiser™ does have some competitors that meet similar needs. Some products that are already on the market are strollers, scooters, wheel chairs and skateboards. The prototype completed by our team is similar in some aspects to all of these products. Like the stroller, the Collapsible Kid Cruiser™ has four wheels and a handle bar that pushes from the back. A scooter and the skate board allows the child to stand upright, however with the Collapsible Kid Cruiser™ the child is pushed by a person instead of having the child use his or her leg to push off.

The most similar product to the Collapsible Kid Cruiser™ is a stroller. Both the Cruiser and a stroller carry a child that is pushed or pulled by an adult. They both have four wheels (some cases strollers have 3 wheels). Also, they both are safe and foldable. The differences between the two products are what make the Collapsible Kid Cruiser™ a unique item. The Collapsible Kid Cruiser™ has the child standing and holding on to a safety mechanism instead of sitting. Some strollers have this added feature in their design, however the platform for the child is small and confining, while the platform for the Collapsible Kid Cruiser™ is large and fits a child comfortably.

Next is the collapsible process for each. A stroller is limited to how much it can fold as well as the fact that it is uncomfortable to carry because of its bulk. The Collapsible Kid Cruiser™ folds up into a backpack size in less than 30 seconds. This allows the adult to carry the Collapsible Kid Cruiser™ with ease as well as in a reduced form that fits in small places.

Lastly, strollers are for children of young ages ranging from 1 to 5 years old. The Collapsible Kid Cruiser™ is targeted to children that are between 4 and 10 years old providing a transportation solution for a new consumer group. Because the range of ages varies greatly and children grow at different rates, the Collapsible Kid Cruiser™ is flexible because the safety system telescopes to different heights.

III. Analysis

Figure 1, a radar chart comparison of competitors is helpful to compare different products that are similar to the prototype. A radar chart was completed to determine how the Collapsible Kid Cruiser™ is superior to and as suitable as products that are presently on the market. According to the chart, the Collapsible Kid Cruiser™ possesses features of all of the products currently on the market. Therefore the final product design attempts to combine all of the strengths of competitor products as well as eliminate some of the weaknesses.

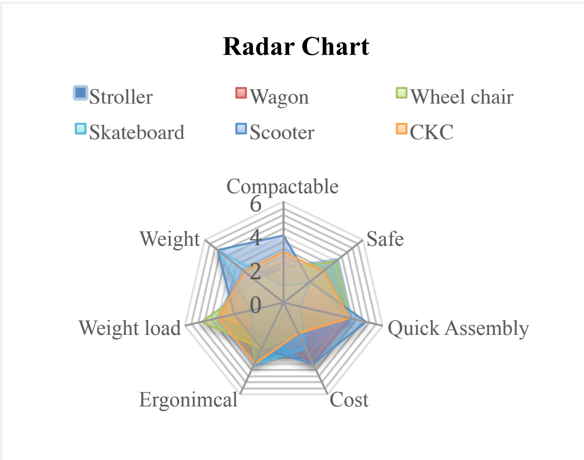

Figure 1: The radar chart compares different competitor specifications with the prototype.

IV. Specifications Definition

The client's needs for this product are to have a strong, sturdy, and affordable system that can be used to transport their child safely and can easily be carried when not in use. Safety is the main concern while designing and building this product because failure of the product could cause injury to the child riding it or the person pushing it. The first design specification was that the transportation system has to be able to withstand a 250-pound load to ensure the system will not buckle while there is a child on it. The next standard was that the weight of the system should not exceed the goal of 8-pounds, so that the person carrying the product will not be strained when holding it. This specification proved to be difficult because the materials that are used in the system, e.g. aluminum, plastic, steel, can be heavy and the weight increases as more material is added to the system. Another specification was the system should collapse to the size of a standard backpack so it is not awkward to carry on a person's back. The final specification was that the product should cost only $25 to manufacture. This is to make the product inexpensive to mass produce and affordable for the consumer.

V. Discussion of Alternative Design Solutions

Even among the best designers and engineers in the industry, the first design concept is almost never the perfect solution to the requirements at hand. The design is refined and grows as the problem is revisited throughout the span of the project. A major portion of the process of creating a design is the development and dismissal of alternative concepts and ideas. Developing several conceptualizations of a design can help further the understanding of the requirements of the design. Having several different, fully developed concepts also accentuates the functionality or practicality of the subsystems of the overall design. In the event of a complication arising with a particular subsystem, having alternative designs is advantageous. These alternatives can help work around the problem by simply implementing a more practical alternative from a different design rather than discarding the entire design. It is important to explore all of the possible avenues before deciding on the optimal design.

The problem statement for this design project only gave requirements based on capabilities of the device and did not specify the means of meeting these requirements which left the concept almost completely open for development in any direction. At first, the natural reaction was to apply the requirements to devices that already exist that perform similar tasks to the object of the design such as a stroller or a wagon. However, after defining the features and functions that set the design apart from the preexisting products, the possibilities emerged and each member of the team put the preliminary designs on paper. It is clear that each member had a different interpretation of the problem statement and ideas for the means of solving the problem. This is one of the great advantages of working on a multidisciplinary team because of the wide range of ideas that emerge which offer more solutions to work with allowing the best solution possible. Figures 2-6 below show the preliminary designs.

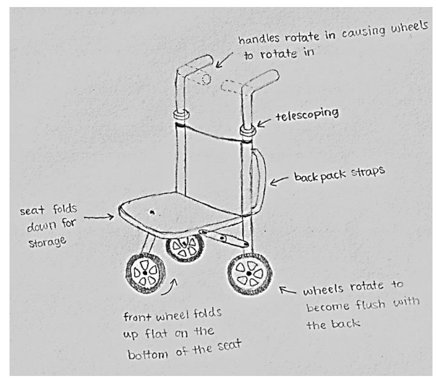

Figure 2: This figure shows a preliminary design concept where the child would be in a seated position while the parent would push using the handles from behind. While the device is not in use, it folds in several different ways to become one flush surface to be worn as a backpack.

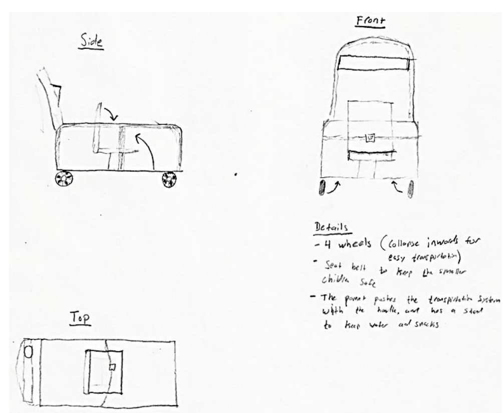

Figure 3: This concept employs the idea of a wagon except instead of the parent towing the device from the front, it would be pushed from behind and there would be a seat within the wagon for the child to sit on. The wheels would fold up to the underside of the device, the seat would fold down and the entire platform would fold up to the handles.

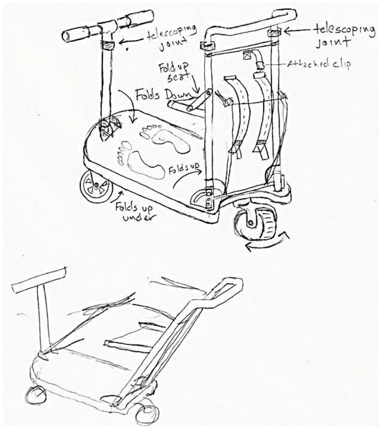

Figure 4: This preliminary design has 3 wheels, one of which is located in the back of the device that articulates, a folding seat, telescoping handle for the parent to push with, and a folding handle for the rider to hold on to. Like the other designs, the base folds up to the handles and can be worn as a backpack.

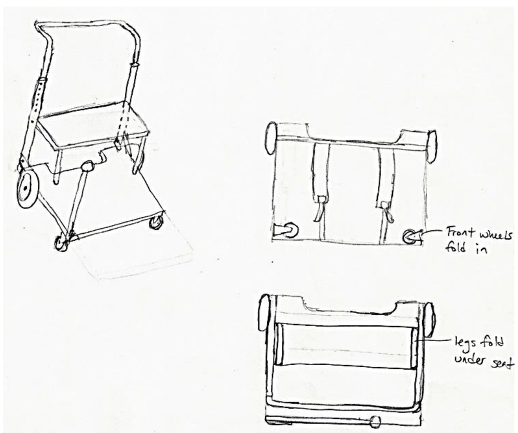

Figure 5: This concept has four wheels, a folding seat, a folding foot platform, and a telescoping handle. The parent would push from behind while the rider sits facing forward. The two front wheels would articulate for easy steering.

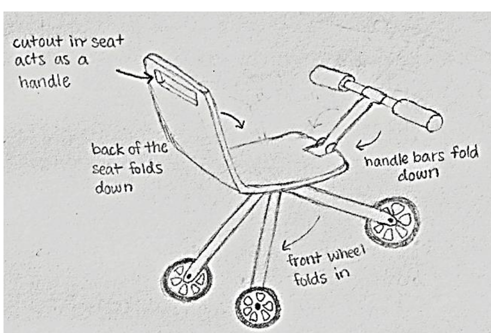

Figure 6: This concept is much different from the rest in the sense that it more resembles a rolling desk chair. It has 3 wheels that all fold to be flat and the seat folds forward. It has a handle that would go between the rider's legs and a handle attached to the back of the seat.

After identifying all of the preliminary designs, there was no definitive way to decide which design concept was best suited as a starting point. Since there were noticeable advantages and disadvantages to each design, the process involved identifying the commonalities of each design that would be included in the final design. For instance, the possible systems for steering were using articulating wheels, having the steering capabilities solely with the parent, having the steering capabilities solely with the rider, a combination of the two where both the handle for the rider and adult would move in synchronization, and the last option was using a tilting ball steering system as seen in the Dyson vacuums. After all of the subsystems were defined with the possible solutions that could be implemented in the design, existing products were explored to identify components that could be used in a prototype or as a starting point to build off of.

VI. Design for the Collapsible Kid Cruiser™

The purpose of the current prototype was to define the subsystems that would ultimately be incorporated into the final design of the Collapsible Kid Cruiser™. The first prototype was developed through the process of re-engineering. Off the shelf parts were purchased and implemented into the prototype. The wheels, base, and safety subsystems were developed using off the shelf parts, while the containment and the pushing subsystems were created from scratch.

VII. Cost Analysis

Table 2 shows the cost of the components for the first prototype as well as the costs that will be incurred as the project moves forward. The numbers in red above are the costs that will be covered by the project client. The prototype costs roughly $119.00 to construct.

To assemble the current prototype, various parts were purchased through Lowes, ACE hardware, and Jo-Ann Fabrics. The total cost of the prototype without tax is $119.34. A list of the Bill of Materials can be found in Table 3.

Table 2: Cost Analysis

Investment	Cost
Flatform Hand Truck	$70.00
Canvas	$11.00
Nuts and Bolts	$8.00
Epoxy	$2.00
PVC tubing and joints	$20.00
Paint	$6.00
Safety Standards Manual	$60.00
Trademark	$325.00
Provisional Patent	$199.00
Total	$701.00

Table 3: Bill Of Materials

Bill of Materials					
QTY	SUPPLIER	ITEM #	DESCRIPTION	UNIT PRICE	TOTAL
1	LOWES	212600	MAGNA CART Aluminum Folding Hand Truck	$74.99	$74.99
8	ACE Hardware	800	Miscellaneous Fasteners	$0.52	$4.16
1	ACE Hardware	12762	Glue Epoxy PC7 20Z	$6.99	$6.99
3	ACE Hardware	43136	TEE 1/2" SXSXS SCH40	$0.49	$1.47
2	ACE Hardware	43122	ELBOW 90 1/2" SCH40	$0.39	$0.78
2	ACE Hardware	43128	ELBOW 45 1/2" SXS SCH40	$0.99	$1.98
1	ACE Hardware	44875	PIPE SCH40 1/2"X10'P END	$2.99	$2.99
1	ACE Hardware	49088	CEMENT PVC 40Z	$3.99	$3.99
8	ACE Hardware	800	Misc Fasteners	$0.68	$5.44
1	ACE Hardware	44894	TEE 90PVC 40 3/4X3/4X1/2	$0.99	$0.99
2	ACE Hardware	44848	PLUG SCH40 PVC 3/4" SLIP	$1.29	$2.58
2	ACE Hardware	44847	SCH40 PVC 1/2" SLIP	$0.99	$1.98
1	Jo-Ann Fabric		Assorted Fabrics	$11.00	$11.00
				Total Price:	$119.34

VIII. Detailed Prototype Design

The working prototype was developed by re-engineering the Flatform Truck™, by WelCom Products Incorporated. The Flatform Truck™ was chosen for its collapsible wheel system and compact design. It can hold a maximum load of 300 pounds, which meets the test load requirement for the Collapsible Kid Cruiser™.

The wheels and the base were the first subsystems to consider. The collapsible wheel system of the Flatform Truck™ was implemented into the current design along with the base. The base was reduced in size by 4 and 7/8 inches, which also changed the wheel system. The collapsible wheel system is shown below. The collapsible wheel system also had to be reduced in size to fit in the new base of the prototype.

Figure 7: Collapsible Wheel System

The next subsystem implemented into the prototype was the pushing system. The handles on the original device were to be used, but required modification to make the design ergonomic for the pusher. The handle bar was cut in half so that the handle turned into two separate handles as shown below. Each handle was drilled to allow for height adjustment.

Figure 8: Modified handles

To make the pushing subsystem more ergonomic, ideas were brainstormed for ways in which the handle system could be extended past its original ninety-degree angle. It was originally thought that the gears used in the release mechanism would allow for an extended angle if the gears were switched around. This in fact did not work because the ninety-degree angle the handles made with the base was not dependent on the gears. The gears only permitted the wheels on the device to collapse when the handle was retracted. New parts would have to be custom designed and machined to allow for the extended angle. These new parts would be expensive and time consuming to produce for the current prototype, so the idea had to be discarded. The decision to discard the idea lead to the development of a new pushing and safety subsystem for the child riding the device.

The new safety system incorporated the existing handles. Only, new adjustment holes had to be drilled into the handles so that the handles could be turned to face the opposite direction. With this alteration, the handles were now a safety design feature that ensured the safety of the child standing on the Collapsible Kid Cruiser™.

For the pushing subsystem, ½ inch PVC tubing was used to create an ergonomic handle that extended more than ninety-degrees. The PVC handle is shown below.

Figure 9: PVC pushing system

It was originally thought that the new pushing system would be placed near the front of the base next to the articulating wheels, but the complexity of the design didn't leave much room for an attachment at the front. So, the handle was attached to the sides of the base, near the back of the device. Two PVC T-joints were drilled and attached to the sides of the device by screws in order to attach the pushing handle and lock it in place. Near the base of the pushing handle, small holes were drilled which would allow for the T-joint cap to lock the pushing system in place once placed into the T-joint on the base of the Collapsible Kid Cruiser™. A SolidWorks rendering of the prototype and the actual prototype is shown below.

Figure 10: SolidWorks Rendering

Figure 11: Actual Prototype

At this time, the device was noticeably tipping toward the front if slight weight was added between the front of the device and the front wheels. To address this issue, the articulating wheels were switched to the back of the device stabilizing it.

The last subsystem was the containment of the device. The containment was designed to transform the device into a backpack form that could be worn by the user. The backpack was sewed to the safety handles on the front of the device. When the device is closed, the backpack wraps around the device containing it so that it can be worn as a backpack. The plans for the containment subsystem are shown below. When the device is in use, the backpack is wrapped around the front of the device creating a pouch to hold various objects. The finalized containment backpack can be seen below.

Figure 12: Actual Backpack Containment

IX. Engineering Analysis

Finite element analysis was undertaken using SolidWorks. A SolidWorks model with loading conditions is presented below. A distributed load of 250 pounds was applied to two 4" x 8" areas to simulate a 250 pound person standing on the Collapsible Kid Cruiser™. A 250-pound test load was used considering the device had to test up to 250 pounds.

In addition to finite element analysis, the current prototype was tested to hold 260 pounds. More weight could have been added, but for the sole purpose of having a working prototype, weight was not added until the failure of the device. The prototype is safe, but other considerations need to be taken into account to ensure the safety of a child. One important consideration that will be addressed at a later date is testing according to the safety requirements of child carriers and strollers, which falls under ASTM F833-13b. The current prototype was used as a means to learn what works well and what does not. These findings will be used for the design of the final prototype.

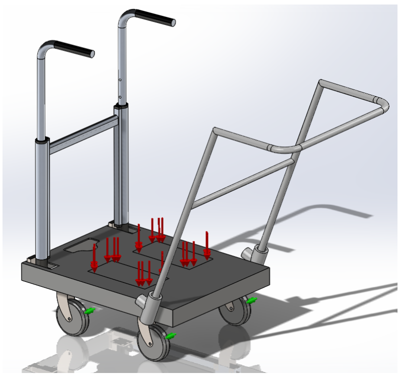

Figure 13: Finite Element Analysis

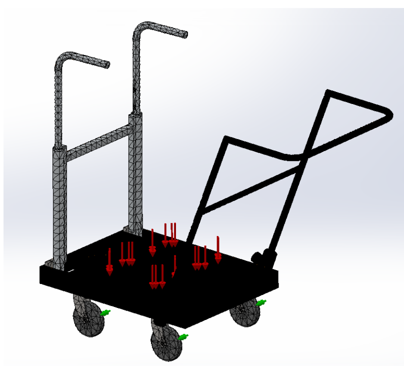

Figure 14: SolidWorks Mesh

X. Testing

The first test carried out was the "static tip test." When the prototype was almost fully complete, it seemed that it would tip forward very easy as the articulating wheels were located in the front of the prototype. To test how the prototype tipped; weights were added to a point an inch in from the front of the cart until the cart tipped forward. This process was repeated in inch increments from the front of the prototype until the prototype stopped tipping, which was when the weights were over the wheels. Below, shows how much weight caused the prototype to tip at certain points on the prototype.

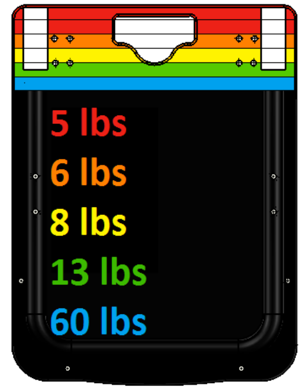

Figure 15: Articulating Wheels on the Front

After, the articulating wheels were switched to the rear of the prototype to determine if it would make it more stable. The same process was carried out where weights were added to each inch increment to see when the prototype would tip. Switching the articulating wheels to the rear did make the prototype more stable in the front, although it made it less stable overall. The prototype started to tip from the back as well as the front. Below shows how much weight caused the prototype to tip in the front and rear.

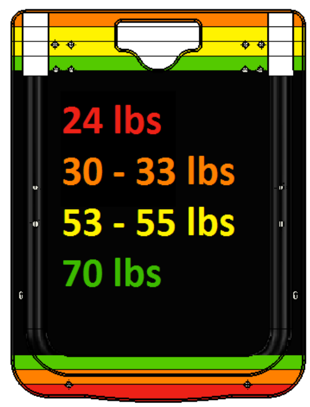

Figure 16: Articulating Wheels on the Back

After the "static tip test" was carried out, prototype was tested to determine what kind of load it could carry. Free weights from the gym were positioned on the cart where the child would be standing. Forty-five pound weights were added until the load on the cart was 180 lbs. The two twenty-five pound weights were added to make the total load 230 lbs. After, ten-pound weights were added until the load on the cart was 260 lbs. The test was stopped here because the prototype had surpassed the specification of holding a 250-pound load and the team did not want to test the prototype to failure because it was to be presented at a later date.

XI. Manufacturability

The overall goal for this project is to have the cost of manufacturing each unit be under $25 at full-scale manufacturing. To achieve this goal, all of the major manufacturing processes must be taken into consideration. The base was produced using machine milling, which will provide sufficient strength with the minimal amount of material, which will help to keep the weight of the unit as low as possible. The handles and frame are constructed from standard sized aluminum tubing, which is lightweight, strong, relatively inexpensive, and easy to bend. The wheels were purchased from a manufacturer.

XII. Conclusion

The first prototype of the Collapsible Kid Cruiser™ was almost completely successful in meeting all of the design specifications. It was able to carry the 250-pound load, and can collapse into a backpack complete with pockets. The prototype is also relatively light, although not below the goal of 8 pounds, it is light enough where it will not strain the person carrying it. The specification that was not achieved this past semester was in making an affordable product. The goal was to be able to design a product that would cost only $25 to manufacture, although, after the price of the Flatform Truck™ and all of the materials used, a total of $119.34 was spent for the semester. If this prototype went on the market, it would be sold for about $250, which is a relatively expensive device for its kind.

From the first prototype it was determined that simplicity in the design is key. The design has to be less complex to reduce the manufacturing costs and problems that may be encountered with the assembly of the device. This most likely will cause an increase in assembly time, but it is a trade-off that must be considered. The more complex the design, the more components involved, and the more limited the design is to work with. The first prototype produced tipping of the base of the device, which will ultimately lead to the correct placement of the wheels and axles to avoid tipping in the future. It was also determined that it would be helpful to incorporate a brake for the device to keep it from rolling away when it is stationary. Taking these considerations into account, a new prototype is currently under development with modified characteristics. These characteristics include the location and attachment of the wheels, axles, and handles. The handle positions need to allow a child to step onto the device while still allowing for the safety of the child. Once the new design is finalized, a SolidWorks model will be generated and finite element analysis will be undertaken. Then the iterative design process starts again.

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Zachary Boorman is a Mechanical Engineering major from Newington, Connecticut. He is attending Roger Williams University and plans to start his career as a mechanical engineer after graduation.

Richard Freitas is from Pembroke, Massachusetts. He is majoring in Mechanical Engineering with a minor in Mathematics at Roger Williams University. He plans on working in a machine shop used to manufacture products.

Kristie Kordana is from Cheshire, Massachusetts. She is majoring in Mechanical Engineering with a minor in Mathematics at Roger Williams University. She plans to attend graduate school for Biomedical Engineering.

Adam Stanley is from Litchfield, Connecticut. He is studying Mechanical Engineering at Roger Williams University and plans to begin his career in engineering design after he graduates.