ME 450
FINAL REPORT
FALL 2006

Innovative Toddler Seat Design Focusing on Ease of Installation

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TABLE OF CONTENTS

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Date: 15 December 2006

Subject: Final Design Results for Toddler Car Seat Design

DIST: Sue Gow, Mechanical Engineering Advisor

FOREWORD

There are many aspects of toddler car seats on the market today which present difficulties for the user. Mainly, these consist of the installation, adjustment, and removal of the seat. Each of these tasks is very difficult to perform when only one person is available. It is essential that the seat can be easily adjusted for changing conditions, such as the size of the child and the vehicle in which it is being used. While maintaining the safety integrity of modern car seats, our design focuses on simplifying the acts of installing the seat, adjusting the safety harnesses, and removing the seat.

INTRODUCTION

Our project focuses on a toddler car seat design which will be easy to install/adjust in any car used in today's world. This seat will have the capabilities of being either a rear-facing or front facing-seat, depending on regulations of the age and weight of the child. For example, a child is not recommended to switch to a front-facing seat until they are both 20 pounds and 1 year of age. It must be noted that our design intends to maintain a level of safety which is at or above the current safety level of toddler seats in use today.

Our contact for this project is Sue Gow, who is the Student Advisor in the Mechanical Engineering Department. Mrs. Gow has a special interest in the project in that she has a young grandson who is currently making the transition from the infant car seat to the convertible toddler seat. She has seen firsthand the problems with installing and adjusting the modern car seat, and she is a great resource for our team in terms of defining our issues which need to be addressed.

The final product of this semester is the successful and innovative design of a new method for which the toddler seat can be installed and adjusted. One of our main goals is that this design will be able to be implemented in any car that is being used on the roads today. In fact, a main problem with today's toddler seats is that certain seats can only be used in certain cars, which can present obvious problems for the user.

PRE-DESIGN FORMULATIONS

Customer Requirements

Our first meeting with Mrs. Gow gave our group valuable insight into what objectives needed to be accomplished. In order to successfully complete the tasks laid forth in the abstract, we needed to use these objectives to design our toddler seat. Because our contact was so knowledgeable about the problems with current toddler seats, we had a good start on gaining additional information. From these customer requirements, we included input from our friends and family members who are using and have used toddler seat. Lastly, we included our own opinions, but these did not have as much weight as the input from our contact and friends (customers). At the end of this process we determined our five main customer requirements to be the following:

- Easy installation/attachment into the car
- Easy removal from the car
- Easy adjustability of straps for different sized children/clothes
- High level of safety
- Minimize cost

We focused on these five requirements while determining our alpha design along with other minor requirements that were not as important.

Engineering Specifications

The first three requirements have forced our team to design several different functioning mechanisms to allow for easy installation, removal, and customization of the child seat. These requirements made our team focus on targets such as forces, dimensions, materials, material strength, and cost. Safety of the child seat will not be compromised due to the restrictions and enforcements placed on child seat systems.

Competitor products also allowed us to establish benchmarks for targets. Some targets such as size, number of attachments, and materials were kept the same while other targets such as cost, forces, and time to install were attempted to be minimized.

In terms of numbers, our engineering specifications have been formulated and they fit within our scheduled targets. Table 1 (pg. 4) depicts a numerical representation of our most prominent engineering specifications.

QFD

By combining our customer requirements and engineering specifications, we were able to create a detailed QFD to relate these, which is shown in Appendix A. Similar to getting information and feedback from our contact and sponsor, we needed to figure out what engineering specifications to focus on. Our QFD related our customer requirements to our engineering specifications and showed how they correlated. Based on the correlation, we determined our main engineering targets. These specifications are as follows:

- Geometry of toddler seat
- Force to tighten attachments to seat
- Force to tighten harness
- Time to take out of car

When designing our toddler seat, we focused on these specifications in order to design the most efficient toddler seat.

Table 1: Numerical Engineering Specifications

Engineering Specification	Quantity	Units
Number of attachments to seat	2	#
Number of attachments on harness	2	#
Force to tighten seat attachment	12.5 ± 2.5	N
Time to put seat into car (with base)	≈ 3	min
Time to take seat out of car (without base)	≈ 3	min
Weight of total assembly	20 ± 5	lbs
Size of attachment slots	2.0 ± 0.3	in

CONCEPT GENERATION

The three problems that our design aims to reduce are: 1) the force needed to securely attach the toddler seat to the car seat, 2) the hassle of detaching and reattaching the toddler seat to adjust the shoulder height of the front harness, and 3) the hassle of detaching and reattaching the toddler seat to change it from forward-facing to rear-facing.

To generate our concepts, we started by talking to our sponsor and numerous other experienced toddler seat users. Each of these people gave us great insight into the problems and nuances that the toddler seat had given them. Once we had listed each of the major problems, we started brainstorming possible solutions. Then, as a group, we broke up each of the solutions into separate categories: practical, impractical, favorable, and unfavorable. Through the use of logical thinking and Pugh Charts, we then narrowed the solutions down to three by choosing the most practical and favorable concepts.

Rejected Designs

During our concept generation, a few of our ideas were determined to be inefficient or improbable. The first rejected design dealt with a method of installing the shoulder harness bar and is depicted in Figure F.1 of Appendix F. This consisted of a pulley system in which the bar was connected to metal wires at both ends. These wires then connected to pulleys which in turn were connected to adjustment levers positioned on both sides of the toddler seat. The main drawback of this design was that the wires would not be effective in terms of lowering the bars because there would be no force mechanism to cause them to descend.

In terms of the seat design, one of our original rejected designs is shown in Figure F.2 of Appendix F. We attempted to construct a seat in which there was only one slot, as opposed to two, in which the seat belt would run through in order to fasten the car seat base to those cars which do not have the LATCH system installed. Once we decided to install the base separate from the seat, this design was rendered obsolete.

Another system which was postulated was a rail system which would be input into the vehicle, shown in Figure F.3 of Appendix F. This system would allow the user to install the toddler seat into the car into the bars, which would in turn send the seat into its desired location into the backseat. This design was determined to be improbable due to the sheer size and space that it would require.

Finally, we proposed a design in which the seat belt would have a female receptor on the side of the toddler seat on the door side. This design, shown in Figure F.4 of Appendix F, would then have a male receptor on the other side of the seat which would in turn lock into the female receptor located in the car seat. This design, however, was determined to be unsafe as the door-side part of the toddler seat would be improperly fastened to the car seat.

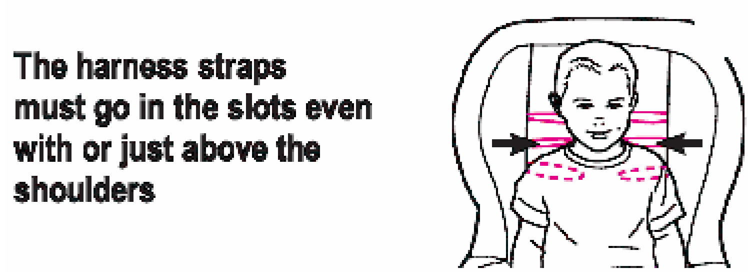
Selected Concept Descriptions

To reduce the force needed to securely attach the seat base to the car seat, our team generated the concept of a ratchet system that will be on both sides of the toddler seat. This ratchet will have the LATCH strap connected to it via a pulley system that will be tightened and loosened by a lever. The amount of force required for such actions is significantly less than that which is applied normally by the user.

Ratchet system

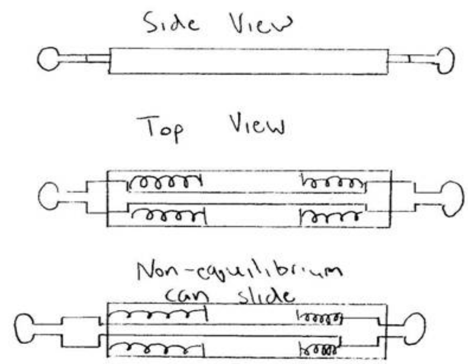
When the crank lever is pulled (in similar fashion to a socket wrench), it will tighten the straps that are attached to the car. This will make it easier for the user because, normally, the person has to get in and push on the seat before tightening the straps, which is very difficult for one person to do. However, with the ratchet system, the lever will do a large percentage of all the tightening work for the user. Also, the system will make it easier to loosen the straps, thus making it easier to take the seat out of the car. The main disadvantages of this concept are that it adds weight to seat, and it only helps cars which have the LATCH system in place.

To reduce the hassle of detaching and reattaching the toddler seat to adjust the shoulder height of the front harness, our team generated the



concept to have an adjustable bar on the back of the toddler seat that you can adjust from either side of the toddler seat. The picture below describes how the harness heights are chosen.

The bar-slider would be installed in the back of the toddler seat. It would allow the user to adjust the height of the harness straps without taking the toddler seat out of the car. When you pull one of the ends of the bar slider out, both will move to a point where they can easily slide up and down the back of the toddler seat. When the bar slider is released, it can no longer slide up and down. The main disadvantage of the bar slider is that it adds weight to the toddler seat.



To reduce the difficulty of detaching and reattaching the toddler seat from rear facing to forward facing, our team generated the idea of breaking the toddler seat system into two separate pieces. One of the pieces, the base, would stay attached to the car seat, while the original toddler seat will easily and securely attach to the seat base. This base will be able to attach to the car with either the LATCH system or the seat belt attachment system. Grooves will be milled into the base in order to allow the seat to be readjustable. A pin will then be attached to the bottom of the existing car seat, which will then fit into these grooves before securely locking the seat in place. Therefore, the toddler can now be put in the seat while the seat faces out towards the opening of the vehicle door.

This would make things much easier in a few ways. First, it would make adjusting from rear-front and front-rear facing very easy because you will not need to totally reinstall the toddler seat. Second, it will make it easier to attach the toddler seat to the seat because the seat base will be much smaller than the total seat and thus easier to work with. The main drawback of the seat base is that it will make the toddler seat heavier.

ENGINEERING DESIGN PARAMETER ANALYSIS

In order to determine the dimensions of our toddler car seat design, we used the seat given to us by the Mott Children's Hospital as a benchmark. Since each toddler seat on the market today is of a different size and shape, this decision was made arbitrarily and out of convenience. The specific dimensions of the seat can be seen in the dimensioned engineering drawing of Appendix E. The material chosen was polypropylene (PP), which is very common for toddler seats and has been proven to have the perfect balance of being lightweight, durable, and strong.

Similarly, the base design was made such that the bottom of the seat fits flush with the top of the base, regardless of whether it is front or rear-facing. The original base design of Design Review #2 was modified to allow for the seat being repositioned from rear to front facing, and vice versa. To do this, a spherical design was formulated, and the various dimensions of the base can be seen in the dimensioned engineering drawing of Appendix D. The material chosen was rigid polyvinyl chloride (PVC), mainly because of its stiffness and strength as compared to the polypropylene seat. It is essential that our base be heavier and stronger in order to allow for a secure attachment between the two parts. Table 2 lists the material properties of our base and toddler seat designs.

Table 2: Material Properties of Toddler Seat and Base

	Modulus (GPa)	Fracture Strength (MPa)	Percent Elongation (%)
Seat (PP)	0.63 ± 0.45	11.2 ± 4.8	237.5 ± 162.5
Base (PVC)	3.25 ± 0.85	45.5 ± 4.5	60.0 ± 20.0

The components of the slider-bar mechanism are detailed in Appendix C. The material chosen was aluminum because it is lightweight and strong. However, further tests will be conducted in the upcoming weeks in order to validate this decision. The spring constant was determined according to the equation, $F=kx$, to be 525 N/m, by assuming a user input force of 10 N.

In terms of the ratchet, we purchased this product from Home Depot., located on Carpenter Rd. in Ann Arbor. We then attached our existing LATCH system belt onto the ratchet, which will be displayed at the Design Expo. To determine the direction and magnitude of the force applied to tighten the LATCH, a free body diagram was constructed, as shown in Appendix B.

FINAL DESIGN DESCRIPTION

As stated before, our design consists of 3 main parts:

- Separate seat base
- Slider-bar mechanism for readjustable shoulder harness
- Ratchet system for ease of LATCH tightening

The inner workings of our design begin with the seat base. This part, composed of rigid PVC, will be attached to the car seat via the LATCH system or the seat belt. The base is installed one way, regardless if the toddler seat is rearward or forward facing. This concept greatly reduces the amount of work done by the user. Attaching the base using the seat belt is similar to the current method. However, the groove the seat belt goes through is open and the user will not have to feed the seat belt through the bulky seat. A demonstration of this can be seen in Appendix D. Using the LATCH system, the belt is attached to the ratchet used for tightening and attached to the car seat using the current method. This design is made possible because the base need only be installed in one direction. Since we do not have the proper resources to injection mold an actual size seat base, we will be manufacturing a scaled-down model in house which will be presented at the Design Expo. A scaled down version of our seat will also be modeled in order to illustrate how the seat will attach to the seat base.

The benefits of the base are significant. First, the installation need only be done once throughout the entire usage of the system, and the installation is simple due to the smaller size of the base. Once the base is installed, the car seat can be positioned in either a front or rear facing position without ever having to adjust the base or the LATCH system.

Instead of exerting a large amount of force, the LATCH belt is tightened by the ratchet system, now attached onto the bottom edge of the seat base. A demonstration of how this ratchet system works will be shown at the Design Expo. However, since the base is being modeled at the UM 3D Imaging Lab, it will not be strong enough to handle the applied load of the ratchet system. Therefore, we will manufacture a system which will simulate the LATCH system present in cars today in order to communicate to guests how are ratchet system reduces the amount of force put forth by the user to tighten it.

The ratchet system serves as a force multiplier for our system. In the past, the user was forced to awkwardly pull on the LATCH belt in order to tighten the toddler seat securely into the car. However, this same act can now be accomplished with a few simple cranks of the ratchet lever arm. The implementation of this system also looks aesthetically pleasing, as shown in the drawings of Appendix B.

The third component of our design, the slider-bar, will allow for six different positions for the shoulder harness. This is a large improvement upon our original seat, which only consists of three positions. Also, the slider-bar mechanism will allow the user to adjust the shoulder harness from either side of the seat, as opposed to having to remove the seat and tighten it from the back.

MANUFACTURING PLAN

Toddler Seat and Base Prototype

Our toddler seat and base prototype was rapid prototyped by the University of Michigan 3D Imaging lab. To reproduce this prototype, you would have to resend the 3D CAD models with the same dimensions as our CAD model to Brett Lyons (lyonsb@umich.edu). He would then send you a price quote which you would have to reply to if you agreed to the price. The instructions we followed are below:

1. Redid our CAD models so they were hollowed out which significantly reduces the cost of a rapid prototype. We mostly used the subtract method on Unigraphics NX which can be read about in Unigraphics NX help feature
2. Scaled down our model to 1/3rd its original scale. We did this because we had to reduce the size of our model so it could fit into the specifications of the printing box which are 10” x 8” x 8”
3. Converted our parts to VRML format which is required by the 3D imaging lab to rapid prototype.

4. Submitted our CAD models to Brett Lyons. To which he gave us a price quote.
5. Checked over the price quote and told Brett it was fine to go ahead and manufacture our part.

Dimensioned models of the CAD model are included in the Appendix I.

A ZPrinter 310 was used to manufacture our prototype. The printer builds prototypes a layer at a time so it can build very complex objects. Its process for rapid prototyping is explained below (from 3D Imaging Lab website, http://um3d.dc.umich.edu/):

1. For each layer, a "plow" moves powder from the feed piston to the print piston where it is spread as a thin surface layer.
2. A print head distributes or "prints" binder solution onto the loose powder layer, thereby, forming the cross-section. Where the binder is deposited, the powder is glued together. The remaining loose powder supports the part as it being printed.
3. When a layer is completed, the feed piston is elevated and the build piston is lowered slightly. A new layer of powder is spread over the previous cross-section. The process is repeated until the build is complete.
4. At the end of the process, the build piston is raised and the remaining loose powder is vacuumed away, revealing the completed part. The left-over powder is recycled and can be used for subsequent printing jobs.

Ratchet System Prototype

The ratchet system prototype we produced represents the seat base of our redesigned toddler seat attaching to the car seat. A step-by-step manufacturing plan for our ratchet system is provided below.

1. Cut a piece of ¼ inch birch to 20 inches by 20 inches using a table saw.
2. Cut a piece of ¼ inch birch to 10 inches by 20 inches using a table saw.
3. Use an angled table saw to cut the long edge of the 10x20 inch piece of birch to an angle of 25 degrees.
4. Lay the angled edge of the 10x20 piece of birch on any edge of the 20x20 piece of birch and screw them together using a screw gun and 2 inch deck screws. The two pieces of birch should now be screwed together at an angle of 165 degrees with respect to one another. These will be a wood model of the actual car seat.
5. Cut two pieces of ¼ inch birch to 8 inches by 13 inches using a table saw.
6. Clamp the two pieces of 8x13 inch birch together using a quick grip bar clamp.
7. Cut one sides of the clamped birch to 25 degrees using a table saw and protractor.
8. Trace a sketch of the model base on the top piece of clamped birch.
9. Cut out the sketch of the model base on the two clamped birch pieces so they are the same shape and size. Do this using a jig-saw. These will be the sides to the wood model of the base.
10. Cut two pieces of 1 inch pine to 4 inches by 6 inches. These will be the supports for your wood model base.

11. Hold the two sides of the wood model base in the wood model of the car seat so the back and bottom are lined up then screw the supports in-between the two sides using a screw gun and 2 inch deck screws.
12. Using a screw gun and the screws provided by rubber feet assembly set, screw on rubber feet at the four bottom corners of the model car seat.
13. Buy one square yard of moleskin and one square yard of soft polysuiting fabric.
14. Stretch the polysuiting fabric around the model around the model seat base and staple it down using an air-powered staple gun. Cut the excess fabric away.
15. Stretch the moleskin fabric around the model car seat and staple it down using an air-powered staple gun. Cut the excess fabric away.
16. Using a hand drill, drill ¼ inch holes 6 inches back and 1 inch high on both sides of the model base.
17. Attach a home depot 1" long handle ratchet strap assembly on both sides of the model base using the holes previously drilled and 2 ¼ inch nuts, 2 ¼ inch 1.5 inch long bolts, and 2 ¼ inch washers.
18. Purchase two latch system accessory straps online and bring them to college shoe repair, at State St. and William and tell them to reduce the width of the latch straps to 1 inch wide and reduce the length to 15 inches long.
19. Buy two 1.5 inch U-Bolt assemblies from home depot.
20. Using a hand drill, drill ¼ inch holes at 4, 5.5, 14.5, and 16 inches on the edge where the two birch pieces of the model seat attach.
21. Follow the instructions provided with the U-bolt assemblies to attach the U-bolts to the model seat. These U-bolts represent the latch system.

The car seat already exists and the U-bolts represent the latch system that also already exists. So to mass produce the harness attachment you would have to purchase or produce two ratchets, two revised latch straps, and two sets of nuts/bolts/washers. The labor included would be to screw the ratchets on either side of the seat base and to assemble the latch straps to the ratchet.

Harness Adjustment System Prototype

A step-by-step manufacturing plan for our harness adjustment system is provided below.

Bars:
1. Stock piece is 10"x10" plate ¼" thick of 1018 low-carbon steel.
2. Cut two 2"x10" plates from stock with band saw at 85 fpm (feet per minute).
3. Square off each side of each plate down to 1.75"x9.5" with ½" end mill (340 RPM).
4. Use band saw to get each long portion down to about 0.5" (85 fpm).
5. Finish bringing each piece to correct geometry with ½" end mill (340 RPM).
6. Center drill for pin hole on each piece with high speed drill press.
7. Drill pin hole with 1/16" drill bit on each piece with high speed drill press.

Brackets:
1. Stock piece is 10"x10" plate ¼" thick of 1018 low-carbon steel.

2. Cut two 2”x7.5” plates from stock with band saw at 85 fpm (feet per minute).
3. Square off each side of each plate down to 1.5”x7” using ½” end mill (340 RPM).
4. Mill 4 horizontal slots into each piece using ¼” end mill (340 RPM).
5. Mill vertical slot into each piece using ¼” end mill (340 RPM).
6. Drill clearance holes for L-bracket connections using ¼” drill bit (340 RPM).
7. File all edges and corners for smoothness.

L-brackets:

1. Cut two 1.5” pieces of 2”x2” mild steel L-bracket from a stock length on band saw at 90 fpm.
2. Drill clearance holes with drill press in each L-bracket using ¼” drill bit.

Base:

1. Cut 18” length from 2”x4” stock piece of pine with wood/plastics band saw.
2. Buy one square yard of moleskin fabric.
3. Stretch fabric over cut pine and staple to the wood on the bottom with a pneumatic staple gun.
4. Cut off excess fabric with scissors.
5. With an X-acto knife, cut fabric away from where screws will enter wood through L-brackets.

Assembly:

1. Slide one of the brackets over one of the bars.
2. Slide one washer, followed by a spring, followed by another washer, onto each of the bars.
3. Slide pin into pin hole on each piece.
4. Weld the two bar pieces together.
5. Grind down weld to make smooth.
6. Grind and file all edges to make smooth.
7. Attach L-brackets to brackets with 1.25” length ¼-20 bolts and nuts.
8. Screw L-brackets into wood with 1” deck screws.

Those are the complete instructions for recreating our harness adjustment system.

If the harness adjustment were to be mass produced many changes would be made. In a production setting they would be manufactured for immediate use with a toddler seat, not for display on a piece of wood. The L-brackets and base would both be unnecessary for production. The material for the brackets and bars would not have to be low-carbon steel since we believe that we over-bought in terms of strength and weight of material. A lighter material could be used to reduce weight and difficulty of manufacturing. The brackets could be molded directly into the toddler seat, if the material the seat is made from was strong enough. The bar could possibly be stamped in a manufacturing setting, removing the need for making the part in two pieces and welding them together.

TEST RESULTS

Toddler Seat and Base

Since we made a rapid prototype of our toddler seat instead of a full-scale model from industry standard materials, we were not able to do strength tests on the design. However, toddler seats on the market are made from polypropylene material and meet required safety specifications. The base design will be made from PVC, which is stronger than polypropylene, so it will also meet safety requirements. The one possible source of weakness comes from where the pin locks in the base. This concern is addressed in the discussion section on page 14.

Ratchet System

The ratchet system was created using store-bought ratchets rated at strength ratings of 400 lbs each, and the existing LATCH belt that came with our donated Evenflo toddler seat. The ratchets have a higher strength than the LATCH belt and the LATCH belt itself already meets safety specifications, so our ratchet system is validated.

Harness Adjustment System

In terms of testing the harness adjustment system, we were not able to do this because testing would only be valid once the system was integrated into a full scale toddler seat. The steel which the current model of the harness adjustment system is composed, can withstand pressures of up to 1030 psi, which is fully sufficient. However, the main testing which would need to be done is how the harness system would react with the polypropylene toddler seat during a crash. We do not have the capabilities to formulate such a test and hope that future teams will.

ENGINEERING CHANGES NOTICE (ECN)

Toddler Seat and Base

Pin Change

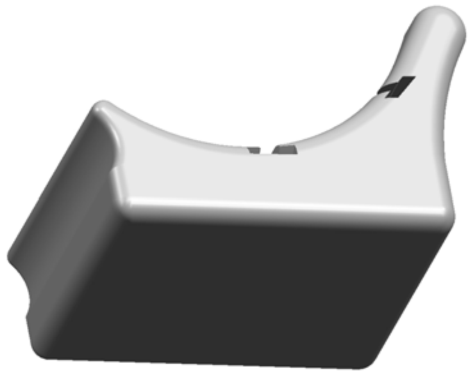
WAS:

IS:

The pin on our manufactured prototype broke off during manufacturing, and, due to time constraints, we had to do without it.

Hollow Base

WAS:



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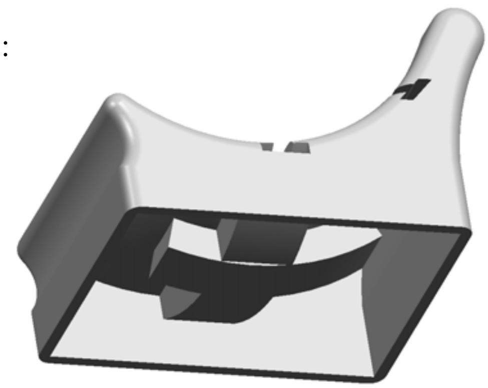
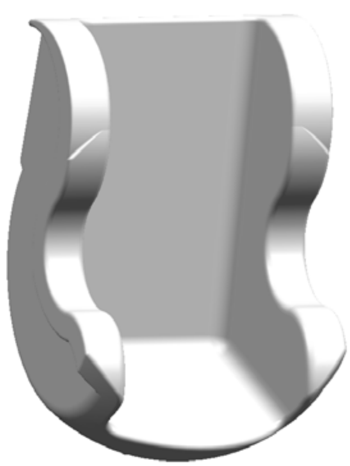


To reduce the cost of our seat base prototype, we had to hollow out our redesigned seat base CAD model.

Hollow Seat

WAS:



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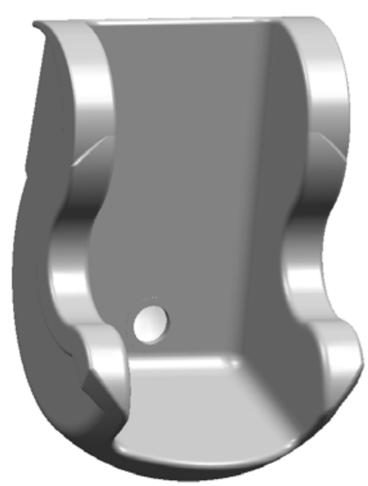


To reduce the cost of our seat base prototype we had to hollow out our redesigned toddler seat CAD model

Ratchet System

LATCH to U-bolt

WAS:  IS: 

Our first idea was to buy an actual LATCH system that is used in cars. With our budget constraints, we decided to substitute this with something less expensive and this led us to the U-bolt assembly shown above.

Strap Size

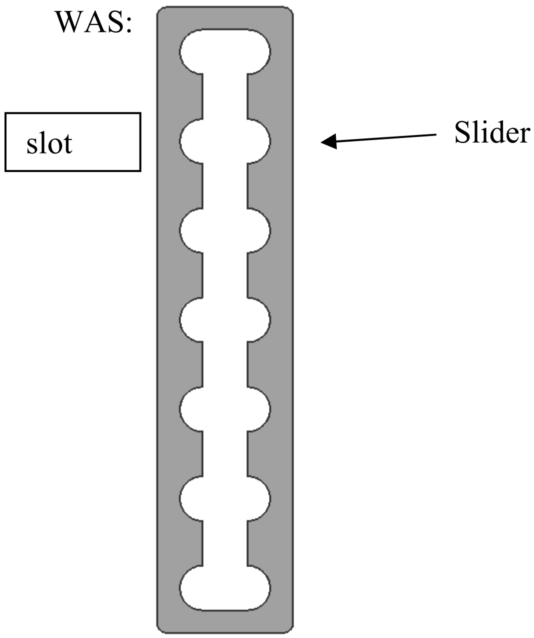
WAS:  IS: 

The original strap size didn't work as expected with the ratchets we purchased so we had to reduce their width.

Harness Adjustment System

Brackets Slot Size

WAS:



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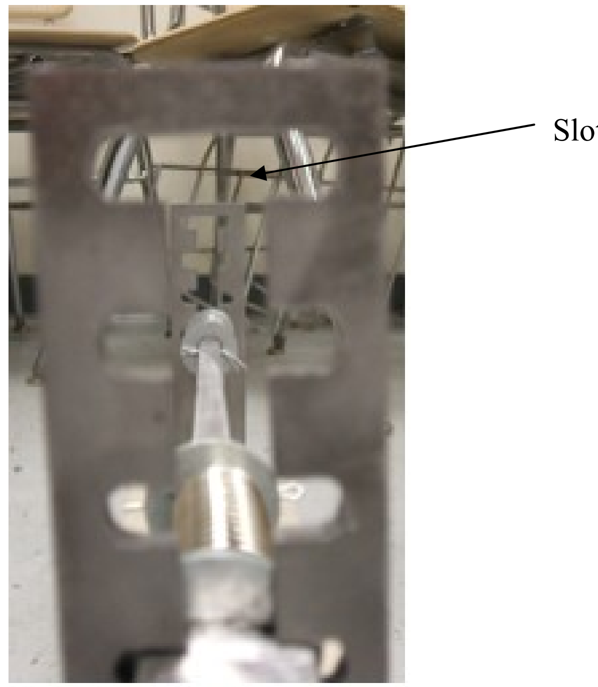
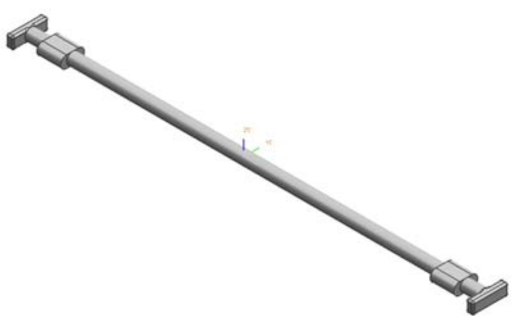


Slots were manufactured as ¼” wide instead of ½” wide as was originally planned. We also only manufactured four slots, instead of the seven in the original CAD drawing. We did this because it was just a working model and the four slots were sufficient to show the functionality of the piece. The slider slot was manufactured 0.4” wide instead of ½” wide as originally planned.

Bar

WAS:

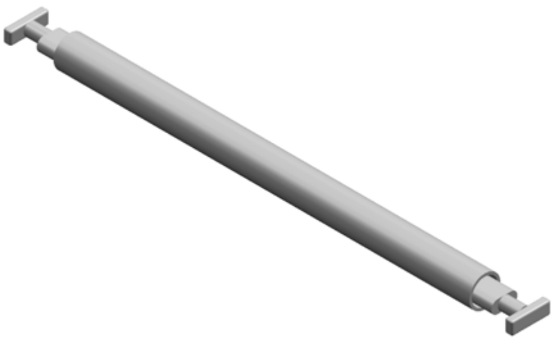


IS:

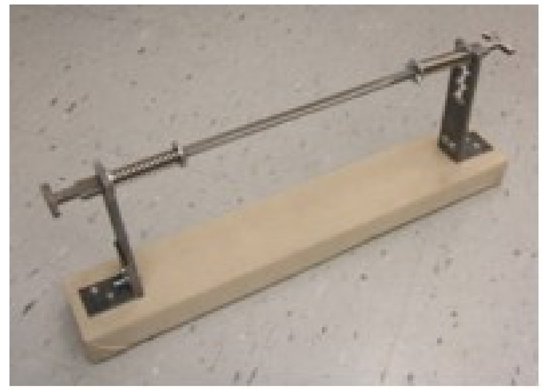
Instead of making the bar out of ½” tube, we used the same material used for the brackets, ¼” steel plate. This was much easier to manufacture since we could do it in two pieces instead of eight.

Assembly

WAS:



IS:



Instead of assembling the system with an exterior tube to hold the springs we used washers to hold pressure on the springs. This was done to make the inner workings more accessible during the design expo. If produced for consumers, a tube would be used in order to keep the dangerous springs away from fingers during use.

DISCUSSION

Overall, we were pleased with the progress we made in designing a new, innovative toddler seat. It was our goal at the beginning of the semester to manufacture a fully functioning prototype of our redesigned toddler car seat. Despite not being able complete this task, our team believes we accomplished our other goals set forth at the start of the project. Although limitations of our budget restrained us from manufacturing all designed and additional components developed throughout the semester, if interested, future groups could be able to follow through with these concepts. We are very satisfied with the models that we did manufacture and the feedback given to us by various viewers at the Design Expo left us feeling very proud about what we have accomplished.

Outcome of the Toddler Seat and Base Prototypes

The centerpiece of our table at the Design Expo was a rapid prototype of our rotating, interactive toddler seat and base. Creating a CAD model of the toddler seat on Unigraphics took a long time to complete because of the complex geometry. Additionally, it took a lot of work to reduce the cost of the scaled prototype by hollowing the CAD model. This took CAD experience which we were not familiar with at the time. Having a model of the toddler seat allowed the guest to rotate the toddler seat 360 degrees while remaining flush to the base. Rapid prototyping the toddler seat and base was a very costly endeavor which engrossed a large portion of our allotted budget.

However, the scaled model was perfect for our project because our budget did not allow for a full scale, injection molded seat.

The main weakness of this component and prototype pertains to the locking mechanism which forcefully attaches the seat base to the toddler seat. Because we were not able to manufacture the toddler seat or base using the proposed materials, it became difficult to conduct a full-scale force analysis. Our proposed plan was to have the grooves on the base lined with aluminum in order to more firmly hold the locking pin on the bottom of the toddler seat. This locking mechanism is of immense importance and must be designed more effectively in the future. Unfortunately, when the rapid prototype was being created, the preliminary designed locking pin located on the bottom of the toddler seat broke off. This did not allow users to get the full feeling of the interaction of the rotating seat and stationary base. Also, the rapid prototype of the toddler seat was fragile, so we were not able to fully test the model. Finally, because the rapid prototype was created from a plaster powder, it had a high amount of surface friction. When guests tried to rotate the base it did not give them the smooth feeling like they would experience when rotating a plastic, manufactured seat and base.

Outcome of the Ratchet System Prototype

Our working model of the ratchet system effectively and efficiently showed how the ratchet system would work on a full scale model. Because of the complexity of ratchets, we simply purchased a pair from the local Home Depot. Because it can withstand up to 400 pounds of force, it was indeed strong enough for implementation into our final design. Our working model gave guests at the design expo a chance to see how the ratchets reduced the amount of force required to install the seat. An additional positive aspect of the ratchet system is that we were able to assemble most of the model in-house, keeping the cost to a minimum. The seat base and car seat models were manufactured from wood, and the LATCH hook was imitated by attaching a U-bolt to the model of the car seat.

Because the working model was determined to be used as an example of how the ratchet system worked, rather than how the base fit in the car, we were not able to test the model in a car. Another weakness lies in that we were not able to attach a ratchet to a full scale seat base manufactured from PVC, which is due to the fact that we were not able to cover the cost of injection molding a seat base. However, it is our hope that future groups will find a way to cover this large cost and manufacture full scale working models.

Outcome of Toddler Seat and Base Prototype

The model of the harness adjustment system clearly and effectively illustrates the purpose of the redesign. It shows the user how they can simply adjust the child’s shoulder harness while still looking at the child as they are strapped into the toddler seat. This is a huge improvement which greatly reduces the biomechanical stress put on the user, and many new mothers were very impressed with this aspect at the Design Expo. It also added more adjustment levels in the same span than the amount currently on many toddler seats, which will simply introduce a more secure and safer fit for the child.

In order to withstand the forces induced from a crash, we determined that this system must be manufactured from steel. Therefore, we manufactured our prototype from steel in the University of Michigan Student Machine Shop. This turned out to be a costly error, as it was not paramount that we use steel because this is simply a model in order to convey the use and effectiveness of this implementation. Because of the strength of steel, the machining processes became very difficult and very time consuming. For example, when using the mill, we were only able to take off 0.02 inches of material during each pass.

Another area of improvement with this system lies in the ability to operate this system with one hand from either side of the seat. This was the original goal which our group had in mind, yet we were not able to manufacture a prototype that would allow the user to raise or lower the harness bar simply one level at a time. However, it was discovered that the user could easy adjust the system with two hands while the child was rotated to face the car door. This would allow the seat to be kept in the car while adjusting the harness and the user could be looking at the child straight on in order to find the perfect fit. It also must be noted that the protective tubing that is supposed to enclose the moving harness bar in between the supports was left out of the prototype in order to convey the inner workings and springs of the system.

RECOMMENDATIONS

We truly hope that the toddler seat redesign project which we undertook during this semester will be carried on by students in the future terms. There are indeed more areas of improvement and this section will clearly explain them and offer possible plans.

First, it is essential that this project be sponsored by a company which manufactures toddler seats (e.g. Britax, EvenFlo, Eddie Bauer) in order to provide the funding which is necessary to injection mold the seats and bases from the proper polymers. Our sponsor, Mrs. Sue Gow, was a tremendous help to us all semester, but another sponsor must undertake this project in order to add on to the help and guidance that were provided to us by Mrs. Gow.

The issue of the locking mechanism on the bottom of the toddler seat is of paramount importance. This must be analyzed in great detail, and we suggest that crash tests are conducted in order to determine whether or not the pin will be able to withstand the forces of a crash without causing the toddler seat to detach from the seat base.

In terms of the harness adjustment system, we suggest that future groups look in to manufacturing this out of a metal which is more lightweight than steel. We realize that the strength of this system is reflective upon the strength of the whole design, but if a more lightweight material is used this will lighten the weight of the toddler seat and make it more user-friendly.

Finally, the ratchet system currently in place is perfectly effective. We suggest attaching this to a full scale seat base via the attachment point which we have made. This will then be able to be incorporated into any crash tests which are run in order to validate that this system is indeed safe.

CONCLUSIONS

We have now designed and manufactured three working systems which represent each facet of our toddler seat redesign. A 1:3 scale rapid prototype was manufactured in the UM 3D Imaging Lab, which clearly depicts the effectiveness of rotating the toddler seat 360 degrees while it sits flush on the seat base. A model of the ratchet system was made by manufacturing wood models of the car seat and seat base. We then attached the ratchets onto both sides of the bases, fed the LATCH belt through the ratchets, and clearly demonstrating how much less force was required to tighten the system in place. The model for the harness-adjustment system was manufactured with steel in the UM Machine Shop. The outer tubing was left out in order to convey the inner working of the springs and pins. Our final toddler seat design greatly reduces the amount of time and effort required to place a toddler safely into the car. Although we were not able to manufacture a working prototype which integrated each facet of our design, we are very pleased with each of are systems and the tasks which they perform.

ACKNOWLEDGEMENTS

The successful completion of this project would not have been possible without the help, guidance, and support that we received from others. We came into this semester with essentially no knowledge or experience pertaining to toddler seats or their function. However, a semester later, we feel that we are experts in the field and that we have made an important contribution to it.

First, we must thank our sponsor, Sue Gow. Sue helped us out from the first day we began this project up until the Design Expo. In order to allow us to learn about toddler seats and their function, Sue allowed us to take her car keys out into the parking lot and get acquainted with her seat, which she uses to transport her grandson. It was at this point that we actually realized how difficult and painstaking the process of installing and adjusting a toddler seat truly is. From there, Sue was with us each step of the way, and she presented some ideas to us which eventually became influences upon our final design. On a final note, the "babies" which we had in our rapid prototype at the Design Expo were provided to us by Sue, and we would like to thank her again for that.

We must thank our Section Leader, Professor Alan Wineman, who was instrumental in terms of guiding us along in our progress. Professor Wineman was always very flexible and willing to meet with us in order to discuss our project. Each of the Design Reviews which he held for us were very influential parts for the advancement of our project. We were pushed as a team in order to meet the requirements for these reviews, but, without these deadlines and attentiveness from Professor Wineman, it is highly doubtful that we would have had the successful result which we attained. We would also like to thank Professor Wineman for his positive attitude and cheerfulness, because he would always motivate us to leave meetings feeling very optimistic.

Another contributor to the success of this project was Dr. Kathy Klinich, who is a Senior Research Area Specialist at the University of Michigan Transportation Research Institute (UMTRI), in the Biosciences department. We received her contact information from Professor Wineman, and she was very willing to offer her insight to us once we contacted her. In fact, she invited us to attend a colloquium at the Institute which addressed the issue of child passenger safety. This was indeed a very timely occurrence, as it gave us valuable facts and information regarding current products on the market today.

Jennifer McIntosh, the coordinator of Safe Kids for Washtenaw County, was a large contributor to our success. She allowed us to attend a toddler seat training class on Wednesday, September 27th, which gave us additional insight into some of the requirements and regulations regarding the installation of toddler seats. Upon completion of the class, we were given a toddler seat, which became the basis for us in terms of what to improve. This seat was donated to us by the Mott Children's Hospital, which is where the training class was located, and we would like to thank them for that.

The process of machining each of our working models would not have been possible without the support of Bob Coury and Marv Cressey for their assistance in the UM Machine Shop. They were always very supportive and helpful when we had questions regarding our manufacturing plans or using the machines themselves. They were extremely busy during the last few weeks of this course, and we understand that we were not the only ones under stress during this time.

We would also like to thank Professor Kota for his guidance and suggestions. He carefully listened to our design concepts and manufacturing plans during the final Design Review, and used his expertise to suggest some alternative ideas to our current manufacturing plan.

Finally, we would like to thank the UM 3D Imaging Lab for manufacturing our prototype of the seat base and toddler seat. Specifically, Brett Lyons was our contact there, and we are grateful for his assistance in the process.

INFORMATION SOURCES

We have contacted all of the leading toddler seat companies (e.g. Graco, Eddie Bauer, Britax, Evenflo, etc.). We asked each company for the donation of a convertible toddler seat and also other information related to toddler seats. We decided not to pursue a free toddler seat from Britax when we were informed we would receive one from Safe Kids for Washtenaw County.

We also contacted Safe Kids for Washtenaw County and talked with the coordinator, Jennifer McIntosh. She informed us of a toddler seat training class, in which we took part at the Mott Children's Hospital on Wednesday, September 27th. She was very excited about our project and donated us a toddler seat which has been very helpful for us in terms of formulating our design concepts.

Dr. Kathy Klinich is a Senior Research Area Specialist at the University of Michigan Transportation Research Institute (UMTRI), in the Biosciences department. She has offered her assistance to our cause and we recently attended a colloquium at the institute which addressed the issue of child passenger safety. She has done a lot of research in the area of child safety and has been a big help to our project when it comes to addressing the safety issues of the toddler seat design.

The technical benchmarks for our convertible toddler seat are the restrictions set by the Federal Motor Vehicle Safety Standards (FMVSS). Sections 213, 215, 225, and 255 are the sections of the FMVSS that are pertinent to convertible toddler seats.

In order to get a better understanding of the current toddler seats on the market, we visited the local Babies 'R Us. There is a wide variety of seats which range from $60 to upwards of $400. The seat which we are basing our design upon will be modeled towards the lower end of that price range, as we wish to reach a wide customer base. While at the store, we noticed that some of our preliminary designs were in fact already circulating in the market, but only to a certain extent. Our design will aim to add features to the current seats which will ease the installation and adjustment while maintaining a high level of safety. We used these seats for benchmarking our ideas.

To determine the customer requirements, numerous friends and family members who have used toddler seats were contacted. Their responses to a quick survey which we prepared gave us a much clearer idea as to which components of the toddler seat process are the most important to the user.

Finally, in order to manufacture a working model depicting the interaction of the seat base and the toddler seat, we contacted the UM 3D Imaging Lab. Brett Lyons was our contact there, and he instructed us on how to go about taking material away from our original CAD models in order to reduce the material cost of the model.

PROBLEM ANALYSIS

In order to achieve our goal of manufacturing a more user-friendly toddler seat, we have drawn on multiple scientific and engineering fields. Previously conducted tests on existing toddler seats to obtain data that w as used as benchmarks for our seat re-design.

Engineering Disciplines

The first field that will be used is solid mechanics. The seat is stationary in the vehicle under most driving and installation conditions. A force analysis must be conducted on an existing seat to determine the magnitude, direction, and location of the forces exerted on the seat to keep it securely installed into the vehicle. This must be done for both the LATCH mechanism installation and seatbelt installation. It must also be proven that our design for the new child restraint system provides sufficient force to keep the toddler securely in place without disrupting the child's ability to move its extremities. The ratchets used to tighten the LATCH straps must also be specified to handle the forces involved with an automobile accident. In addition, we will implement our knowledge of dynamics in regards to the process of installing the toddler seat onto the base.

The properties of the materials we decide to use will also be examined. Toddler seats are given expiration dates by their manufacturers because of the fatigue life of the plastic used. The materials we add to the seat must have a fatigue life that is equal to or greater than that of the seat itself. They must also be strong enough to withstand the forces mentioned above.

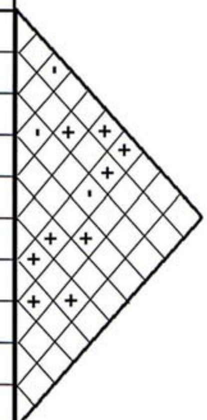
Since improved safety is not our primary goal for this project, the dynamics related to the seat moving during a crash are less significant. We need only stay consistent with the safety level achieved by seats already on the market.

REFERENCES

1) Kathy Klinich, Research Area Specialist Senior, Child Passenger Safety, UMTRI Biosciences Department
2) Colloquium on Improving Safety for Child Passengers, UMTRI, September 20, 2006.
3) Jennifer McIntosh, Coordinator, Safe Kids for Washtenaw County
4) www.chop.edu
   -Children's Hospital of Philadelphia website
   -contains a very beneficial video about installation and safety regarding toddler seats
5) www.carseatdata.org
6) Federal Motor Vehicle Safety Standards
   -Section 213, 215, 225, and 255 deals specifically with quantifiable numbers regarding certain aspects of toddler seats.
7) Babies 'R Us
   -Variety of toddler seats on the market
8) www.gracobaby.com
   -Figures contained in the report were obtained here.
9) Dowling, Norman E., Mechanical Behavior of Materials, 1999, Prentice Hall Inc., New Jersey
10) http://en.wikipedia.org/wiki/Polypropylene
11) www.mcmaster.com

APPENDIX A - QFD/Custom Pugh Chart

Part Characteristics / Customer Requirements	Ranked Importance	Rating (%)	Total	Target (Plan)	Competitor (Seats at Babies 'R Us)	Now (Donated Seat)	Units	Weight of seat	Seat can face forward and rearward	Durability of seat	Look of seat	Safety of child	Easy to remove seat from car	Easy to install seat in car	Easy to adjust harness	Cost of seat	Comfort of child	Child can unlock harness
								USER-PERCEIVED QUALITY										
Normalized Importance to Customer (Relative Weight)								0.7	1.0	0.7	0.3	1.0	1.0	1.0	1.0	0.8	0.7	0.5
Number of attachements to car seat (LATCH)	4	10.5%	35.7	2	2	2	#	1	7	3	1	3	9	9	1	3	1	1
Number of attachements on harness	3	10.6%	35.9	5	5	5	#	1	1	3	1	9	1	1	9	3	7	9
Able to be used in old cars	9	8.9%	30.1	Y	Y	Y	Y/N	1	7	3	1	1	7	9	1	1	1	1
Manufacturing & development cost	10	6.7%	22.7	?	?	?	$	1	3	9	1	1	1	1	1	9	1	1
Force to tighten/loosen attachments of harness	8	9.1%	30.9	?	?	?	N	1	1	5	1	7	1	1	9	1	3	9
Force to tighen/loosen attachments to seat	7	9.3%	31.7	?	?	?	N	1	3	7	1	7	9	9	1	1	1	1
Time to put in/take out of car	5	10.2%	34.5	-3	-3	-5	min	5	3	1	1	1	9	9	7	1	1	1
Geometry	1	11.6%	39.5	?	?	?	ft	9	5	1	5	1	7	7	3	5	5	1
Force to break seat from car attachment	5	10.2%	34.5	?	?	?	N	9	5	1	5	1	7	7	1	3	3	1
Size of attachment slots	2	11.5%	38.9	-6	-6	-5	in	5	9	5	3	1	9	9	1	1	1	1
TOTAL - CUSTOMER REQUIREMENTS								23.8	44	26.6	6	32	60	62	34	22.4	16.8	13
Rating (%)								7.0%	12.9%	7.8%	1.8%	9.4%	17.6%	18.2%	10.0%	6.6%	4.9%	3.8%
Ranked Importance								7	3	6	11	5	2	1	4	8	9	10



Design Concepts	Total	Weight of seat	Seat can face forward and rearward	Durability of seat	Look of seat	Safety of child	Easy to remove seat from car	Easy to install seat in car	Easy to adjust harness	Cost of seat	Comfort of child	Child can unlock harness
Ratchet for LATCH tightening	8	-1	0	0	0	2	5	5	0	-3	0	0
Pulley system for harness adjustment	3	-1	0	0	-1	1	0	0	4	-2	2	0
Spring loaded attachment for harness adjustment	3	0	0	-1	-1	1	0	0	5	-3	2	0
Base and rotating toddler seat	13	1	5	-1	0	-2	5	5	2	-2	0	0
Combining LATCH/seat belt slots	5	-1	-2	-1	0	-1	3	3	0	4	0	0
Seat belts on each side of seat	1	-1	0	1	-2	-3	5	5	0	-3	0	-1

Satisfaction of Customer Requirements [-5 (doesn't satisfy) to 5 (satisfies)]

1	Not related
3	Weakly related
5	Neutral
7	Moderately related
9	Strongly Related

APPENDIX B - The Ratchet System

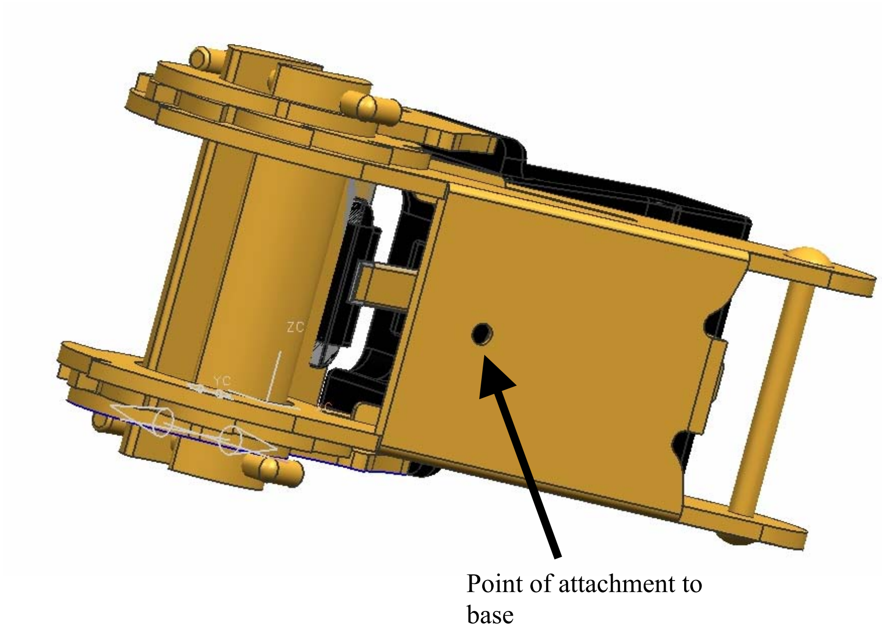


Figure B.2: Attachment point of ratchet system and base.

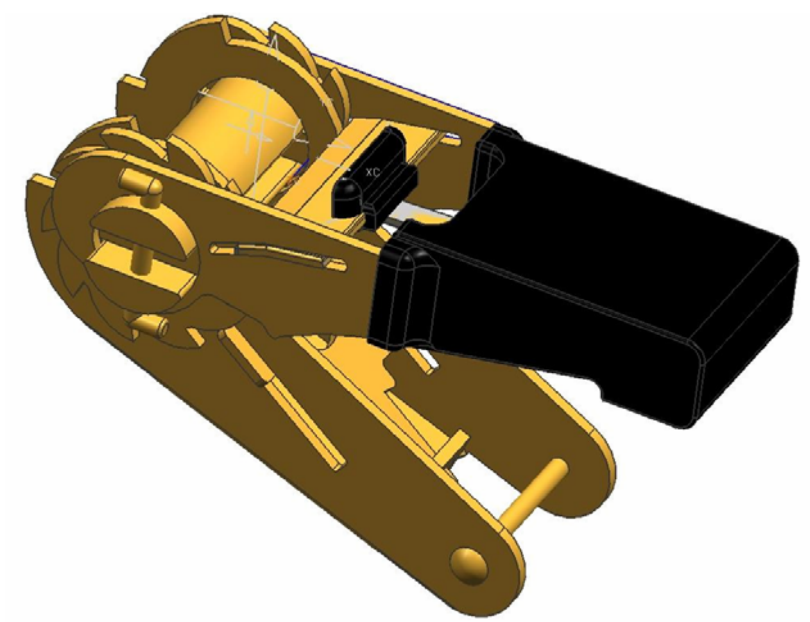


Figure B.1: Isometric view of ratchet system.

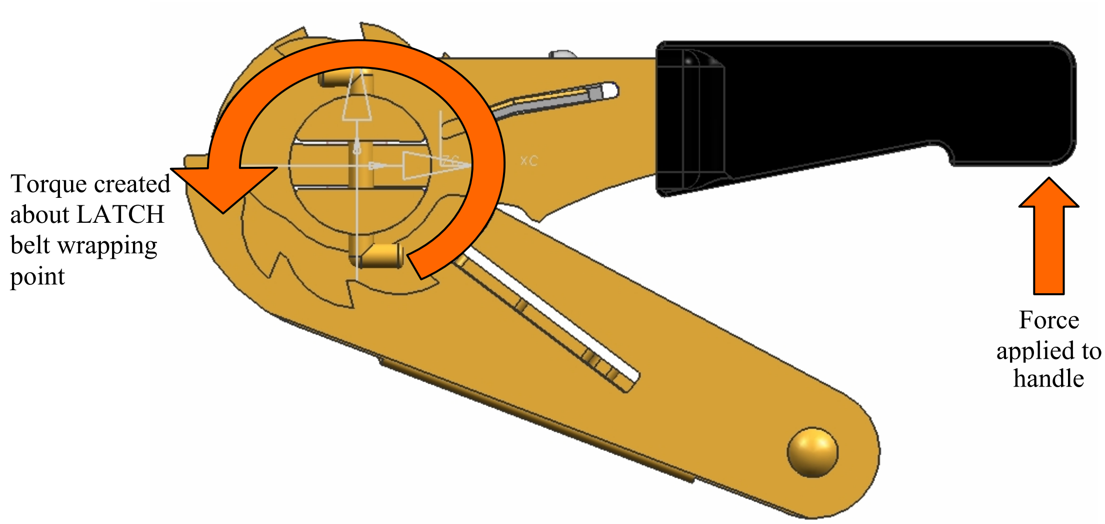


Figure B.3: Free body diagram of ratchet system. The applied force creates a moment which allows the LATCH belt to be tightened.

APPENDIX C - Slider-Bar Mechanism

Figure C.1: Isometric view

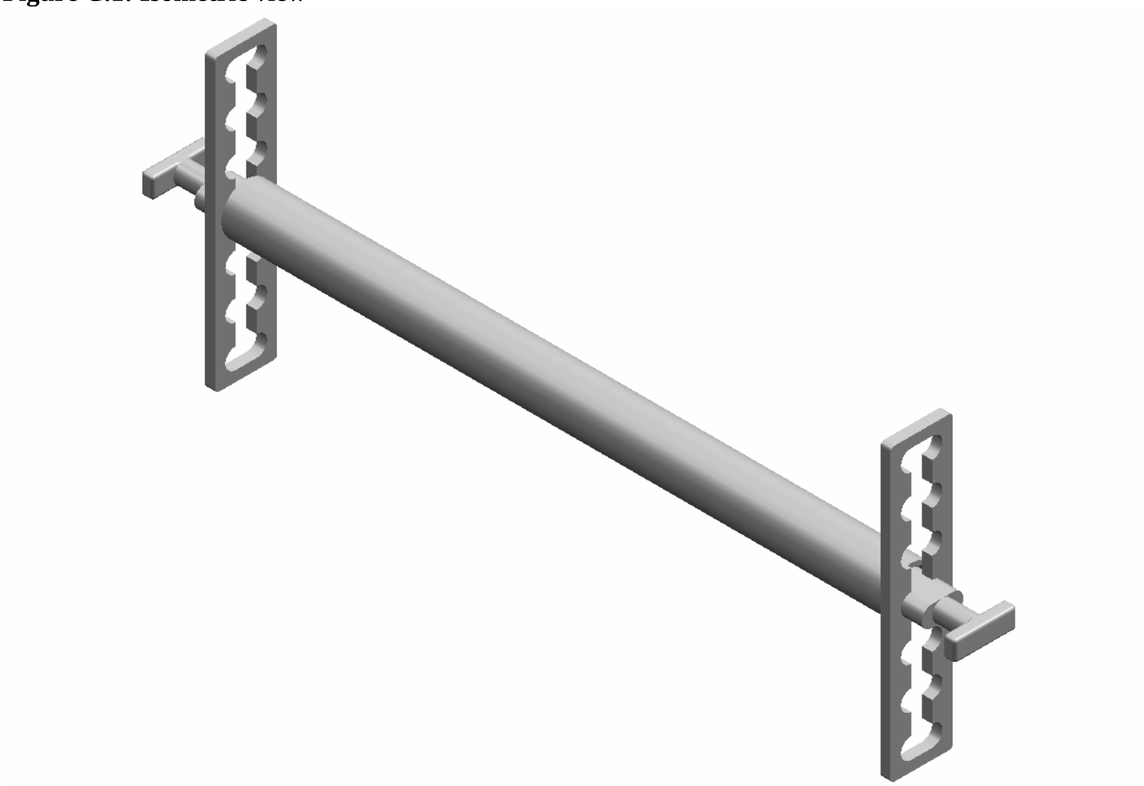


Figure C.2: Isometric View of the Bar

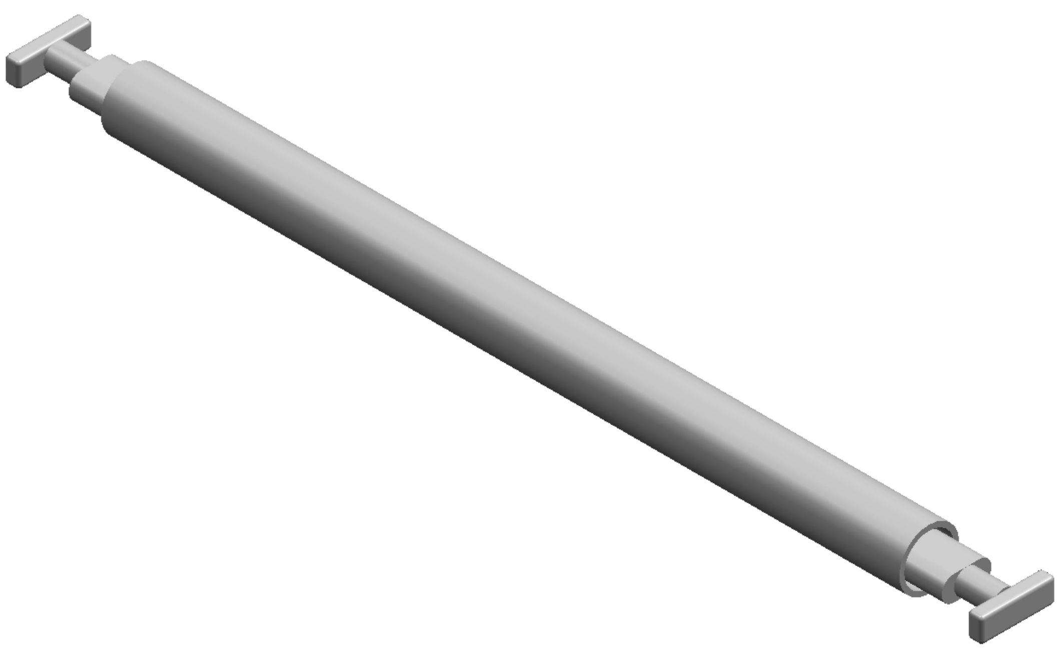
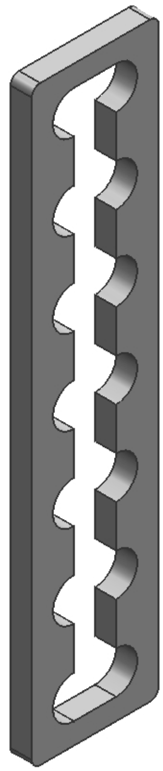


Figure C.3: Isometric View of the Slider



APPENDIX D - Seat Base

Figure D.1: Dimensioned Drawings of Seat Base

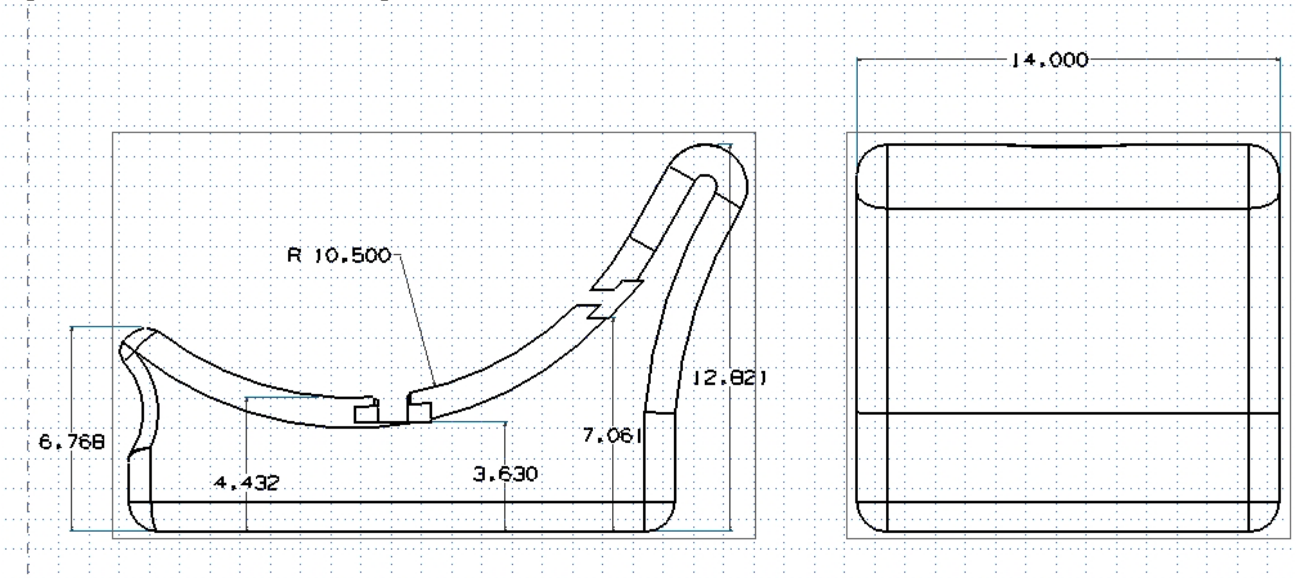
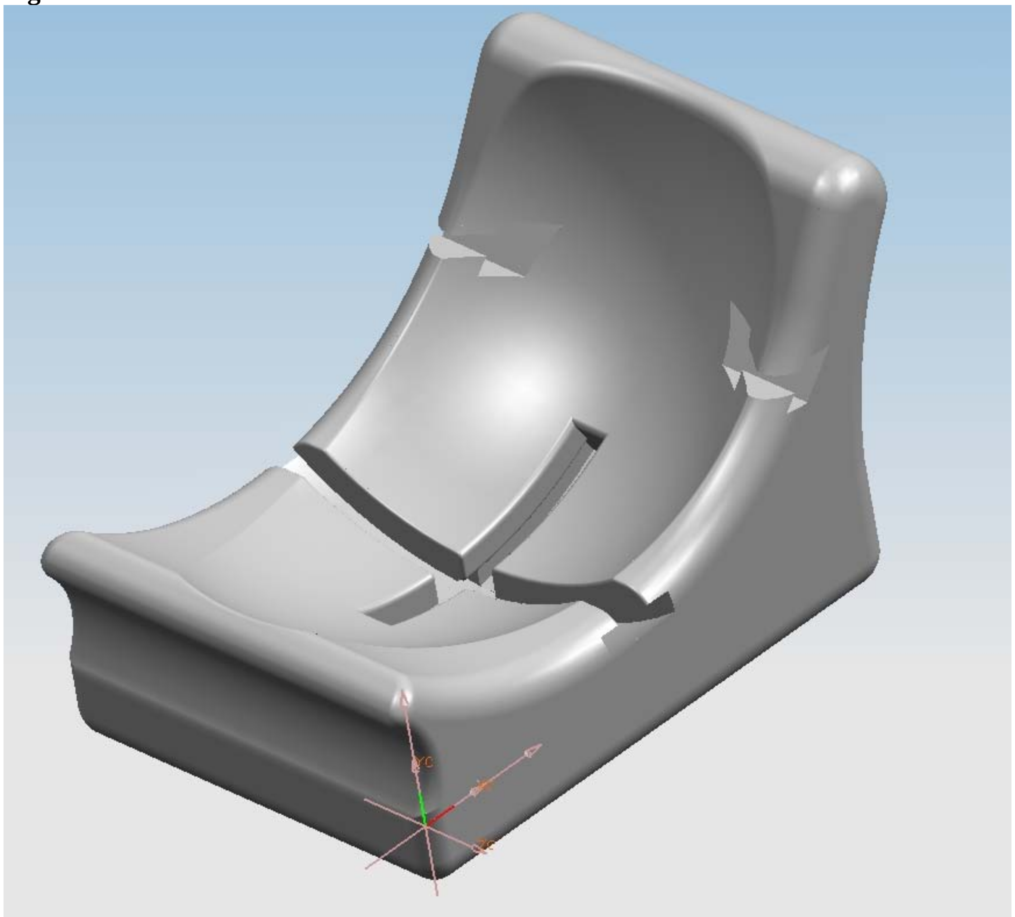


Figure D.2: Isometric View of the Seat Base



APPENDIX E - Toddler Seat

Figure E.1: Dimensioned Drawings of Toddler Seat

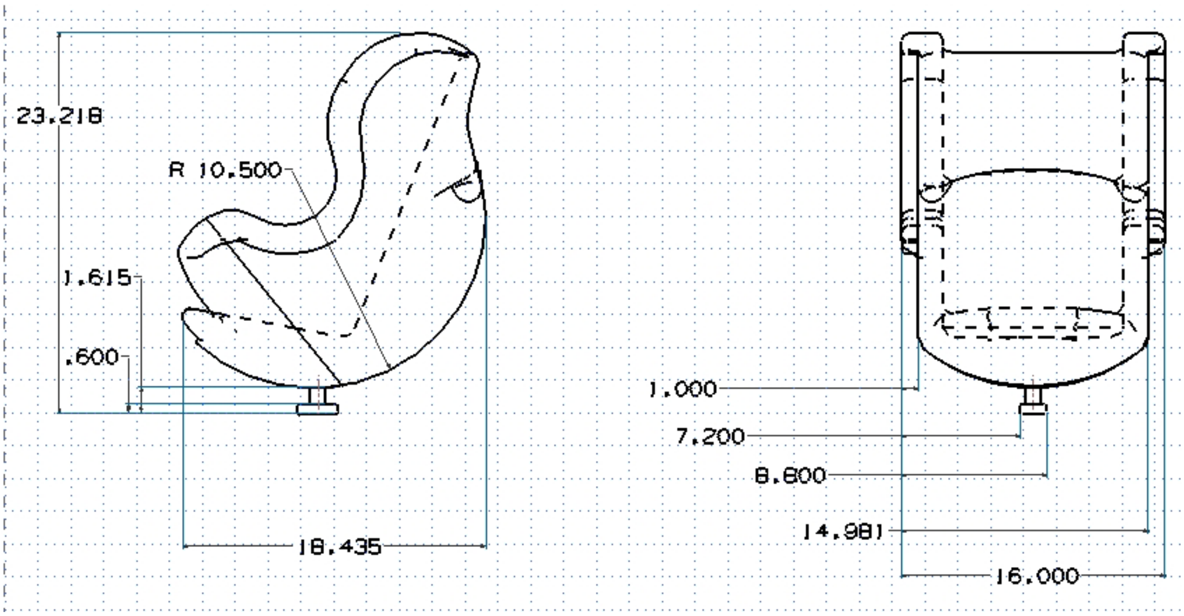
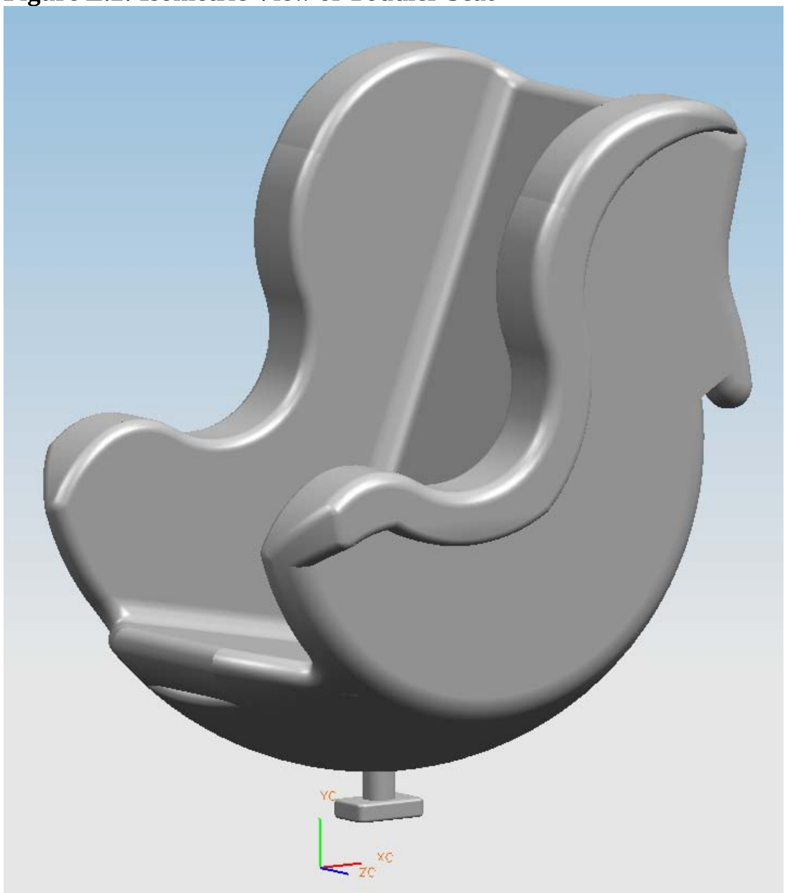


Figure E.2: Isometric View of Toddler Seat



APPENDIX F - Rejected Designs

Figure F. 1: Pulley system for adjust

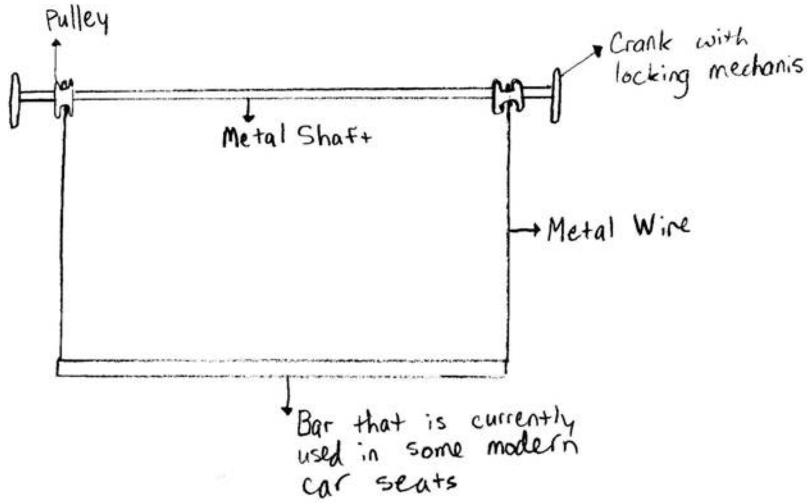


Figure F.2: Two-One Hole Conversion

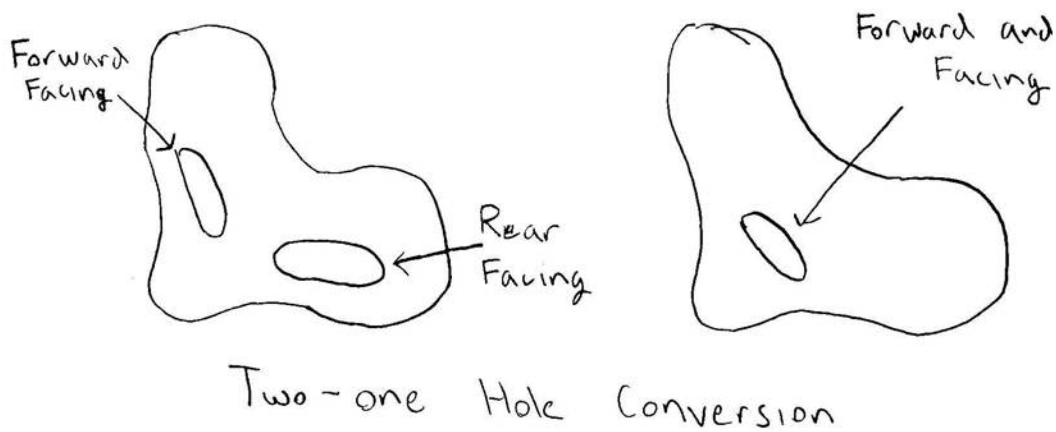


Figure F.3: Rail System

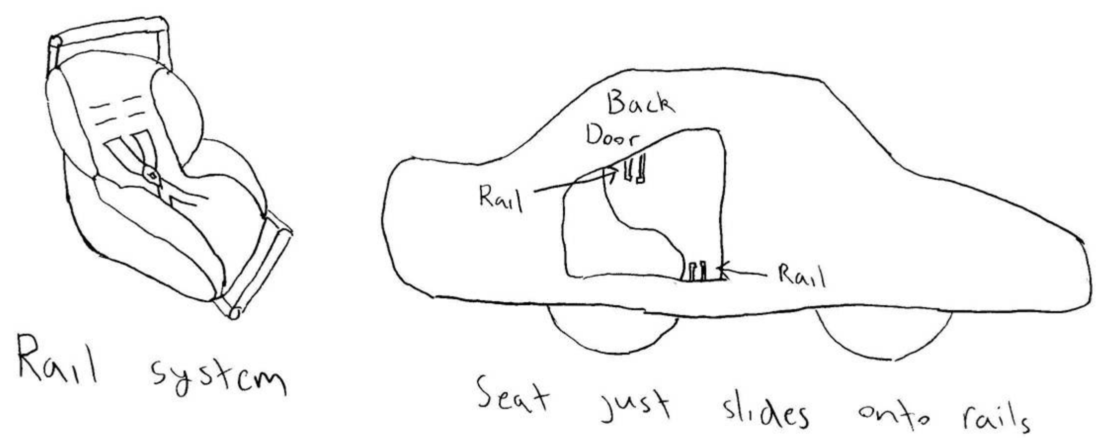
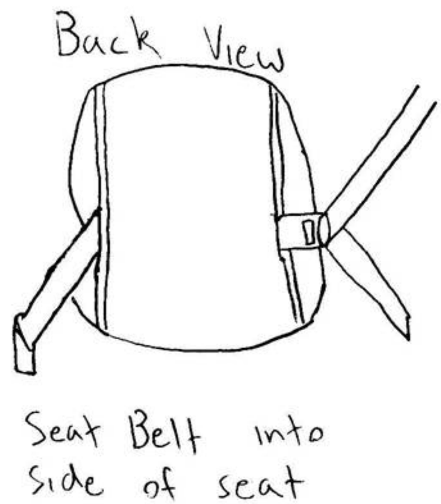


Figure F.4: Seat Belt Into Side of Toddler Seat



APPENDIX G - Gantt Chart

APPENDIX H - Bill of Materials

Figure H.1: Bill of Materials for Prototypes

Quantity	Part Description	Purchased From	Part Number	Price
	Model of Toddler Seat and Base			
1	Scaled Model of Toddler Seat	U of M Digital Commons, Ann Arbor		$306.95
	Model of Ratchet System			
1	Set of 2 Ratchet Tie Downs	Home Depot, Pittsfield Township		$19.60
2	U-Bolts (LATCH System)	Home Depot, Commerce Township	071514002316	$5.07
1	Set of 4 Rubber Stoppers	Home Depot, Commerce Township	049793066589	$2.25
1	1.125 Yards of Moleskin	Jo-Ann Fabrics, Ann Arbor	8511958	$5.91
1	0.5 Yards of Soft Polysuiting Fabric	Jo-Ann Fabrics, Ann Arbor	8560617	$2.10
1	Modification of LATCH Strap	College Shoe Repair, Ann Arbor		$4.00
	Wood - Birch	Dr. Christopher Heberer		$0.00
12	Decking Screws	Dr. Christopher Heberer		$0.00
	Model of Harness Adjustment System			
1	Carbon Steel Seamless Tubing: 1" OD, 0.902" ID, 0.049" Wall, 3' Length	McMaster-Carr*	9220K96	$11.91
1	Low-Carbon Steel Sheet: 0.25” Thick, 10” x 10”	McMaster-Carr*	6544K24	$31.30
	McMaster-Carr Order Shipping			$9.00
			Total Cost:	$398.09
	*www.mcmaster.com			

APPENDIX I - Photographs of Final Prototypes

Figure I.1: Toddler Seat and Base

Figure I.2: Ratchet System

Figure I.3: Harness Adjustment System