



Innovative Proposal for Multifunctional SUV Rear Seat

A Major Qualifying Project Report
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By

Edgar J Buenrostro

Alberto A Mateo

In partnership with Shanghai University
and Partners
Xianliang Chi and Benjian Huang
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Approved By:

Professor Yiming (Kevin) Rong, Advisor, WPI, ME

ABSTRACT

The principal objective of this paper is to exhibit the most feasible method to design a multifunctional SUV rear seat successfully. The intent of this project is to provide a detailed explanation of the steps taken to design the rear seat. Thus, it provides the essentials of the SUV seat market as well as samples of the designs from the group, in which it is possible to appreciate the common risks and mistakes a designer is susceptible to while implementing an idea. In addition, it includes an explanation of the methodology utilized by the group.

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Chapter 1. Introduction

At the present time it is crucial for all types of businesses to exist in a competitive environment. Competitiveness functions as a constant motivation given the fact that everyone requires to deliver the best product in order to obtain a good profit. However, delivering the best product involves countless aspects depending on the specific business type. Johnson Controls as an instance, being the main car seat manufacturer globally, is obligated to be innovative and reliable.

In order to become competitive in the coming years Johnson Controls necessitated having an innovative solution for the SUV seating. Therefore, the company had assigned the team to support this task as a senior design project. Johnson Controls' main idea was to develop an ingenious functionality without compromising cost and visuals. With this accomplishment the company planned to be able to widen its knowledge and services to ensure the customer the best quality output.

The role of the team during this project was to work closely with Johnson Controls to successfully achieve the goals set. Design an innovative mechanism for the movable and foldable functionality of the rear seat of an SUV. For this task the team was assigned to an advisor from Johnson Controls in order to be able follow all company standards.

Students from WPI and SHU were required to work together for seven weeks in order to complete the proposal in a timely manner. Overall this project was substantial because it was not just a grade for a class; Johnson Controls was investing its time and trusting its outstanding position in the vehicle industry on the team. Therefore as a group the students put all their efforts to deliver

a good product just like Johnson Controls has always dependably been doing in order to be one of the most competitive car seating manufacturers globally.

1.1 Project Description

With the purpose to provide a clear understanding of the project, Johnson Controls sent the group a concise presentation with the project description. As it was entitled, “Innovative Proposal for the Multifunctional Rear Seat for SUV”, this brief presentation clarified the main objective; to develop a new advanced and appealing functionality for the rear seat of an SUV.

Johnson Controls interest on the SUV market was aroused by the Global Market Research Company JD-Power forecast. The SUV market is expected to increase in China in the following five years. Additionally, OEM (Original Equipment Manufacturer), incorporate components into new products with its own brand name, had demonstrated its attention on the developments of SUV during last years. Especially concerning the combo luggage space, which would require versatile movable and foldable rear seats.

Johnson Controls in China had never worked with SUVs therefore a feasible and innovative solution for the rear seat of an SUV was required in order to become competitive in this detail market in the following years. The initial goals presented for the group were the followings:

- Make a benchmark for the SUV rear seat trend
- Create concepts for the rear seats new functions
- Finish 3D data and movement evaluation
- Produce a Prototype

These goals would provide a good product to show the customers and help the first phase to quote the new SUV rear seat functions. However, based on the duration of the project and the numerous functionalities that could be implemented to the SUV rear seat, the goals were slightly changed. As it will be explained in Chapter 4, Johnson Controls in accordance with the group decided to focus in a single functionality based on the customers' needs.

Chapter 2. Background

This section of the report contains the background information of the sponsor company and the SUV. A brief investigation about the history of Johnson Controls was made in order to learn more about the company the group was going to work with. Additionally, the evolution of the SUV was researched to target the main improvements over the years. Different types of SUVs were also traced to be aware of the necessary space the group needed to take under consideration.

2.1 Company Background

The founder of Johnson Controls was Professor Warren S. Johnson. It was not until he received a patent for the first electric room thermostat, that he had the opportunity to begin building the control industry. The name Johnson Controls was established in 1974, after a group of investors integrated the Johnson Electronic Service Company in 1885. The purpose of this adopted company was to manufacture, install and service automatic regulation system for buildings. From 1885 until his death in 1911, the professor tried to expand the company by developing new areas such as steam and gas powered automobiles and electric storage batteries. However, at the time of his death Johnson Controls decided to only focus on the business of temperature control for nonresidential buildings.

During the 1950's, Johnson Controls was developing new technologies to better serve their clients managing the buildings. For instance, Johnson Controls invented the Pneumatic Control Center, which monitored all temperature devices installed in the building from a single point. This invention resulted to be extremely helpful since building would have a large amount of devices that control the temperature installed all around such as dampers, valves and thermostats.

The JC80, another technology created by Johnson Controls was introduced in 1972. This minicomputer was also developed to control the buildings. As years passed, the technology at Johnson Controls continued to grow, introducing a digital version of the JC80, the JC85 in the 1980's. This new version allowed a more accurate and faster control of building systems. Throughout the 1990's, the company led the way to allow different devices from other manufacturers to share data. Metasys Facilities Management System is its most recent control system.

Another business adopted by Johnson Controls in the 1980's in was the systems to manage commercial buildings. In order to accomplish this, the company increased its services to incorporate electrical and mechanical tools. The Integrated Facilities Management (IFM) was then introduced to provide to the clients a single center of maintenance and operations for all building functions and systems. In addition the IFM was developed to guarantee a continued dependability and effectiveness to the structure and configuration of the buildings.

As previously mentioned, before his death, Professor Warren S. Johnson had an interest on expanding the company by adding new areas of study such as automobile batteries. In response for his concern, currently Johnson Controls is the main manufacturer of private-label lead-acid automotive batteries in North America. Some of the brands that the company manufactures automotive batteries for are Heliar, LTH, Optima and Varta, in addition to lots of private brands. Furthermore, Johnson Controls also manufactures batteries for telecommunication applications and emergency power back up. The company continues to develop new technologies in automotive batteries and is expanding its leadership to all America and Asia.

In 1985, Johnson Controls acquired Michigan-based Hover Universal, Inc., which started business in the 1960's manufacturing car seats components such as frames, cushions and tracks. After this acquisition Johnson Controls began its business in the automotive seating along with plastics machinery. Now, thanks to its outstanding accomplishments in the car seating industry, the company has become the main manufacturer in five continents. During the last decade, the company has been trying to improve the car seating industry by the development of research, engineering, design and testing capabilities in order to provide both costumers and cars manufacturers systems with enhanced technology, comfort and safety.

2.2 SUV Background

A sport utility vehicle (SUV) is a vehicle that provides the passenger space of a minivan, the towing capacity of a pick-up truck and usually four-wheel drive. The term SUV varies in different countries and is mostly applied in North America. In some other parts of the world different terms are utilized such as off road vehicle, four-wheel drive (4WD) or four-by-four (4x4). The history of the SUV began with the “depot hack”, which was a vehicle that transported people and their luggage from train stations. The Suburban (longest SUV) and the station wagon were created based on the depot hack. However, the terms “suburban” and “carryall” were mainly used in reference to early SUV models in the 1920's. “Carryall” was used since its main purpose was to be practical and carry all, whether it was cargo or people.

One of the main purposes of a SUV is its off-road capabilities. This feature is often required in places with limited paved roads such as northern United States, South America, Alaska, Canada and Middle East. These places need a vehicle with all-terrain handling, large storage space and range. In addition, some SUVs provide a minimum of hydraulic and electric systems such as the

Toyota Land Cruiser and the Land Rover, which is helpful in the unfortunate situation of scarcity of spare parts. Additionally, in order to attract the greatest possible audience, modern SUV models provide a lower ground clearance and suspension especially intended for paved roads.

Throughout the years SUVs have become popular due to their large storage space, higher ride space, larger passenger capacity, improved safety and off-road capabilities. Full size SUVs usually offer three row seating, which is very convenient to transport up to seven people replacing the minivan and station wagons. Furthermore, some modern SUVs have an improved towing capability which can haul boats and trailers. In terms of security, SUVs are also designed to drive in hazardous conditions such as on gravel roads and snow. Their outstanding performance in places where drivers often come across detours, high water, mud and rough roads has placed the SUV in a competitive spot when it comes to efficient driving. Overall it isn't hard to predict the SUV's increasing popularity over conventional cars in the following years.

2.2.1 Types of SUVs

SUV's designs have changed throughout the years as the consumer demands have required different functionalities. SUVs are historically known for its high ground clearance and mid-size passenger space. However, unlike today where SUV's are more of a family oriented vehicle, early SUV's were designed with two doors and some with removable tops. Current SUV's provide much more functionalities that bring out the concepts of comfort and safety to a whole new level. All of which can be very attractive to a family that needs all the versatility.

SUV's designs vary on sizes and are classified in Compact SUV, Midsize SUV and Full Size SUV. The compact SUV refers to the smallest SUV on the market since they are generally built with less passenger and cargo space. Midsize SUV on the other hand are not commonly

known outside North America where it is usually compared and confused with a full size SUV. However, full size SUV's provides the most cargo and passenger space with usually a third row seating space. As shown in Figure 2.1 below, the mid-size and full-size SUV provide the most space in terms of storage and seat capacity.



Figure 2.1 Full Size SUV Interior/Exterior

However, full-size are not very common outside the United States, as United States version of the mid-size is usually considered full-size. Also, due to the nature of the Chinese market the small or compact sized SUV are the most attractive of all the different sizes. It is for this reason that our three benchmark SUV's, the Tiguan (SVW), CRV (HONDA), and Haval (Great Wall), all fall under the compact-size category for SUV's.

2.2.2 Rear Seat Folding Ways

One of the main functions of an SUV is the capacity to rearrange the rear seats to provide more cargo space. Due to the demand in the market for compact SUV's one important feature is the ability to provide better storage when the cargo space is needed over seat capacity. This is important, since compact SUV's do not have the same ability as the full-size SUV's, which provide large cargo space, and great seat capacity. Due to the limitations of space and variations of the different models, manufacturers must implement innovative ideas to meet the needs of the market. They must not only adapt to the shape of the model, but they must provide the best possible storage space rearrangement, while not compromising aesthetics.

There exists several ways to fold and reorganize these seats and it varies based on the manufacturers and models. Some of the main types are the folding, moving, adjusting, disassembling, and rotating. The most popular out of these to fold the rear seats of an SUV are the “folding-flat” and the “vertical-folding”. The folding-flat option provides an intuitive mechanism and a clean look as shown in Figure 2.2. This method usually provides the best look and largest horizontal cargo space. However, one downside to this mechanism is that it does not provide the greatest vertical space. The mechanisms usually tend to be either manually operated, or automated by a press of a button. Generally the manufacturers aim to achieve the folding operation in the least amount of steps, or the lowest number of operations. This is due to the fact that the lower amount operations are a more user-friendly alternative, and could at times also mean a cheaper alternative. However, the automated option is usually for the more expensive or luxurious models, as this is a more expensive option.



Figure 2.2 Fold-Flat Folding

The “vertical-folding”, as shown in Figure 2.3, provides additional space on the floor and also is very convenient in terms of user-friendliness given low folding operations. Both folding options present different mechanisms that also depend on the manufacturer. Some of these different mechanisms could be manual or automated, which in most cases changes the customers’ perspective while making a decision. The vertical-folding option provides somewhat more vertical

storage space as it frees the space needed to hide the seat. However, the downside is that this option is not as neat folding as the fold-flat option. Also, this option provides less horizontal storage space.



Figure 2.3 Vertical Folding Mechanism

A variation of the vertical-folding mechanism exists as the fold and hang as shown in Figure 2.4.



Figure 2.4 Fold and Hang to the Side

This option usually involves folding down of the backrest onto the cushion and then taking the entire folded seat to the side and hangs. This mechanism is usually used as an automated option. While this option provides great space on the center of the storage space, it does not provide as clean of a look as the fold-flat option or the regular vertical folding. Also, this method would usually be used on large-size SUV's as this option would block the side doors.



Figure 2.5 Moving (Sliding) Method

A variation in some vehicles is the moving option as shown in figure 2.5. When this option is used the cushion of the seat does not move of the floor, but rather it slides forward and to the sides. While the seat is able to slide forward to the front seat, this method does not provide a clean look to the vehicle, as it has the most bulk out of the methods we have talked about so far. However, a great benefit to this method is the low cost involved in this option, which is perhaps the main reason it is used in some vehicles models. A slight advantage in this mechanism is the ability to adjust for leg space as needed by the passenger, an option that is not normally available in these models. At the same time this mechanism also provides slight increase in storage space while not having to reduce the seating capacity. A feature that can come in very handy in certain situations.

Also, another application of the idea of the mechanism is the integration of a movable rear seat that could add convenience for disabled passengers by placing the seat out of the door. This feature as shown in figure 2.6, can make it easier for these passengers to go into the car.

In addition, this mechanism idea can also be applied for luxury models. It can provide a rotating seat that allows for better communication between the passengers shown in figure 2.7, such as in business interactions. However, due to limited space in the SUVs this may present a design complication, and an additional cost to be able to design these features into the rear seat of the SUV, while still taking into account the need to provide storage space.



Figure 2.6 Moving Option for the Disabled



Figure 2.7 Luxury Moving Option

The disassembling method is another option currently used in the vehicles. Here the backrest is able to fold into the cushion, mainly just for adjusting of the backrest. For the extra storage space the seat must be taken out of the vehicle by disassembling as shown in figure 2.8. This option provides the most available space for storage, and one of the most economical options. However, it comes with the disadvantage that it is not very user friendly, since it requires the owner to exert a lot of force in order to carry the seat out of the vehicle. Although, the customer may be able to use the car seats as an additional seat at social events, since the seats are out of the car when the storage space is used, it does not provide the flexibility of being able to have the same seating capacity after the cargo is unloaded.



Figure 2.8 Disassembling Option

Another variation for folding of rear seat is the rotating option as shown in figure 2.9. In this method the seat just rotates as if making the seat for trunk seating. This method is not as practical as it does not provide protection to the seat trim. At the same time it does not provide any additional cargo storage space, but rather it just provides an option to whether the cargo is stored in the trunk space or where the cushion once was. As this option could be useful in some cases depending on the type of cargo it is not as practical. However, the fact that the seat can be used from the trunk by rotating makes it a useful feature for use at social events, as it almost serves as an outdoor couch, and it is not an expensive mechanism.



Figure 2.9 Rotating Option

Chapter 3. Objective

The given objective of this project was to design a feasible mechanical and structural solution for a multifunctional SUV rear seat for Johnson Controls. Due to the information provided by the company being rather vague, since a rear seat of an SUV could be implemented in numerous ways, the group in accordance with Johnson Controls decided to focus on the folding mechanism functionality. Consequently this decision provided a new more concise objective:

Develop an intuitive and attainable mechanism for the folding functionality of the SUV to be evaluated by Johnson Controls engineers. This innovative solution needs to provide a maximum cargo space and a safe, user friendly solution without compromising visuals. Moreover it must guarantee the customer safety while providing an affordable result falling under the sponsor company standards.

Chapter 4. Methodology

During this section, the system of methods utilized to successfully complete this project was established. As the flow chart in figure 4.1 demonstrates, a plan was followed. Initially, the PQP provided time for the group to be well prepared to address possible solutions and future obstacles. Once in China, the research made to address the problem presented was discussed with the sponsor company in order to be pointed to the right direction in terms of solutions.

Based on the project description provided by Johnson Controls, the group did research to target main functionalities for the SUV's. Throughout this investigation it was possible to get a better understanding of the SUV market. The group was able to learn about the demographics of the main SUV customers as well as their main demands while searching for the best quality vehicle. Furthermore, it was necessary to research the company background to have an insight on how Johnson Controls works and what do they focus on in terms of vehicle solutions. There was constant communication with the Chinese partners through emails during the PQP in order to combine findings and improve presentations.

PQP weekly presentations were prepared with the support of the group members in China to obtain feedback from the professor in charge of the project and students that had completed a similar project in China. At the time to expose the final PQP presentations after the seven weeks, the sponsor and customers' needs as well as the benchmark study were fully understood by the group in order to present them to Johnson Controls and obtain the final feedback necessary to start working on the developing of the ideas for the mechanism.

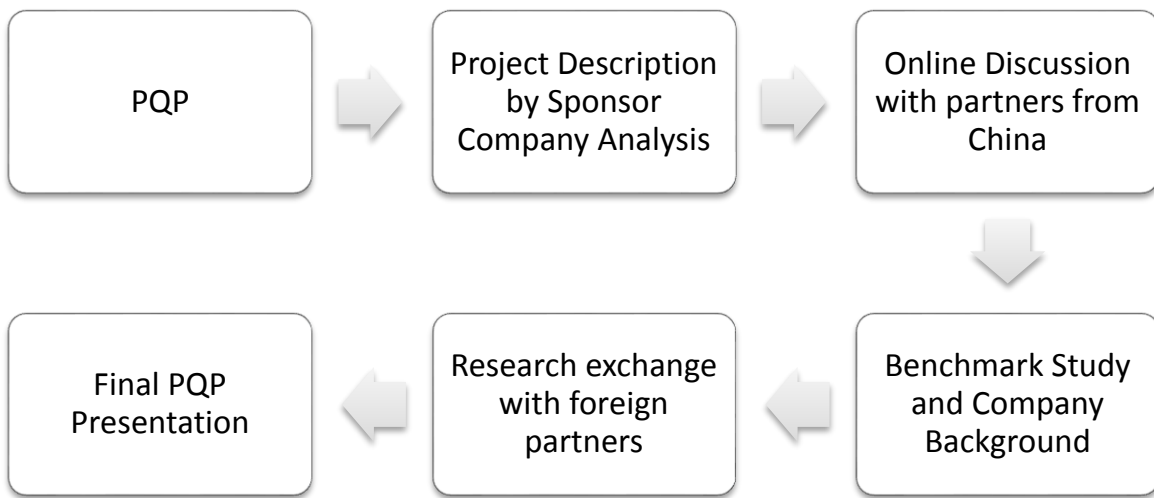


Figure 4.1. PQP Flowchart

Once in Shanghai China, multiple visits were made to Johnson Controls to meet the people running the project in order to work closely with them and to get a better understanding on what is expected from the group. Moreover it was possible to get a closer look at the company's manufacturing processes by the provided tours which were very helpful while coming up with innovative ideas for the mechanism.

An intern working for Johnson Controls was in charge of the project and to work closely with the group. After discussing all different rear seat functionalities researched during the PQP and based on the customers' needs it was decided to work with the folding functionality of the SUV. This functionality was chosen because it targeted the main SUV characteristics demanded such as the storage space and aesthetics.

Once the specific SUV functionality for the rear seat was selected, the group and the intern from the sponsor company decided to brainstorm possible folding mechanisms in order to begin

the technical work and choose the feasible solutions from all the ideas generated, some which can be found in appendix A. Designs were then created for all the mechanisms that proved to be innovative after several meetings and discussions with Johnson Controls engineers.

Lastly, comparisons were made to all final designs to assess advantages and disadvantages. However, in order to better appreciate the capability of all these designs, CAD models were created to present simulations and be able to apply a structural test.

Figure 4.2 illustrates all the process described in this section for a better understanding.

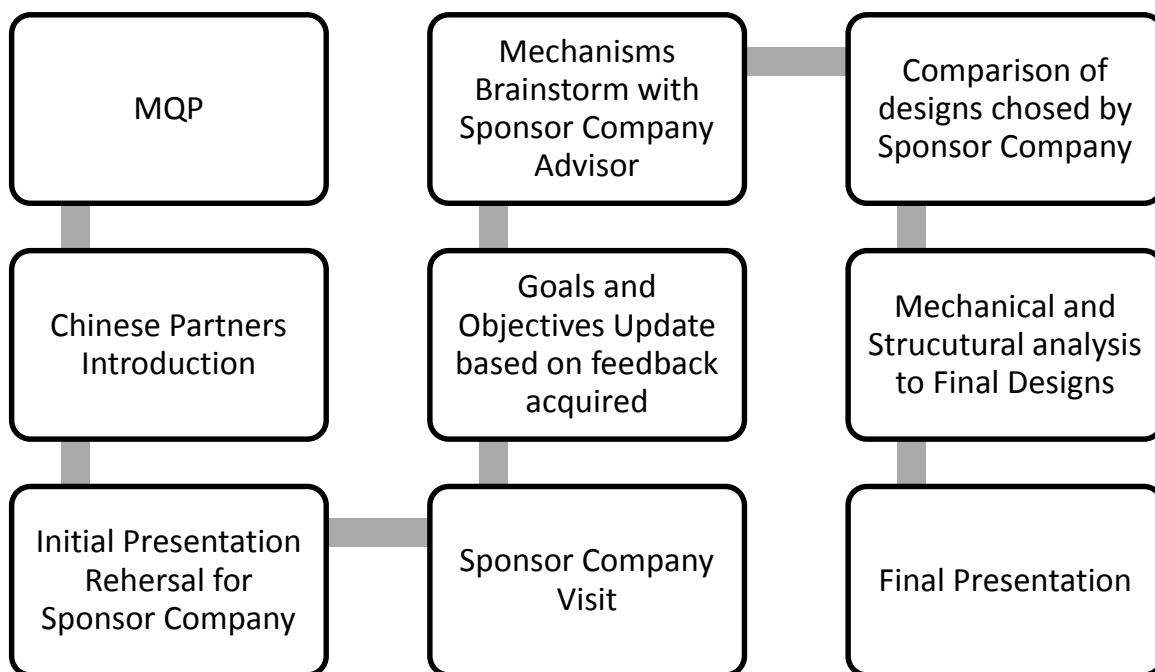


Figure 4.2. MQP Flowchart

4.1 Pre Qualifying Project

During the seven weeks of the PQP, both the students from WPI and SHU prepared a presentation to introduce the project and the main topics such as project objectives and benchmark

studies. The PQP's principal objective was to visualize what was expected to be completed while in China in order to accomplish all objectives successfully on time.

4.1.1 Benchmark Study

The benchmark study was carried out to compare current functions implemented on the SUV rear seat and analyze the current SUV market situation such as its growth reason, main customers, main uses and main characteristics. Additionally in this section the research about the SUV models Johnson Controls was targeting to make the implementation on was followed, some additional research can be found in appendix B.

The group investigated functionalities for the rear seat SUV in order to come out with new ideas and present them to the sponsor company. Some of the functions included the sliding function, which as shown in Figure 2.5 allows the user to slide the entire set either up, down, backwards or forward. The rear seat can move through the rails on the chassis of the car to allow leg space flexibility and also extra storage space.

The luxury moving function allows the opportunity to provide a better communication between passengers for luxury and larger SUV's as shown in Figure 2.7. Additionally, also demonstrated in Figure 2.6, is a rotating movable rear seat that adds convenience for disabled passengers by placing the seat out the door. Although this function was not considered for the project, it was very helpful for the group while brainstorming ideas.

The following functions provide comfort for the user. Figure 4.3 shows how the head restraint could be independent and adjustable to suit the users' needs. Moreover, also demonstrated in figure 4.4 the backrest provided a multilevel adjustment to fit the users posture required. Both these adjustments were taking under consideration while designing the final mechanism.

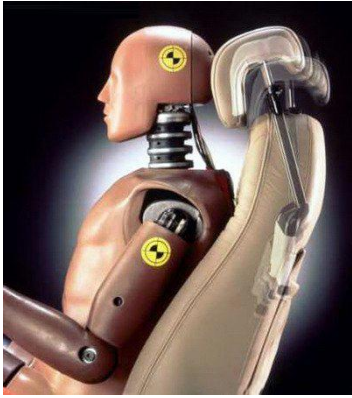


Figure 4.3 Head Retrain Adjustment



Figure 4.4 Backrest Adjustment

The SUV situation in the market was also researched to show the sponsor company the current situation vs. last years. Figure 4.5 demonstrates how there has been an exponentially growth in the SUV sales trend from 2009 to 2011. Showing the same behavior the SUV market share has been increasing also shown in Figure 4.5. Based on the investigation the SUV market has done very well in the past years, however it is necessary to check how the rest of the market has been doing to make a comparison. Figure 4.5 below shows the contrast between the total car market growth rate and the SUV market growth rate. These results confirm the speculations about the SUV market having a success in the following years which reinforce the purpose of the project.

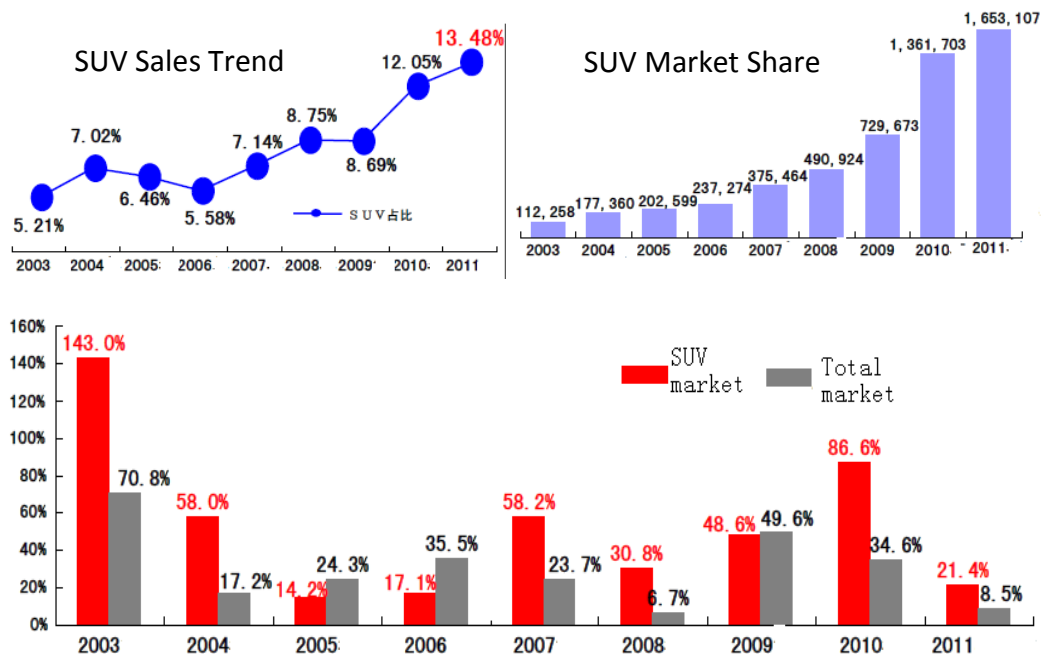


Figure 4.5 SUV Evolution

Evidently the SUV has become very popular in the market. This in part is due to the match of the consumer individuality demand and the advanced characteristics that the SUV have been developed over the years. Monetarily the SUV has also become more accessible to consumers in the past years since typically small SUV's are less expensive and have better fuel economy. Newer versions provide extra cargo space and also extra traction in slippery conditions which is extremely important while analyzing safety. Another great characteristic to consider is that new SUV are no longer only for country side, they are now also suitable for the city.

The SUV models provided by Johnson Controls to make the implementation on were the Tiguan from SVW, the CRV from Honda and the Haval from the Great Wall. For all these SUV's the group researched all their information such as space available for each one as shown in figure 4.6 below.



Figure 4.6 SUV Models Provided

Normally SUV's are recommended for people with big families or that live in a countryside. However, nowadays the SUV market with its new improvements and appealing looks has been attracting all kinds of customers all over the world. During the groups research it was found that the characteristics that the main SUV customers were:

- Nearly 80% users are men
- Age of 30 to 40 years old
- Good Education Background
- Commonly married and have children
- Yearly income of 200000 – 300000 Yuan

Being aware of these demographics helped the group to target the main functions that could be implemented to attract a wider range of customers and also to keep the current ones. In order to

do that, it was also necessary to relate the main features these customers based their decisions on, while buying a SUV over any other car. These main features were found to be the following:

- Off Road Capabilities
- Simple Operation
- Visuals
- Extra passenger and cargo space
- Multifunction

SUV drivers are known to take advantage of the cargo space. They usually use it to transport heavy and large equipment. Additionally, the driving capabilities during extreme climate situations are very appealing features. Therefore the group focused in these main characteristics for the final mechanism idea.

Chapter 5. Results

Throughout this project, we were able to learn a great deal of things. We not only got to experience what the business culture was like, but we were also able to learn new technical skills. Through the communication and mentoring from students, faculty and engineers we were able to refine our skills in order to provide the results. We toned our CAD skills and expanded the CAD software programs when taking our ideas to computer and using a different software than what we had learned. One of the abilities that we were able to improve the most was the ability to work with others and presenting our ideas. This was done through various meetings, networking and presentations to professors and company employees.

5.1 Mechanism Ideas

Throughout the progress of the project we had to brainstorm constantly in the search for an innovative idea. At first little instruction was provided with the purpose to help us think outside the box, or rather different than someone in the field of car seat manufacturing. We were to show our different ideas at our meetings with the company. There our ideas were reviewed and criticized so that we could move to the next phase. Our next phase was to combine our ideas and concepts with the ones that the company had worked on. Then, we would have another brainstorm for new ideas based on the new set of concepts.

The focus was to come up to develop what desired path of the cushion and backrest would be. At first we were just given the cushion and backrest model and from it we were to think of possible paths for the cushion and backrest in order to achieve the folding operation. Shortly after we were provided with all the requirements as to what our constraints were sample shown in Appendix B. The reason to let us develop ideas without all the constraints was so that they could see ideas that were outside the box and provide inspiration for something innovative.

After presenting various ideas that were not limited by the common knowledge of the engineers that had been on the field for several years and have a better understanding of what works and what does not, they provided us with feedback. With this feedback we did iterations and narrowed down our concepts and presented to the engineers. The engineers picked the concepts path to be focused on which are shown in figure 5.1. The concepts were compared and given scores based on company criteria for mechanism designs. Explanation of terms used in the comparison can be found in Appendix C.

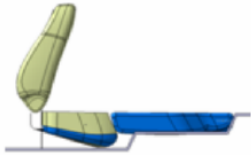
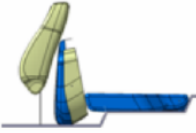

Concept Number	Space	Feasibility	Easy to Operate	Cost	Environment
1 	10	10	8	10	5
2 	7	10	8	10	10
3 	10	6	8	2	4

Figure 5.1 Design Concept Finalists

After the brainstorming and narrowing down options we then had to detail our options. We started to develop concept ideas for the mechanisms of these concepts as seen in figure 5.2. After the brainstorm we would again meet with the company and have the engineers give us their input

on it. Then we would go back to the drawing board and iterate the ideas. Then again some were discarded and the ideas narrowed.

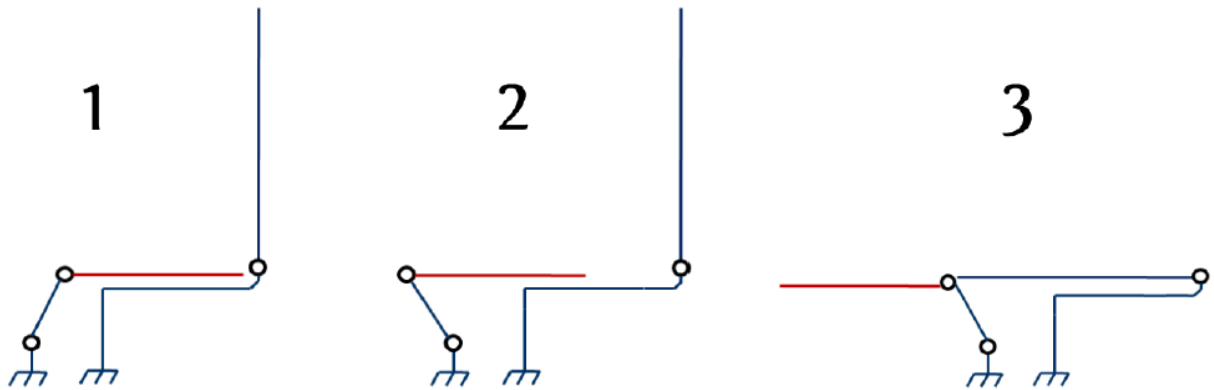


Figure 5.2 Sample Brainstorm Mechanism Concept

Now with narrowed down concepts and mechanisms we could start to design in more detail by starting to do model in CAD. By performing the models we would be able to do analysis of the designs. After, having the three concepts we did models for each one. In each one we still were still keeping options open for new ideas that may surge while working on the model.

5.2 Final Design

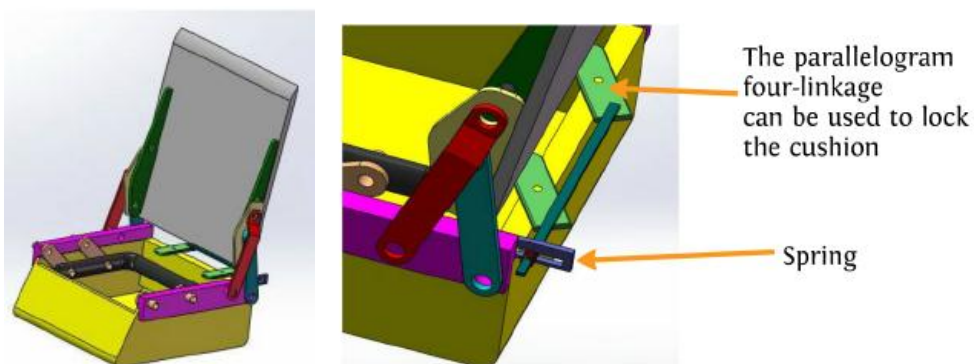


Figure 5.3 Box Concept Design

For the box concept shown in figure 5.3, we developed a few iterations as initially the idea was not as feasible to the engineers as other options. The way this concept works is that the cushion is supported by boards on a parallelogram four-linkage that locks it in place, and moves out of the way for folding when operated. This concept has the advantage that the mechanism for it is not very complex nor is it expensive in comparison. However, one disadvantage is the environment adaptability, as this concept would require a bottom box for the cushion to be stored, and that may not be of preference to the customer.

However, they we still continue to develop the box idea and models.

After meetings with the engineers the box concept was decided to be dropped as a major focus for us due to the time constraint. They told us that they had a preference toward concept one and two shown in figure 5.4, and that we should focus our energy on improving these models in the interest of our time. However, the company would still consider this concept and put some more thought towards it, and not discard it completely. So the two main focus were although considered as two, were actually one as the same mechanism could be implemented to achieve both.

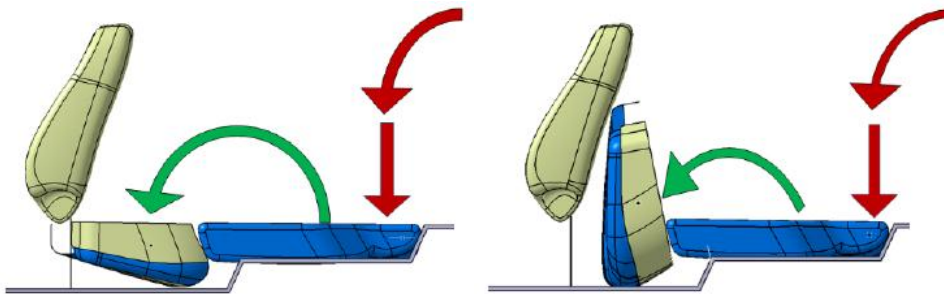


Figure 5.4 Final Design Concept

5.2.1 Iterations

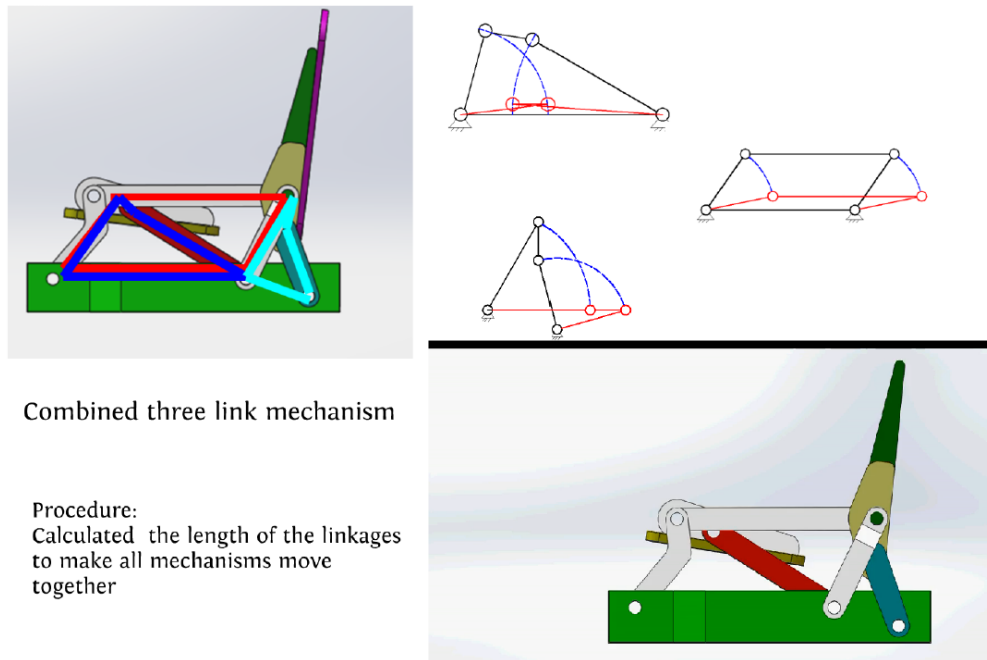


Figure 5.5 Final Design Iteration 1

After going over design concepts we were able to come up with two iterations that were to be considered as very possible. Iteration one was focused on the idea of having the lowest amount of user operations to fold the seat without the need for it to be automated. With this in mind the concept for the mechanism developed. Our goal was to be able to push the backrest and have the cushion follow it. Then, when being unfolded all that would be needed would be to lift the backrest and the cushion would follow. All this with the ability for the backrest to still have the ability for the passenger to be able to recline the seat and be comfortable on it.

In order to have the mechanism function the way we needed it to, we had to calculate the lengths of the linkages to make all the mechanisms move together as shown in figure 5.5.

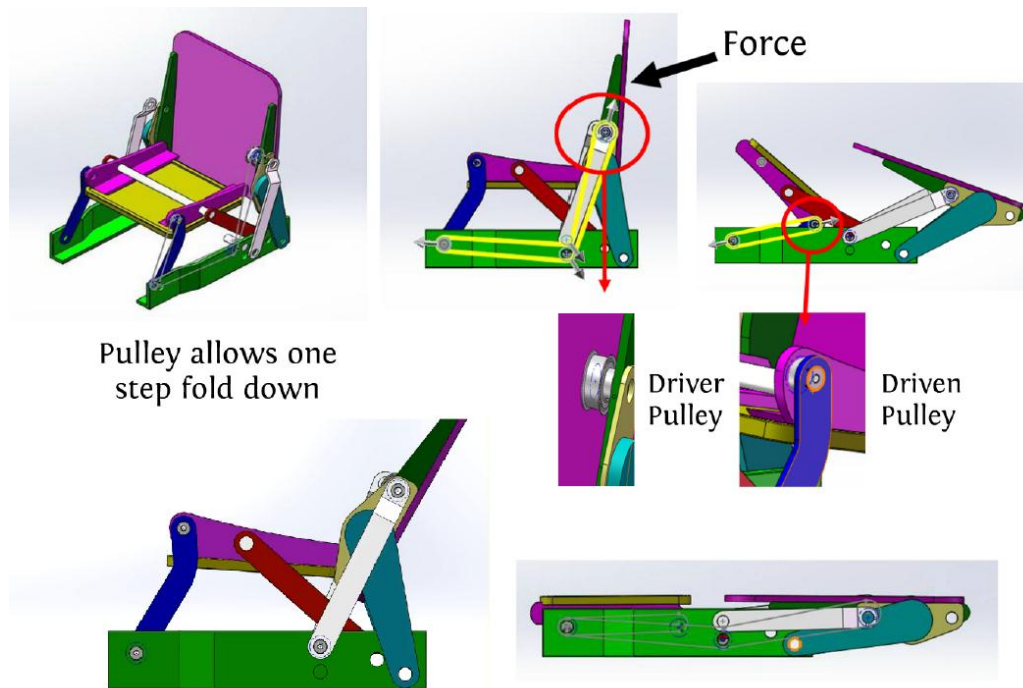


Figure 5.6 Final Design Iteration 2 (Chosen Design)

Another iteration that was developed that made it to what we may call for this purpose “the finals” was iteration two. This iteration consists of pulleys and belt to have the one step operation. This iteration was the outside the box thinking. No similar function is known to be currently in the market for seat manufacturing.

Pugh Analysis

Our comparison basis for our two iterations was based on the decision matrix that the company had already set up for their design process. This method was the pugh analysis as seen in figure 5.7 which shows our comparison for iteration one and two.

PUGH ANALYSIS TABLE				
Alternatives	weight	Baseline	Iteration 1	Iteration 2
space available	10	0	1	1
modernity and progress	9.2	0	0	1
easy to operate	8.4	0	1	1
environment	7.5	0	1	1
strength/safety	6.7	0	1	0
length of life mechanism/warranty	5.9	0	1	0
weight	5.1	0	0	0
Appearance/styling	4.3	0	-1	1
intuitive operation	3.5	0	1	1
leveraged components	2.6	0	0	0
BSR buzz, squeeze and rattle	1.8	0	0	0
ease of JIT assembly	1	0	0	0
			2	1
TOTAL			37.7	42.9

Figure 5.7 Pugh Analysis

5.3.2 FEA

In all of our CAD models we needed to do a motion analysis to make sure it was a possible idea, and that it would at least run on computer. After running motion analysis on some models we had to go back and iterate those since in the motion analysis the model would show conflicts.

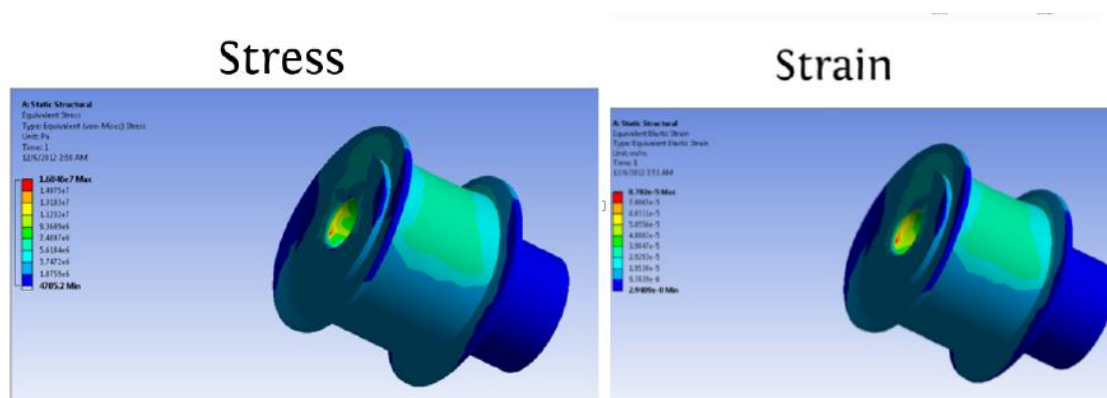


Figure 5.8 Our ANSYS Tests

In order to better represent our design we had to do structures testing to provide the company with a good pitch for this idea. The main concert with iteration two was that pulleys and belt were not currently being used in the market, which would lead to the question of life and reliability of the product.

For this we did research on similar designs and then compared our ANSYS results shown in figure 5.8, for validation of our tests. We can see the sample test from the online study in figure 5.9.

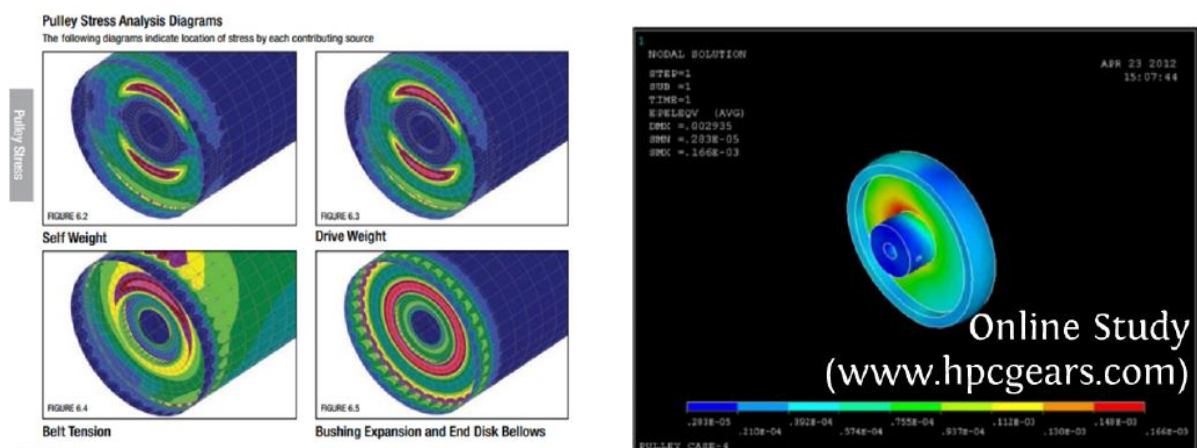


Figure 5.9 ANSYS Results From Online Study

The study from hpcgears was mainly an application for large production lines where they were testing the pulleys and belts with different materials to see if they would be able to run with a cheaper material.

5.3.3 Cost Analysis

After having a design that was innovative but at the same time would raise questions, we needed to present the company with everything possible for them to be able to do a good comparison of the different models. So we decided to research the proposed cost of such mechanism with this innovation implementation.

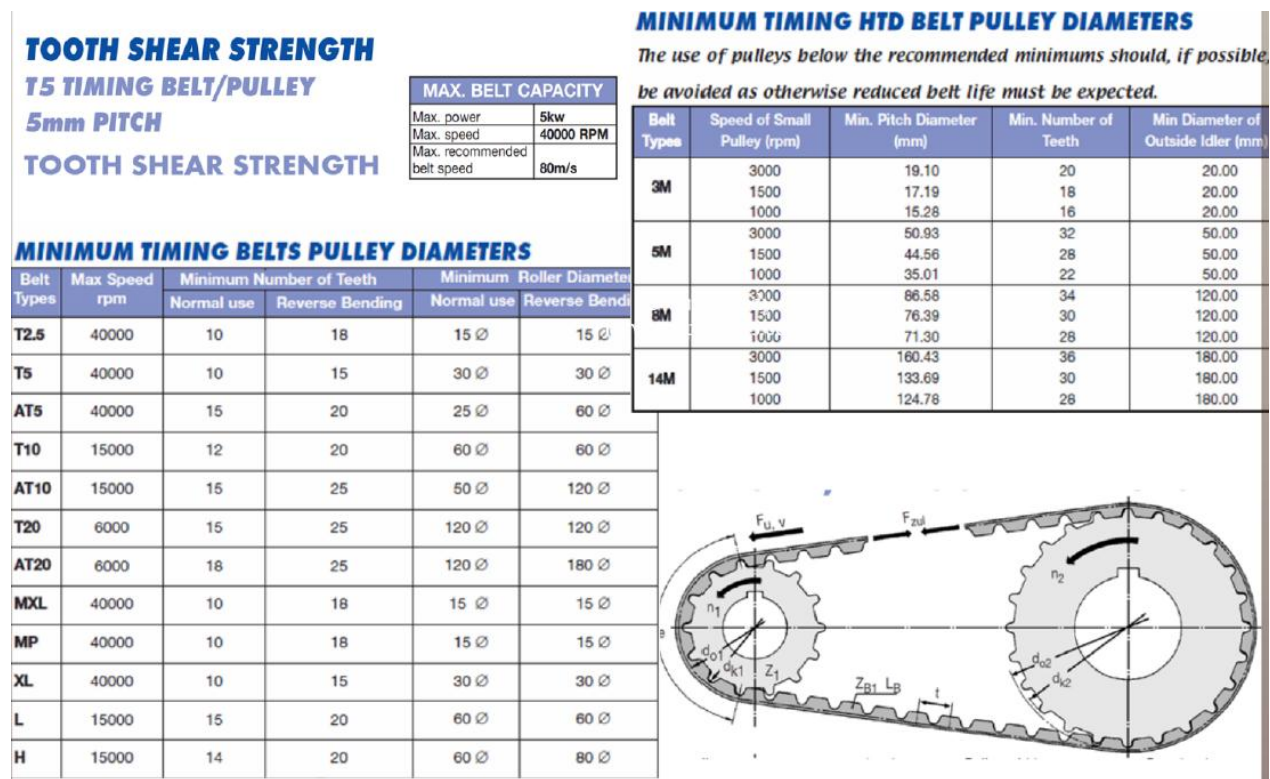


Figure 5.10 Belt Selection Charts

After doing some research we were able to come up with the proposed option for the sizes and belts needed for the design. This was also necessary to be able to come up with the cost

analysis. As shown in figure 5.10, we can see the available options for the needed force capabilities of the mechanism.

Pulley Type	Material	Cost
T5 Timing Belt Pulley	Aluminum Alloy	19 RMB
HTD5 Timing Belt Pulley	Aluminum Alloy	20.29 RMB
T5 Timing Belt Pulleys	AISI 1045 Steel	23 RMB
HTD5 Timing Belt Pulley	AISI 1045 Steel	23 RMB

Belt Type	Material	Strength	Cost
T5 Timing Belts Pitch 5mm	Nylon Covered, Fiberglass Reinforced, Neoprene	800N/mm	11.7 RMB
HTD5 Timing Belt Pitch 5mm	Nylon Covered, Fiberglass Reinforced, Neoprene	1440N/mm	9.67 RMB (available in higher quantities)

Figure 5.11 Cost Analysis Chart

We researched and called several suppliers in the area to get quotes for the specific options that we had available for the specifications of our mechanism and made a cost analysis chart as shown in figure 5.11. After this we concluded that the best option was the HTD5 Timing Belt Pulley for 20.29 RMB along with the HTD5 Timing Belt Pitch 5mm for 9.67 RMB.

Chapter 6. Conclusion and Recommendations

The main constrain while doing the project was the limited time provided. By the time the group finally had a feasible idea it was necessary to learn the CAD software CATIA. All members were not familiarized with the software and were not able to use any other because that was the one utilized by the sponsor company. Johnson Controls was extremely supportive in the issue but still was a struggle with the time frame provided.

Additionally, the language barrier resulted to be a great challenge. The group was able to overcome this obstacle, however slowed down the productiveness during meetings and presentations. Luckily the advisor provided by Johnson Controls spoke perfect English and the communication was not an issue there.

The communication between the company and Johnson Controls turned out to be very efficient. The team visited the company every week and sometimes twice a week and the meetings lasted sometimes more than four hours. The advisors and engineers from the company were extremely helpful and worked very closely with the team of students.

The group is very pleased with the project results and hopes Johnson Controls is as satisfied. The group also hopes the company sponsors more WPI and SHU student projects in the future. Johnson Controls is a great place to work for and we feel honored to have had the opportunity to contribute in their everyday success.

Chapter 7. References

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Chapter 8. Appendix A

8.1 Chart Score Explanation

Space- represents how much cargo space is available after seat is folded

Environment- is the adaptability of the mechanism to be used in various models or vehicles.

Easy to operate- how many steps or effort is required to fold seat

Appearance/Styling- how smooth the design looks and how well it hides the mechanisms

Intuitive operation- how easy it is for someone to operate it, without having seen or read anything about it beforehand

BSR buzz, squeeze and rattle- how much noise the mechanism makes and how well it fits

Ease of JIT assembly- how many previous parts available at JC are used

Chapter 9. Appendix B

9.1 Mechanism Concepts

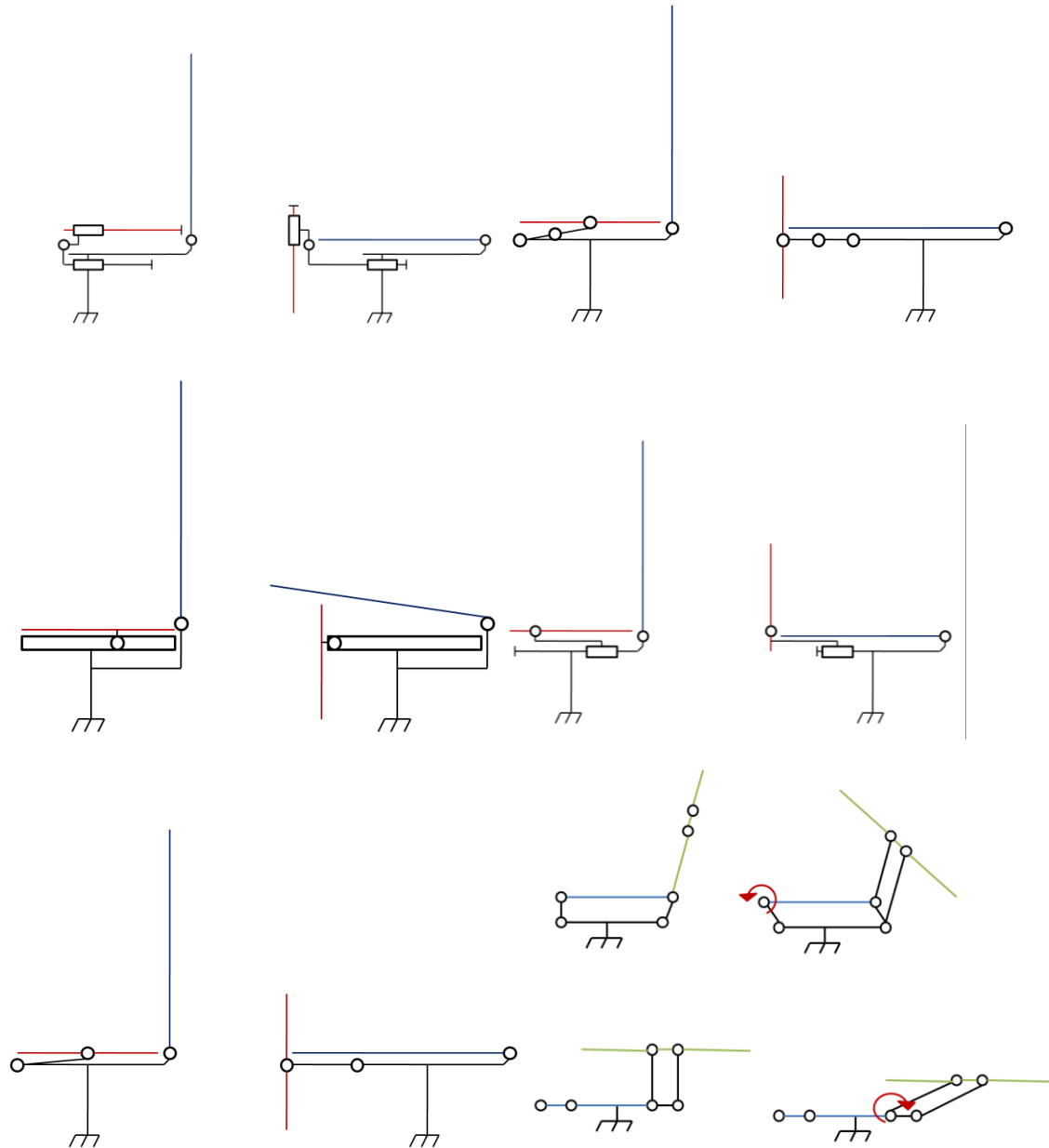


Figure 9.1 Mechanism Concepts

9.2 Design Iterations

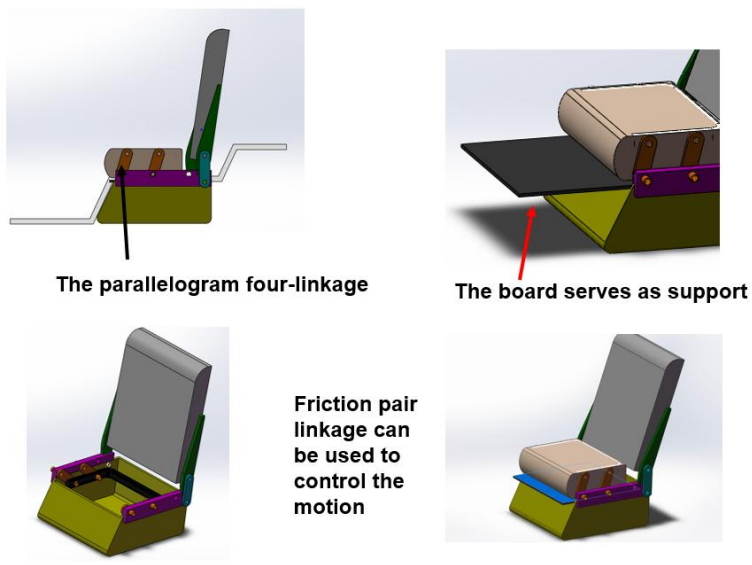


Figure 9.2 Box Iteration 1

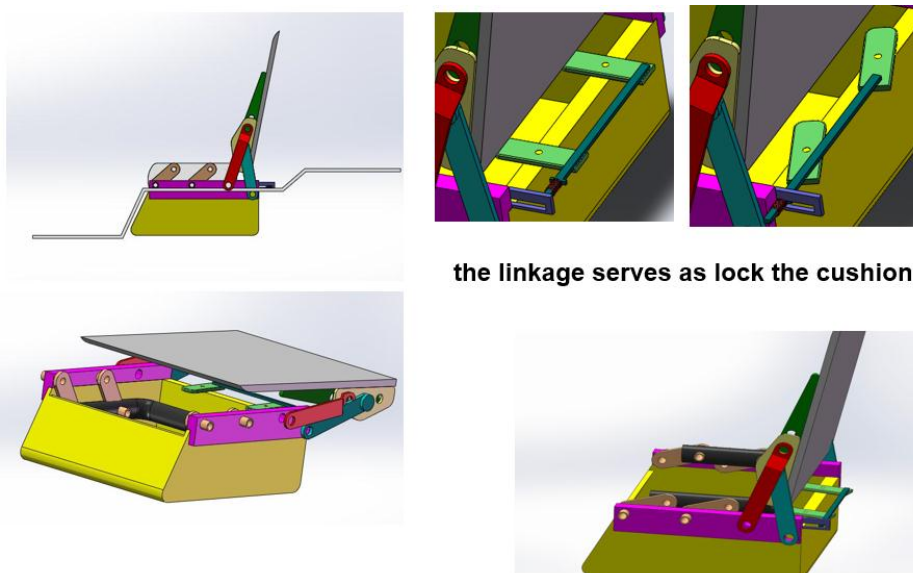


Figure 9.3 Box Iteration 2

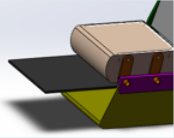
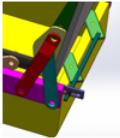
	Advantages	Disadvantages
Iteration 1 	Simple Low cost Stronger	Board
Iteration 2 	Easy operation Adaptability Space	High cost Complex

Figure 9.4 Box Concept Comparison

Chapter 10. Appendix C

10.1 Seat Basic Specs

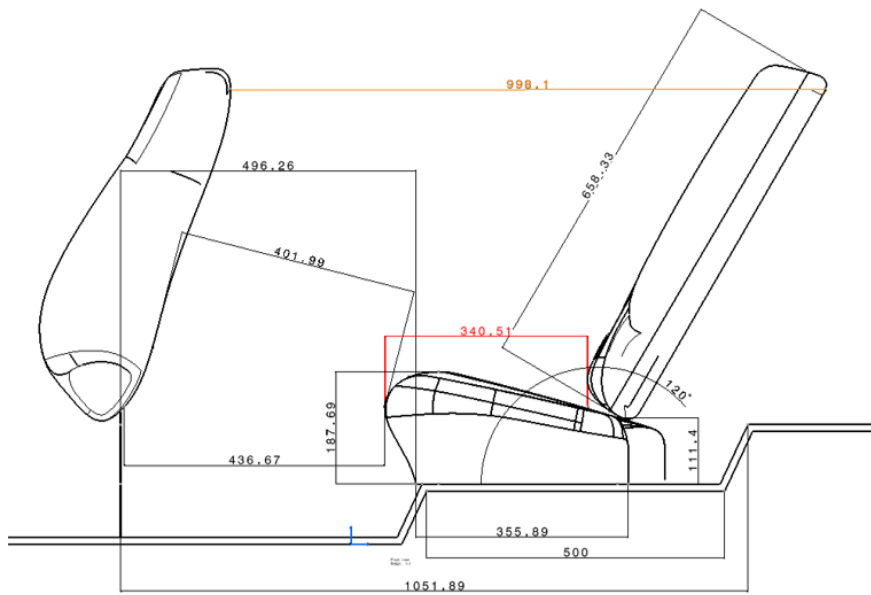


Figure 10.1 Seat General Specifications

Chapter 11. Appendix D

11.1 Project Gant Chart

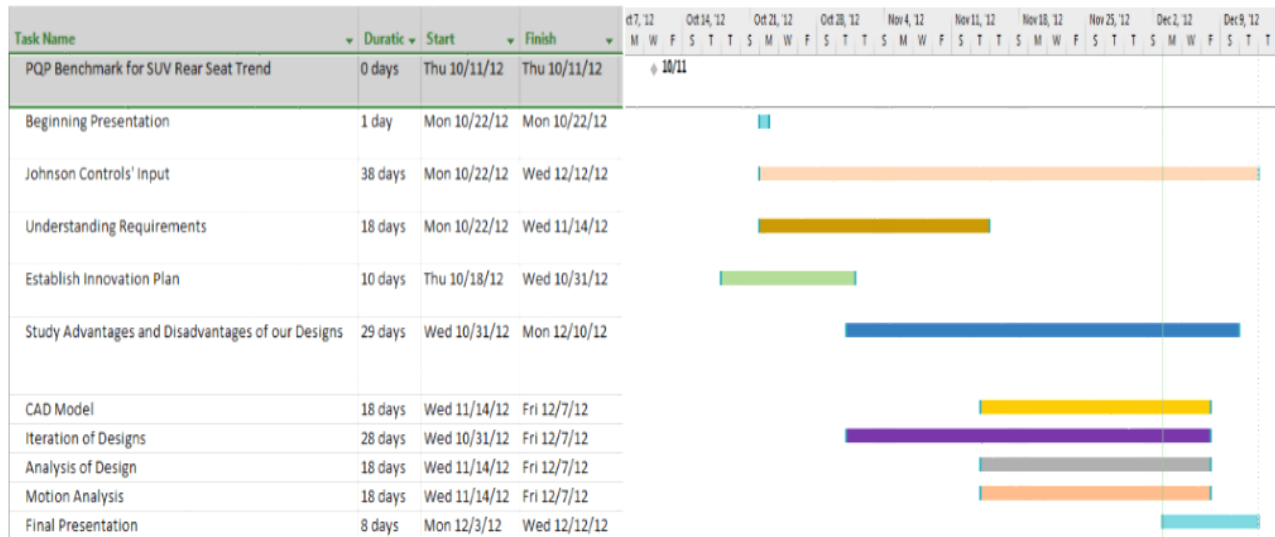


Figure 11.1 Project Gant Chart