Environmentally Friendly Driver Seat
Final Report

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EXECUTIVE SUMMARY

With the rising cost of oil and the recent scientific consensus concerning the threat of global climate change, environmentally friendly, or "green," vehicles are being adopted in the industry due to regulatory and market forces. These "green" vehicles are made unique by having an alternative fuel drive train. In the near future, the rest of the automobile will be made "green" as well, such as the vehicle interior. The area of focus for this project is the driver seat.

The purpose of this project is to define what "green" means to the target demographic and integrate this into a design that conveys that message. Our target demographic is young adults who are most likely to consider the environmental impact of a vehicle. Environmentally friendly can mean many things, such as recyclable, renewable, and fuel efficient. We will focus on elements that make up one environmental message, which is "make a mark, leave no trace." This message was chosen after completing a market research survey. The survey found that the target demographic was interested in simple designs that have as little of an environmental impact as possible. The "make a mark, leave no trace" story means that we will focus on making an impact by using these unique seats, but leaving no waste or by-products that can have negative consequences for the environment.

From this point, we selected a set of materials and generated numerous concepts that satisfy our engineering considerations as well as fit our environmental message. For inspiration for the designs we consulted "green" designs from other industries such as clothing and furniture. Consumers must recognize the final design as being environmentally friendly from the look of the seat alone.

The materials that we selected are not all ready to be implemented right now, but will be in the future. The frame of the seat is a bio-based composite that we invented for this specific application. It has a very low environmental impact while being very strong. The design also uses recyclable foam and bamboo fabric.

Driver seats are required to meet a wide range of federal regulations. Since this is a concept seat and we are not looking to implement it in the near future, we used a simplified set of strength requirements. The final design can withstand prescribed forces in the forward and rearward directions as well as at the seatbelt anchor points and in the padding at the front. Cost is not a major focus, but materials were selected to keep costs reasonable.

The team validated the effectiveness of the design with a few different methods. The environmental requirements were validated by gathering information about the selected materials. The visual requirements were validated by giving a survey to the demographic about the final design, which showed that the majority of people thought that the design looked environmentally friendly. Strength requirements were validated by using Finite Element Analysis.

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1. ABSTRACT

We have developed and prototyped an automotive driver seat concept that meets structural requirements, has as many renewable and biodegradable parts as possible and has a design aesthetic that conveys an environmental story. The seat must follow an environmental message that we created, which is "Make a mark, leave no trace." This means that the seat will leave as little environmental damage as possible while giving the user an opportunity to make a statement. The structural requirements have been simplified to a forward, rearward, cushion, and two seatbelt anchor loads. The intent of the environmental focus is to design a novel seat that has components that are environmentally friendly. One of the goals is to define what an environmentally friendly product means to our market, young adults. The design aesthetic conveys the environmental message. Our main goal is the successful integration of the environmental, structural, and design aesthetic requirements.

2. INTRODUCTION AND PROBLEM STATEMENT

Our team is made up of four senior mechanical engineering students from the University of Michigan. The team is being advised by Dr. Lalit Patil and Professor Steve Skerlos from the Michigan faculty. The project is sponsored by Lear Corporation.

Lear Corporation was founded in 1917 and is currently the 2nd biggest automotive seating company in the world. Lear ranks 130 on the Fortune 500 list of companies. Over 90,000 employees are employed at 236 facilities in 33 countries. Lear is interested in this project because they want to see a fresh approach to the future of seating. They are interested in any idea that could potentially be used in the future. Lear has provided valuable advice to the team. Notes from our initial meeting can be found in Appendix A.

The core of our team is Lindsay Klick, Nidhi Shah, Yen-chien Wang, and Aaron Williams. Lindsay Klick is our team contact person. She is responsible for communicating with the faculty advisors and sponsor. Nidhi Shah is our treasurer. She is responsible for keeping track of team finances. Yen-chien Wang is our facilitator. He keeps members on task during meetings and will guide discussion when we stall. Aaron Williams is the team scribe. He is in charge of keeping notes at meetings. All team members share design and analysis duties.

We have developed and prototyped an automotive driver seat concept that best meets our customer requirements. Our deliverables include the design of a future driver seat which has an environmental message and also a collection of prototypes that demonstrate its novel features.

3. INFORMATION SOURCES

We gathered information before we started the design process. We found different structural regulations that the seat would need to comply with, as well as benchmarked to find different environmentally friendly products on the market today, not necessarily automotive driver seats.

3.1 Government/Industry Regulations There are some structural requirements that have to be met due to government and industry regulations on driver seats. These regulations demand the seat to be able to withstand certain loads applied in different directions to different parts of the driver seat. The standards are as follows:

1) Seat must withstand a force 20 times the seat's mass applied through the seat's center of gravity horizontally in the forward direction. (Federal regulation FMVSS 207) [1]

2) The inboard seatbelt mounting point has to be able to hold 13,500 N of force and the outboard seatbelt mounting point has to be able to hold 6,750 N of force. (Federal regulation FMVSS 210) [1]

3) A torque of 745 Nm applied rearwards about the occupant's hip-point results in a permanent deflection of no more than 5 degrees. (Industry standard provided by the sponsor) [2]

4) 1110 N load applied vertically downwards through a 127mm diameter hemisphere into the cushion does not damaging the seat. (Industry standard provided by the sponsor) [2]

3.2 Benchmarking We studied environmentally friendly products from other industries to provide guidelines for how to approach the design problem. We also continued to research more products throughout the project. The application of environmentally friendly materials and visuals that convey environmental messages were the focus. Figure 1 below is a bean bag seat made of hemp and recycled foam [3]. Instead of using ordinary materials, the product can be made environmentally friendly by using materials that have smaller impacts on the environment.

Figure 1: Bean bag seat made from hemp and recycled foam

Some materials are recognized as being environmentally friendly. By showing these environmentally friendly materials to the consumer, the product then can be easily recognized as environmentally friendly as well. An example is Fig. 2, a chair made of rattan [3]. This chair is recognized as a “green” product because of the material.

Figure 2: A chair made of rattan

“Green” products are expected to have different impacts on the environment. These differences can be translated into the appearance helping to convey the products’ environmental messages. Figure 3 below is a Honda motorcycle [3]. It appears environmentally friendly even if the technical details are not known. With an obvious visual difference, it is easy to advertise the motorcycle to make the connection to its environmental impact. We need to achieve the same connection with the driver seat.

Figure 3: Unique Honda motorcycle

One material that is in a lot of our research is bamboo [4]. Bamboo is very strong and grows very quickly with a small environmental impact. We were sure to include bamboo in the materials that we considered during the material selection process. A bamboo char is shown in Fig. 4 below.

Figure 4: A chair made from bamboo stalks

Another element that we would like to include in our design is unique stitching. We have seen many products that stand out because of their stitching [5]. Figure 5 below is an example of an everyday item that is unique because of its patterns and stitching. This could easily be implemented in our seat.

Figure 5: Unique stitching makes this pillow stand out

3.3 Survey Results In order to collect information about our target demographic, we conducted an online survey. The survey was distributed to University of Michigan students of all class levels who are studying numerous subjects. The complete results can be seen in Appendix B. We learned that consumers are interested in simple designs that are curvy and thin. One of the results from the demographic survey was the way people want their environmentally friendly product to look. The majority of those surveyed responded saying they wanted environmentally friendly products to look just like their standard counterparts. Another important result was that the consumers want the seat to have as much of a positive impact on the environment as possible. There were many students who were resentful of "green washed" products. These results guided us in concept generation and selection.

We distributed a second survey to judge how successful our design is at communicating our environmental message. The results from this survey will be discussed later.

4. CUSTOMER REQUIREMENTS AND ENGINEERING SPECIFICATIONS

Due to the open-endedness of the project, some of the customer requirements are vague. The purpose of the vagueness is so that we can define certain requirements ourselves rather than be limited by subjective parameters. Examples of these customer requirements are to choose materials that are environmentally friendly and a design that displays the environmental message. The meaning of these two requirements is to be defined by our own creativity and brainstorming. We decided through brainstorming and discussing what exactly "environmentally friendly" means, whether it is recyclable, recycled, renewable, low impact, or any combination of those.

The customer requirements were divided into three levels depending on their relative importance. Level 1 includes the requirements that are absolutely necessary. These are the following: environmentally friendly materials, design aesthetic that conveys environmental message, and meet structural requirements and regulations. These three main sets of requirements are the basis for the project and are to be equally weighted during the development process. Level 2 is defined as requirements that are important but not the key components of the project. The intent of these levels is to create a context in which to be creative. Level 3 are customer requirements that could be taken into consideration but are not meant to limit the creativity in the design and materials chosen for the project. These requirements are intended to provide a context for creativity. Table 1 shows the customer requirements divided into the three priority levels. Each requirement has a letter next to it to easily identify it when relating the engineering specifications to it.

Level 1	Critical to Project
a	Environmental
b	Look of Chair Tells Environmental Story
c	Meets Strength Requirements
Level 2	High Priorities
d	Appeals to Young Adult, Young Professional Demographic (Gen. Y)
e	Looks Innovative/New/Fresh
f	Fits People Between 5th and 95th Percentile Size
Level 3	Lower Priorities, Not to Hinder Creativity and Innovation
g	Weighs Less Than 20kg
h	Ability to be Comfortable
i	Budget / Cost of Chair
j	Easily Deconstructed
k	Fits Small-Medium Car

Table 1: Customer Requirements

Once the customer requirements were arranged based on priority, we converted those into engineering specifications. The engineering specifications serve as guidelines for what the product needs to accomplish from an engineering standpoint. Not all of the specifications can be quantified, but those that are quantifiable have the values listed.
In order to prioritize the engineering specifications, they were each compared to the customer requirements. For each requirement to which a specification is related, the corresponding letter was placed next to the specification. For example, if a specification related to the first requirement in Table 1 (requirement "a") then the letter "a" was put next to that specification. Next, points were assigned to each engineering specification based on which customer requirements related to it. If a specification related to a requirement from Level 1, it was given three points. For Level 2, two points were given. For Level 3, one point was given. These points were then added together and the

engineering specifications were prioritized from highest points to lowest points. Table 2 lists all of the engineering specifications based on priority, along with which requirements relate to each specification.

Engineering Specification	Relation to Requirements	Points
Composed of Renewable Resources	a,b,d,e,h,i	12
Composed of Recycled/Recyclable Materials	a,b,d,e,h,i	12
Design Conveys Environmental Message/Theme	b,d,e,i,j,k	10
Design Appeals to Target Demographic	b,d,e,i,k	9
Uses Advanced Materials for Strengths	a,c,g,i	8
Seat Size Should Fit 5^{th} through 95^{th} Percentile of People	f,h,k	4
Weighs Less than Standard Seat of 20 kg	a,g	4
Easily Separable Parts	a,j	4
Handles Inboard Seatbelt Load 13,500 N with 20% Safety Factor	c	3
Handles Knee Load of 1110 N downward through 127mm Diameter Hemisphere into Cushion without Damaging Seat with 20% Safety Factor	c	3
Handles Rearward Torque of 745 Nm about H-Point with <5 Degrees Permanent Deflection with 20% Safety Factor	c	3
Handles Outboard Seatbelt Load of 6,750 N with 20% Safety Factor	c	3
Handles Forward Load of 20 Times the Load of the Seats Weight at Center of Gravity with 20% Safety Factor	c	3

Table 2: Engineering Specifications

The relationships between engineering specifications are important. Two or more specifications can compete with each other or enhance each other, depending on how they are applied to the product design. From Table 2, we can see that several of the engineering specifications relate to each other. If two or more engineering specifications relate to the same customer requirement, then these specifications can affect how the others are incorporated in the product. For example, strong materials are important in order to satisfy the strength requirement, and recyclable materials are important to satisfy the environmental requirement. Strong materials can be environmentally friendly and recyclable materials can be strong, so they both relate to two of the same requirements. But there can be tradeoffs between related engineering specifications. A strong material may not be environmentally friendly or a recyclable material might not be strong enough. The product needs to meet strength requirements but it also needs to be environmentally friendly so there has to be a balance between the two specifications. As a result, a compromise has to be met between relating engineering specifications. Table 2 allows us to easily identify the relationships between specifications based on which customer requirements relate to them and as a result we can plan better how to approach them. A complete display of the interdependencies in our requirements is shown in Table 3 below.

The table shows all of the engineering specifications in a matrix. Specifications that are strongly related are marked with an X. Those that are only weakly related are marked with an O. If there is no relation, there is no mark at all. This table will help us when we consider different design possibilities.

	Renewable	Recycled(able)	env. Msg.	target demog.	adv. Mat.	5-95% size	weight <20kg	easy separate	IB SB load	knee load	deflection	OB SB load	forward load
Renewable		X	X		X		O		O	O	O	O	O
Recycled(able)			X		X		O		O	O	O	O	O
env. Msg.				X	X		X	X					
target demog.							X						
adv. Mat							X		X	X	X	X	X
5-95% size							X						
weight <20kg									O	O	O	O	X
easy separate									O	O	O	O	O
IB SB load										X	X	X	X
knee load											X	X	X
deflection												X	X
OB SB load													X
forward load													

Table 3: Many Engineering Specifications have an effect on each other.

5. CONCEPT GENERATION

In order to generate concepts, we first decomposed our problem in order to understand the functions of the chair. We brainstormed materials and designs and arranged them into a morphological chart. Also, in order to create designs, we defined an environmental story that we want the seat to tell. The message we chose is “make a mark, leave no trace.” This means that the seat should be made from materials that are either recycled or renewable, and when the chair has been through its life cycle, it can be recycled or biodegraded. The “make a mark” portion encourages the consumers to make a personal statement by helping the environment and standing out from the crowd by using this unique seat. We generated a list of concepts and chose the best five. All of the concepts can be found in Appendix C.

5.1 Problem Decomposition The problem decomposition for the driver seat is different from most functional decompositions in that there is no flow of energy, mass, or signals. As a result, no outputs come from the seat. There is also no sequential order of events or actions within the seat.

Instead, the functions in the seat are broken up by the overall system to which they belong. These systems are comfort, support, protection, durability, and appearance. Each of these systems includes the functions that are supposed to be accomplished in order to achieve a good seat design.

There are several inputs for the seat design, most of which are different from those in usual functional decompositions. The human input is what defines most of the seat's design since it has to fit the human and be supportive, comfortable, safe, and visually appealing. The impact forces, torque, impulses, and pressure inputs define the structural requirements that the seat needs to be able to achieve. The seatbelt input needs to be safe, affects the physical design of the seat, and relates to some of the structural requirements. The surroundings refer to the overall car and relate to spatial and durability effects on the seat. The visual input defines the look of the seat and how it portrays the environmental theme.

Each input relates to one or more of the systems previously mentioned. Figure 6 below shows the relationships between the inputs and the systems of functions.

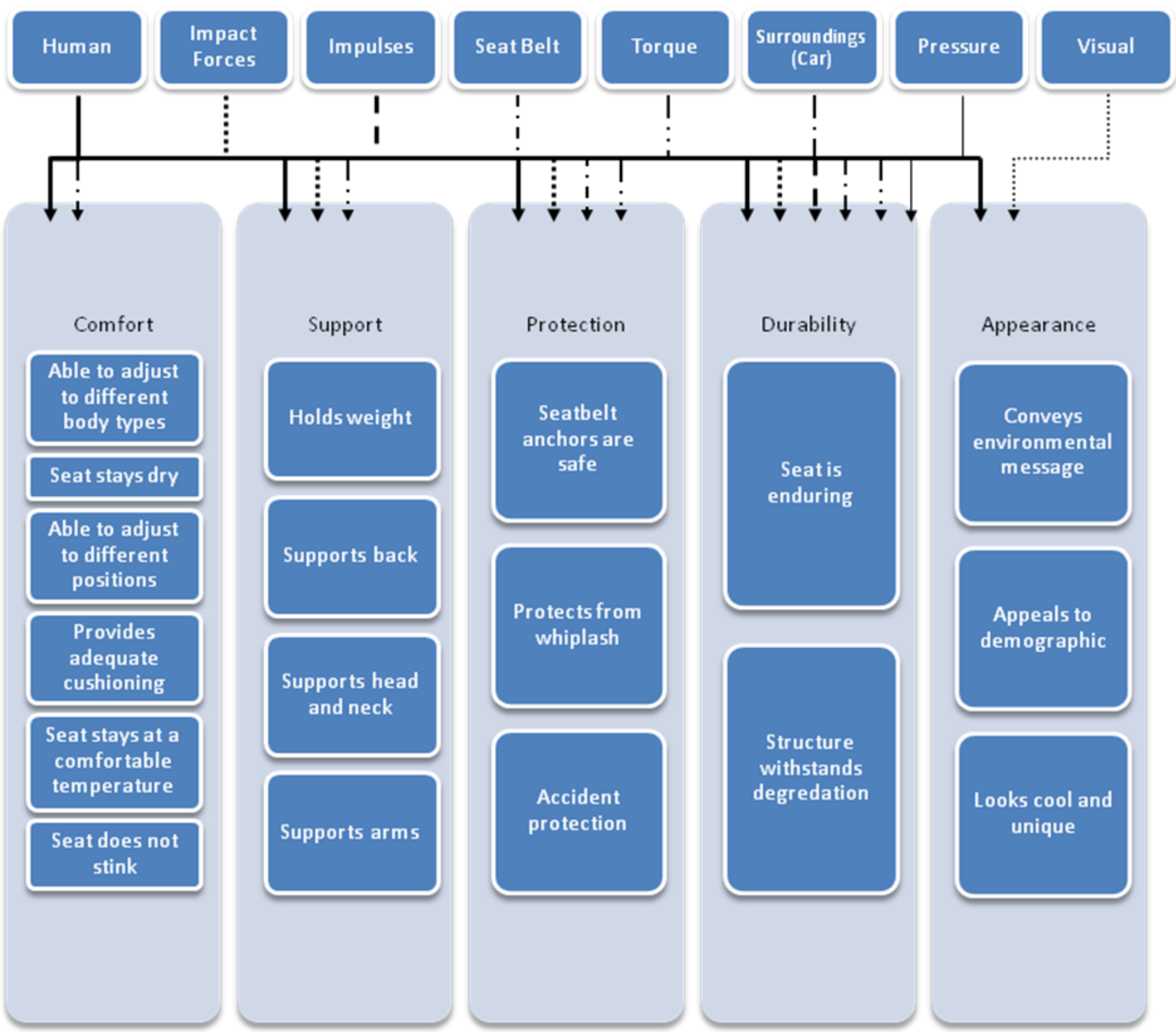

Figure 6: Problem Decomposition relates inputs to seat functions

From the problem decomposition, forms can be derived from each of the functions. These forms are how these functions are accomplished, and there can be many forms for each function; for example, there are many ways that a seat can provide adequate cushioning. There are several different materials or combinations of materials that can be used for padding.

5.2 Concept Generation Brainstorming sessions were used to come up with lists of possible ways to accomplish the functions of the seat. The results from the brainstorming sessions are organized in the morphological chart below.

In order to generate concepts, we used the chart to group different types of materials that could be used for different functions in the chair, as well as different visual design elements. The morphological chart displays a list of each of the possible solutions for accomplishing the functions of the design. For the seat, the major categories are materials and visual design. The materials include fabrics of the seat covers, structural materials for the frame, and various forms of padding. Figure 7 below shows the morphological chart. By choosing one or more items from each list, a design concept can be generated. Theoretically, tens of thousands of concepts can come from these lists alone.

Fabric

- Animal Print
- Translucent
- Plastic
- Cotton
- Hemp Thread
- Patchwork
- Pleating
- Ruching
- Advanced Seam
- Potato
- Silk
- Leather
- Microfleece
- Neoprene
- Fur
- Synthetic Fiber

Frame

- Exposed Frame
- Integrated Shell (Ford GT)
- Fabric Support
- Bamboo
- Balsa
- Hydroformed
- Seat Belt Guide
- Deploying Side Restraint
- Backpack Seat Belt
- Cement
- Ceramic
- Springs
- Wood
- Aluminum
- Steel
- Metal Alloy

Padding

- Styrofoam
- Advanced Wood Foam
- Water Pads
- Composting Chair
- Cotton
- Green Tea Leafs
- Cardboard
- Latex
- Rubber
- Cork
- Recyclable Foam
- Shredded Recycled Tires
- Air (Changing Support)
- Sponge
- Memory Foam
- Lumbar Support
- Drive Number (TM)
- Temperature Control
- Bean Bag
- Indratech

Visual Designs

- Lily Pads
- MIB Pod Chair
- Bright Color
- Lava Lamp
- Ambient Lighting
- Lighted Seat
- Rope Lights
- Whoopy Cushion
- Holes
- Simple
- Hand Chair
- Lip Chair
- Banana Chair
- Interrogation Chair
- Bicycle Chair

Figure 7: Morphological Chart organizes all of the concepts

Every idea was recorded regardless of relevant that idea was to our chair. This way we were easily able to think outside the box and come up with more innovative ideas.

5.3 Concept Sketches After brainstorming the lists of material and design concepts, several sketches were generated. The main features of each sketch were discussed and then the top five design concepts were chosen. The top five concepts are shown and described below. The rest of the concepts are listed in Appendix C.

The concept shown in Fig. 8 was chosen for its simplicity and versatility. Features that were most liked were the ambient lighting (denoted with blue shading) and the exterior structural component seen in the side view. One of the results from the demographic survey was the consumer wanted their environmentally friendly product to look just like their standard counterparts, and this concept looks most like a regular seat while still looking innovative and fresh. This concept uses ambient lighting, exposed frame, and lumbar support from the morphological chart.

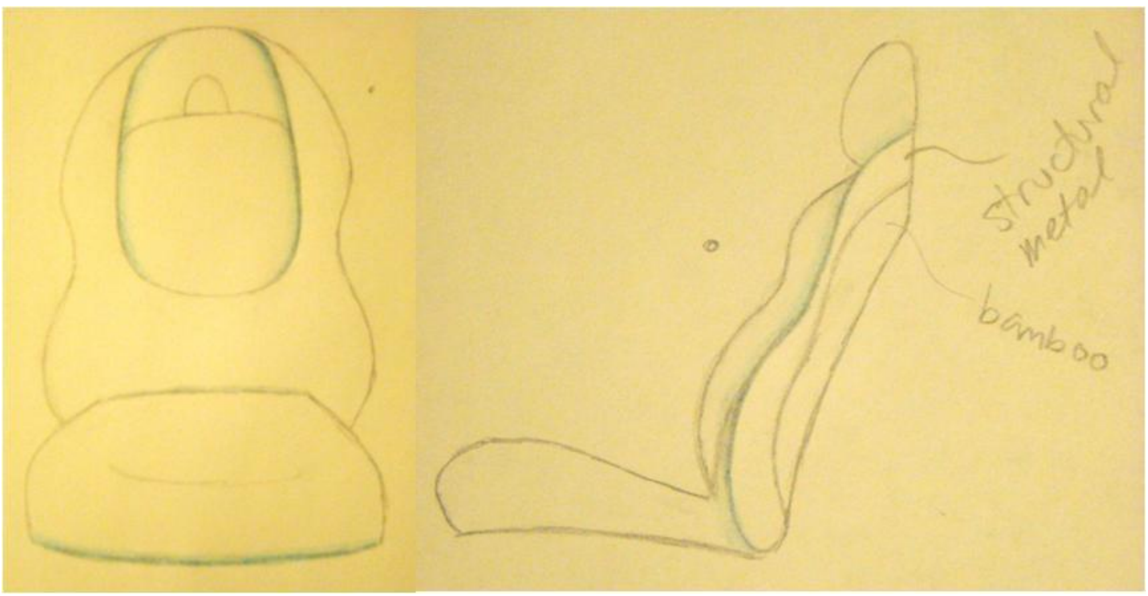

Figure 8: Concept 1 – Ambient lighting

The design shown in Fig. 9 was chosen for the holes, heated and cooled headrest, and low material volume. The holes create a light and airy look, which according to our survey was found to appear environmentally friendly. The lower the volume of material, the more environmentally friendly a product looks because of low material consumption. The heated and cooled headrest was chosen because it is more efficient at making a person feel warm or cool than the regular HVAC system, requiring less energy consumption to attain the same feeling of heating or cooling. This concept uses holes, aluminum, and memory foam from the morphological chart.

Figure 9: Concept 2- Holes

The concept in Fig. 10 was chosen for its simplicity. It has the simplest design and the survey results show that this is what the demographic wants. It has integrated padding for comfort and minimal material consumption. This concept uses simple design, steel, and interrogation chair from the morphological chart. This concept was seen as the most environmentally friendly from our focus group because of how thin and simple the design is.

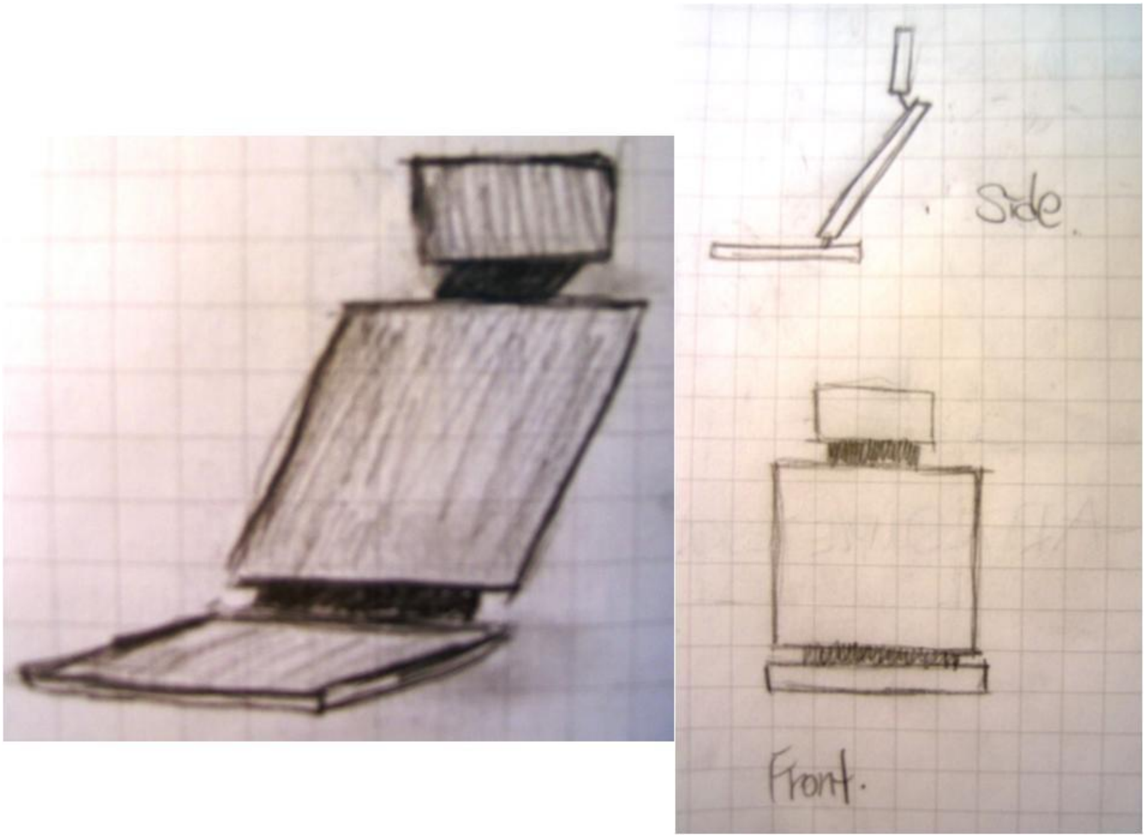

Figure 10: Concept 3 - Simple

Figure 11 shows the next design which was chosen for its bold color scheme and unique symbol. The survey results showed that some people liked bright colors, even for environmentally friendly products. Most current seats are more subdued colors, so bold, bright colors would be a fresh way to differentiate between current seats and the new environmentally friendly seat. The symbolic headrest is also a reason this concept was chosen. It less subtly shows the environmental theme so it gets the point across. This concept uses bright colors, recycled foam, and the recycle symbol from the morphological chart.

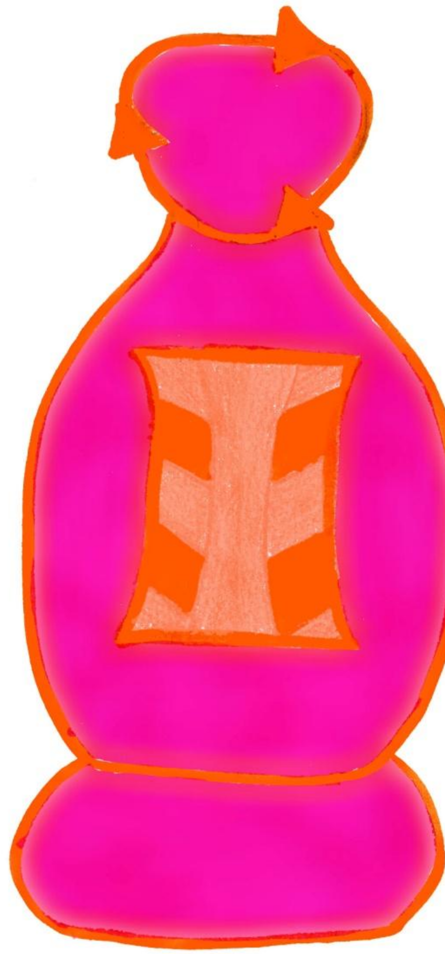

Figure 11: Concept 4 – Bright seat

The concept shown in Fig. 12 was chosen because of its unique fabric pattern and integration of bamboo. Bamboo is one of our favorite ideas for added structural stability and support as well as being environmentally friendly. It also has wide shoulder padding for added comfort. This concept uses bamboo, recycled foam, and unique stitching from the morphological chart.

Figure 12: Concept 5 – Unique pattern

6. CONCEPT SELECTION

In order to choose the best concept to create our alpha design, we created a Pugh Chart to compare the concepts. This tool helps us assign points to each concept and find the one that works best. For the weighting, we assigned 10 points to the most important criteria, 5 points to the important criteria, and 1 point to the less important criteria. There are two Pugh charts, one for design and one for materials. The Pugh charts are shown in Table 4. To find the material properties we used CES software [6].

Design Criteria	Weight	Ambient lighting	Holes	Simple	Bright Seat	Unique Pattern
Design Conveys Environmental Message/Theme	10	0	0	1	D	-1
Visually Apealing	10	1	-1	-1	A	0
Thin and Sleek	5	1	-1	1	T	0
Curvy Smooth Lines	5	2	-1	-1	U	0
Versatility	5	2	-1	1	M	0
Simple Design	5	1	0	2		-1
Weight	1	1	2	2		0
Easily Separable Parts	1	0	-1	1		0
TOTAL		41	-24	18	0	-15

Design Criteria	Weight	Aluminum	Steel	Bamboo	Cork	Hemp Mesh
Strength (Tensile and Shear)	10	D	1	-1	-2	-2
Environmental Impact	10	A	0	2	2	2
Design Conveys Environmental Message/Theme	5	T	0	2	2	2
Weight	5	U	-1	1	2	2
Durability	5	M	0	-1	-2	-2
Easily Separable Parts	1		0	-1	-1	1
Cost	1		1	2	3	2
TOTAL		0	6	21	12	13

Table 4: A Pugh chart is used to select the best design

Using the Pugh chart, we decided to use the ambient lighting chair as our base design, modifying it to create the alpha design. The materials chart will help us later during material selection and is not meant to find one supreme material. One specific material is not chosen, since we will be using many in the design. Valuable information can still be gained from comparing the different materials. For example, cork and hemp mesh are weaker than the metal materials, but are more environmentally friendly so they can still be used in a non-structural application.

7. ALPHA DESIGN

To create the alpha design, we started with the design that was chosen from the Pugh chart above. Then we added other elements that we liked from the other designs. This allowed us to create the alpha design, which is shown in Fig. 13.

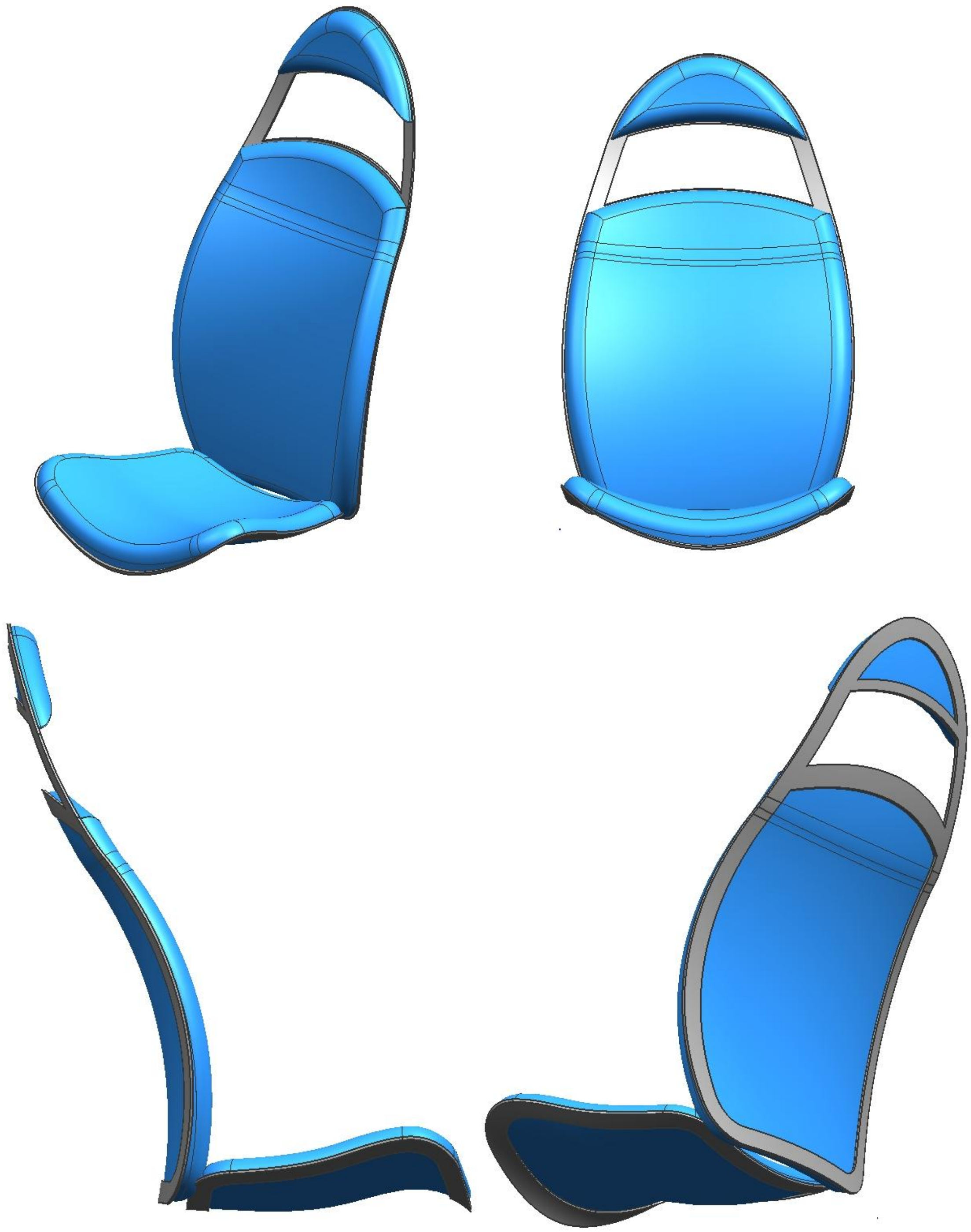

Figure 13: The alpha design uses several elements from the other designs

We chose the base design to be the ambient lighting chair in Fig.8. This seat was the most versatile, as the materials used in the chair could be changed easily. Also, the lighting in the chair made the chair look comfortable. However, the chair did not look as environmentally friendly as some of the other chairs. We wanted the alpha design to have open space in the seat back, similar to the design shown in Fig. 9. We changed the design so that the holes would be made by the construction of the chair rather than by removal of material. We also incorporated the separable nature of the Simple design, by having the visible part of the chair composed of four different parts: the seat, the backrest, the headrest, and the "frame", which would be partly on the outside in order to show the material of the frame.

Before going further with the design, we wanted to rigorously define the “make a mark, leave no trace” message. The idea is that the seat will limit the negative impact it makes on the environment. This means that we will choose materials that are renewable and that are bio-degradable at the end of their life. The main point is that the seat has a minimal environmental footprint.

The idea of ambient lighting was dropped from the final design because it did not fit with this environmental message. Since it didn’t add to the message and it would have consumed power, the idea would not have added to the overall design.

8. CONCEPT EMBODIEMENT

The alpha design is only a rough representation of the final design. The final design must have all of the dimensions clearly defined and all of the materials chosen. This is an iterative process, since making changes in one area affects others. The final design must meet all of the requirements that we have set while delivering the chosen environmental message.

8.1 Parameter Analysis Before defining all of the dimensions for the design, all of the materials were chosen. This is important for this project because the materials are the largest contributor to the overall environmental impact. The main materials that were chosen were for the structural components, the cushioning, and the fabric.

For the structural components, we started by considering fiber reinforced composites. These materials have a large range of mechanical properties. They are also lightweight, corrosion resistant, impact resistant, and have great fatigue strength. However, they tend to have very negative impacts on the environment which is not suitable for this particular project. The negative impacts are mainly caused by the difficulty in recycling them. In order to recycle composite materials, the fiber reinforcements would have to be separated from the matrix material which is very difficult and expensive. Most composites are also non-biodegradable. This means the biggest issue when using composite material is how to deal with them after their life cycle.

One solution is to use a special composite made of a bio-based resin reinforced by natural fibers. They also have a large range of mechanical properties just like ordinary composite materials. It is still very difficult to recycle bio-based composite materials but there would be little need for them to be recycled since they use renewable resources and are generally biodegradable. Bio-based composites would be a suitable framing material for this project because of their properties and low environmental impact. The material fits the engineering specifications and also the environmental message.

Through research of various types of fibers and matrix materials, we decided to combine the strongest bio-based matrix and fiber materials we could find. The end result is a composite material made of Maleinized Monoglyceride (SOMG) [7] matrix reinforced with flax fibers. At 12ºC, SOMG has an elastic modulus of 1.49 GPa and a tensile strength of 15.6 MPa. Flax fiber has a tensile strength of 1.1GPa and an elastic modulus of 27GPa [8]. This composite has never been created before; it was created by our team by choosing the two strongest bio-based composite materials.

With the material chosen, we next calculated the composite properties and the frame dimensions that worked best with the mechanical properties. We decided to have the flax fiber reinforcement woven in the pattern shown in Fig. 14 below. The fibers run in the two principal directions orthogonal to each other to maximize the tensile strength. After all of the material properties of the composite were calculated, we used the program ANSYS [9] to approximate the maximum stress on the frame under prescribed loading conditions.

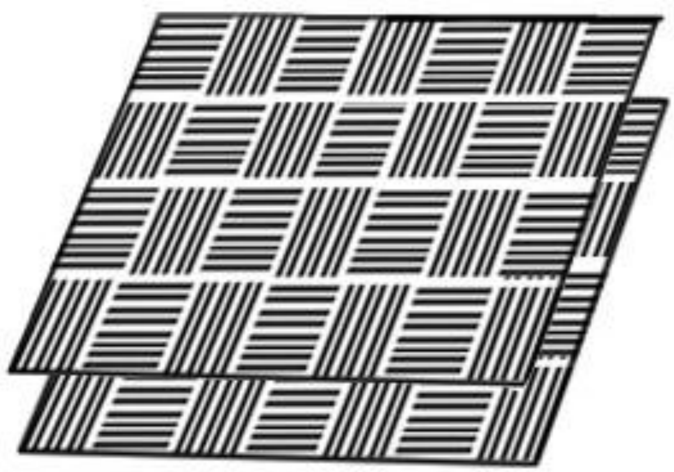

Figure 14: Sketch of the composite

Equations 1-7 were used to calculate the elastic modulus *E*. The suffix *m* refers to the matrix, while the suffix *f* refers to the fiber reinforcement. *V* is the volume fraction of each component. E_{c0} refers to the elastic modulus of the composite with the fibers arranged in the longitudinal direction, i.e. at 0 degrees. E_{c90} refers to the elastic modulus of the composite with the fibers arranged at 90 degrees. ξ is the geometry coefficient of the fiber. In our case, this number is 2 because we assume that the fibers have a square cross-section. η relates the strength of the fiber and the matrix and is used to simplify the *E* equations.

$$E_{c0} = E_m \times V_m + E_f \times V_f$$

$$E_{c90} = \frac{1 + \xi \times \eta \times V_f}{1 - \eta \times V_f}$$

$$\eta = \frac{E_f / E_m - 1}{E_f / E_m + \xi} \qquad \text{[Eq. 1-5]}$$

$$\xi = 2$$

$$E_{overall} = 0.5 \times \left(E_{c0} + E_{c90} \right)$$

To calculate the tensile strength, we assumed that the flax fiber and the SOMG matrix are perfectly compatible. It is calculated using the following equations.

$$\sigma'_{overall} = \frac{\sigma'_m + \varepsilon'_{90} \times E_{c0}}{2}$$

[Eq. 6-7]

$$\varepsilon'_{90} = 0.5 \times \left(\frac{\sigma'_m \times V_m}{E_m} + \frac{\sigma'_m \times V_f}{E_f} \right)$$

We iteratively changed the dimensions of the frame and the volume fraction of the fiber material in order to determine the design that best suits our application. By increasing the volume fraction of the fiber, we increased the tensile strength of the composite material but also increased the manufacturing cost and difficulty. Increasing the frame thickness would help us to achieve the required strength with lower fiber volume fractions. However, drastic dimension changes are undesirable because that would affect the visual design. In the end, we decided to have a composite material with 35% of fiber reinforcement by volume and a rectangular fiber cross-section to achieve the required frame strength. With these attributes, the composite is projected to have a yield strength of about 44.5 MPa and a Young's modulus of 6.9 GPa.

The rectangular cross-section of the frame is not only visually appealing but also is able to withstand the required load. Using ANSYS software, the maximum stress relevant to the design is calculated to be about 35 MPa. There are higher stresses in the structure but we are not concerned with them because they are due to the fact that we used an applied point force rather than a distributed pressure. Also, the simulation is only a rough estimate of the actual stresses. It is also important to note that this is only a concept and in the future it will be made stronger and to fit a more detailed list of federal seat requirements. From the finite element analysis, the material we have chosen will be safe to use with a 20% factor of safety. The dimensions of the cross section are 2 inches wide by 0.5 inches thick.

The shape of the seat was created with the survey results in mind. It was made to look curvy and thin. This is the overall aesthetic was requested in the survey. The curves were created using splines which makes the exact radii hard to document. This isn't a problem, though, because the frame can be made with computer manufacturing.

In order to reduce stress concentrations and eliminate any sharp corners that could cause injury, fillets were added to each corner and edge. The radii for these fillets were chosen on a case by case basis for each fillet. They were chosen to be big enough to reduce the stress concentration but also small enough to not harm the design aesthetic. Fillet radii range from 0.05 up to 0.25 inches. Certain areas of the frame require extra reinforcement in order to handle the loads applied, so support bars were added to the frame to provide extra support and also transfer the loads to other parts of the frame. A dimensioned drawing of the frame is shown in Fig. 15 below and a more complete detailed list of dimensions can be found in the CAD model.

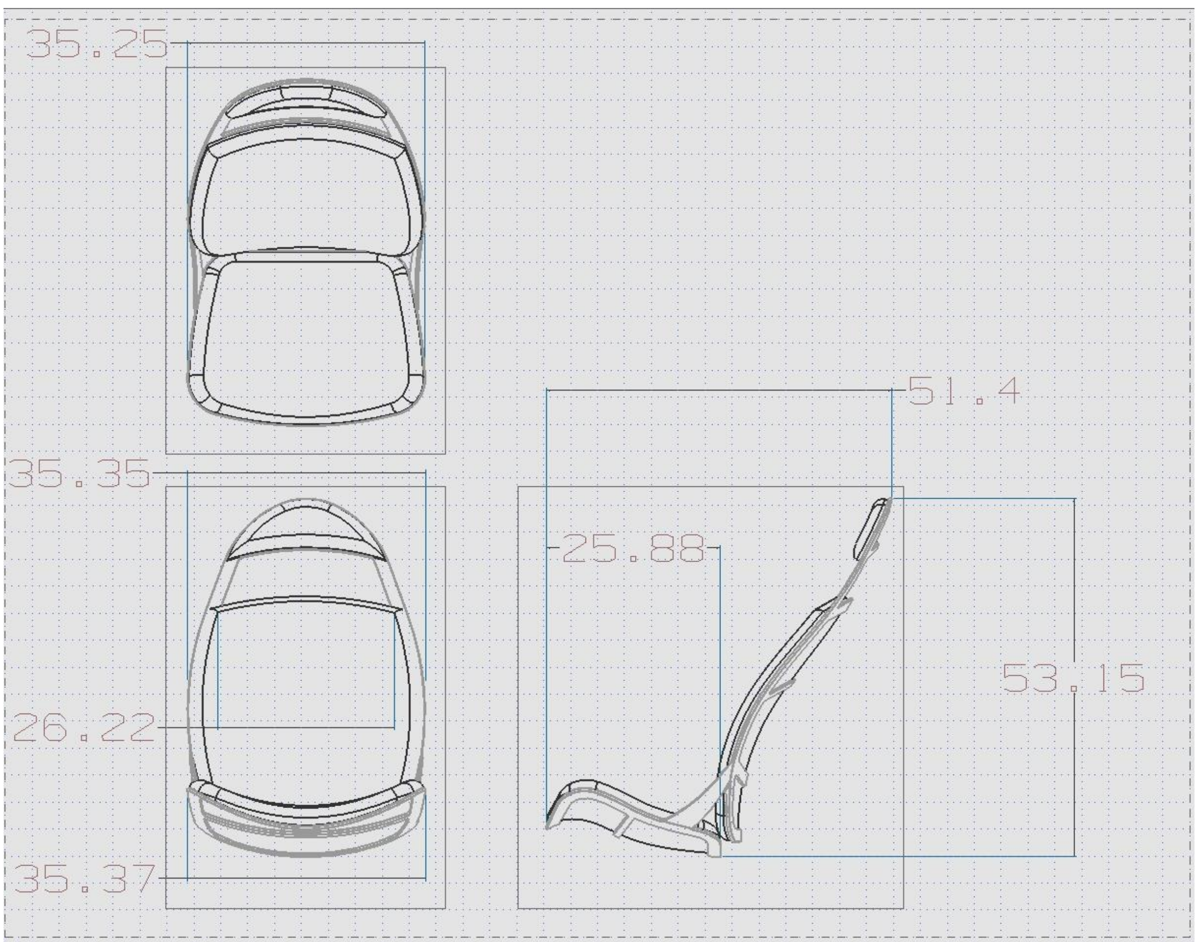

Figure 15: Engineering drawings of the design

Next we chose the material to be used in the padding. Instead of traditional padding, we chose a material called Indratech Performance Fiber (IPF) [10]. The IPF is made from recycled materials and is 100% recyclable itself. This matches our environmental story and also meets the engineering design specifications. The IPF can be cut and handled just like standard foam. Other natural padding materials were considered, like latex, but this was not chosen because of its tendencies to cause allergic reactions in many people.

A fabric was chosen as well for the cover of the seat. We needed a material that fit the “make a mark, leave no trace” environmental message. For that reason we have chosen to use a bamboo fabric which can be used the same way as normal fabric, but is environmentally friendly because it is made of bamboo. Bamboo is a very eco-friendly material to use because it grows very quickly and cleanly.

8.2 Design Description We want the materials and look of our seat to "make a mark, leave no trace." In other words, we want all or most of the components to have as little environmental impact as possible, while still following the engineering specifications. It also encourages the consumer to make their own personalized environmental statement. We based our message on what were the most important engineering specifications, and also from what we thought the consumer wanted. Our survey results showed that many people thought that biodegradability, renewability, and recyclability were the most important environmental considerations when they choose an environmental product.

Our final design fits the environmental message because the materials are all biodegradable or recyclable so none of the components will go to waste when the product is through with its life cycle. The chosen materials are environmentally friendly because they are recyclable, biodegradable, and renewable [11]. The materials also meet the engineering specifications because the material and shape of the frame are strong enough to withstand the mechanical loads. The padding material is also strong enough to handle the knee loading as well and is supportive enough that it will be comfortable to sit on and will not produce any waste because of its recyclability [12]. Together, the design and materials meet the strength requirements for the various loading conditions.

Snaps attach the cushions to the seat frame as shown in Fig. 16 below. The parts of the seat are easily separable because of the snap attachments, which makes it easy to process at the end of its life. It will be easy to take apart and recycle or reuse the components of the seat since none of them are permanently attached to each other. The snaps also allow the seat to be customizable. Since it is so easy to remove the cushion and cover, it will be possible for consumers to personalize their individual seats to make a statement by just changing the bamboo fabric covering. According to market research, the target demographic for the seat is very interested in customizable products.

Figure 16: The cushion is attached with snaps for easy separation

From the survey results, we determined which visual details would best portray the environmental message to the customer demographic. These details were incorporated in the visual aspect of the design, like smooth curves, a thin profile, and an overall simple design.

8.3 Design Analysis Before finalizing the design, we used a variety of tools to improve it. The CES software allowed us to compare the properties of materials that were similar to the ones used in our design. This exercise made us aware of other possible materials that we could consider. It also helped us to learn exactly what constraints we wanted to use for our materials. For example, we chose to use materials that were flame and water resistant.

Manufacturing processes were also considered using the CES software. We found that the best way to manufacture our composite would be to use cold press molding. To form the foam, a saw cutting operation will be used. This step allowed us to consider many different manufacturing processes and pick the best ones.

We also applied design for assembly strategies to improve the assembly efficiency of our design. After going through this process, we were able to find a suggestion for improving the design. We believe that this change would be a improvement on the design.

SimaPro software was used to complete a design for environmental sustainability analysis. This allowed us to see how the materials that we selected impact the environment. The impact is broken down into several categories, including human health and resource usage. Since our exact materials are not included in the software, we couldn't analyze the actual environmental impact of our design. We were able to see the impact of similar components and compare them to each other.

A risk assessment using DesignSafe software [13] was also carried out. This allowed us to recognize the major risks involved with using our chair. We learned that there are many ergonomic risks, which is something that we hadn't completely considered before. This led us to make recommendations concerning the ergonomics.

8.4 Prototype Description and Fabrication Plan The purpose of the prototype is to show engineering fundamentals that went into the design and demonstrate unique features of the design. The important aspects we wanted to show were the geometry of the seat, the bio-based composite, and the cushion separation method for customization and end-of-life processing. In order to generate a prototype seat, we thought of a few ways to do this.

One method we used was to have the CAD model put into a rapid prototype machine to get a scaled-down 3-D version of the seat. The advantage to this is that all of the visual effects of the seat would still be evident; however, the tactility and materials of the seat were not a part of the prototype. But this showed the entire shape of the chair and how the various components of it fit together.

The composite material of the frame is a very important part of the overall design. In order to demonstrate the composite, bamboo yarn fibers were woven together in the weave chosen for the actual product. Then an epoxy resin was used to represent the matrix material and was spread over the woven fibers. The epoxy has material properties that are similar to those of the SOMG matrix material. We put multiple layers of the weave into the resin to demonstrate the layering of the material. This would show how the composite would look and feel, as well as demonstrate roughly the strength of the composite.

Another prototype shows the functionality of the snap-on cushions of the seat. This includes the cushion made of the foam core, with a cotton fabric wrapped around it to show that the cover could be easily removed and washed. The snaps were attached to the fabric and a simple wooden frame, which was used to represent the seat's frame. Using three-inch self-tapping screws, the wooden frame was fastened together. All of the parts of the snaps on the frame were attached via half-inch self-tapping screws. The cloth cover of the cushion was sewn together to make a sort of casing in which to insert the padding. Finally, with the padding, cover, and snaps assembled, the cushion was snapped onto the frame.

8.5 Concept Validation The requirements that have to be met are separated into three categories. They are the environmental, the visual, and the structural requirements. Different approaches are taken to validate each category.

Our approach to make the design environmentally friendly is mainly through the selection of materials. According to the survey we gave out in January, 41% of the target demographic thinks being environmental means using renewable resources and 20% of them think it means making the product recyclable. There are three major parts of our seat; the frame, the padding, and the cover. We selected a bio-based composite material that is composed of renewable and biodegradable resources. The padding material we selected can be mostly made from recycled fibers and is 100% recyclable. The cover is made from bamboo fabric. In order to validate our decisions with the consumer, we gave out a second survey out in April. The result shows 94% of the people think that our material selections are environmentally friendly and 91% of them think that the material selections match our message “Make a Mark, Leave No Trace”. One other feature of our design is the removable cushion for customization, easy separation, and cleaning. 50% of the people think it’s environmentally friendly and matches our message. The complete results of this second survey can be found in Appendix D.

The visual requirements of the design are that it not only has to be visually appealing, but it also has to convey the environmental message. In other words, the seat has to look good and “green”. According to the first survey, people think simple, airy, sleek, and thin designs are environmentally friendly. We believe that by including these elements in our design, the driver seat would then convey our environmental message. The second survey, used as validation, shows 56% think our design looks environmental in comparison to ordinary driver seats. The removable cushion design adds flexibility to customization. It allows people to individualize the seat into something that is visually appealing to them. We believe that this feature makes the seat more attractive, especially to the target demographic, which values individual customization.

Simplified structural requirements were met to validate the strength of our design. Through structural analysis, we wanted to show that our approach to the design problem would be feasible in the near future. Finite element analysis (FEA) was applied to the frame with estimated mechanical properties (elastic modulus and yield strength) using ANSYS to calculate the maximum stress and deflection. The maximum stress calculated is 35 MPa which is slightly lower than the composite’s estimated yield strength of 44.5 MPa. The complete FEA results are shown in Appendix E. The maximum deflection is within the 5 degrees requirement.

Our sponsor Lear Cooperation is very interested in some of our concepts. Positive responses of the overall design were also received from the general public at the exposition. Table 5 below shows a summary of how each engineering specification is validated.

Engineering Specification	Validation Approach
Composed of Renewable Resources	Material selection
Composed of Recycled/Recyclable Materials	Material selection
Design Conveys Environmental Message/Theme	Prototype feedback
Design Appeals to Target Demographic	Prototype feedback
Uses Advanced Materials for Strengths	Material selection
Seat Size Should Fit 5th through 95th Percentile of People	CAD model
Weighs Less than Standard Seat of 20 kg	CAD model
Easily Separable Parts	Material selection
Handles Inboard Seatbelt Load 13,500 N with 20% Safety Factor	Finite element analysis
Handles Knee Load of 1110 N downward through 127mm Diameter Hemisphere into Cushion without Damaging Seat with 20% Safety Factor	Finite element analysis
Handles Rearward Torque of 745 Nm about H-Point with <5 Degrees Permanent Deflection with 20% Safety Factor	Finite element analysis
Handles Outboard Seatbelt Load of 6,750 N with 20% Safety Factor	Finite element analysis
Handles Forward Load of 20 Times the Load of the Seats Weight at Center of Gravity with 20% Safety Factor	Finite element analysis

Table 5: The Engineering Specifications are validated in different ways

8.6 Design Fabrication Plan The prototype is made mainly for demonstration purposes. To fabricate the actual design, further studies in the bio-based composite material must be done. Assuming that the composite material can be manufactured the same way as ordinary composite materials such as glass fiber composites, the suggested manufacturing process is cold press molding process because it allows the use of woven fiber reinforcements that are desired for a stronger frame.

The foam is produced in large blocks and must be cut to the appropriate size. We have selected a saw cutting operation to accomplish this. It is also possible that the manufacturer can mold the foam to the appropriate shape for us. This is likely if a very large order is made.

The fabric has to be stitched together to make the cushion cover. This is the simplest process available to accomplish this task.

From this point, the chair has to be assembled. We have calculated the cost of manual assembly to be $2.00. After making improvements using the DFA charts described above, the total cost of assembly could drop to $1.00.

9. DISCUSSION

With the design complete, the team can look back at the whole process and critique some of our own decisions. This is an important step because it could potentially help other teams working on a similar project.

One element of the design that really helped us was the environmental message. Once we decided on and defined this message, all of our other decisions became easier. This step should have been done earlier in the design process. We were not able to settle on an exact message until many decisions had already been made. This made it difficult to keep our focus narrow. We would advise future teams to set aside time to accomplish this goal as soon as possible.

Another area where we stumbled was the application of Finite Element Analysis. We were advised by both our sponsors and advisers to avoid using FEA if possible, but we did it anyway. It would have been much simpler to make approximations and complete hand calculations. We would advise future teams to avoid complicated methods wherever possible by using simpler approximations if exact calculations are not in the scope of the project.

Even with these missteps, we believe that we created a design that was successful overall. We have met all of the engineering specifications that we set and our sponsor has expressed excitement over our results. The most exciting part of the design is the materials that we selected, particularly the composite that makes up the frame. This was the best application of our environmental message and the strongest part of our design.

While being a successful part of the design, it was very difficult to demonstrate the composite with a prototype. Our composite prototype managed to demonstrate some of the attributes that we wanted it to, but it could have been better. Our prototype would have been much better if we had recognized how important it was to our design and focused on it instead of some of the other prototypes. Unfortunately, we failed to do this, and that caused our prototypes to be the weakest part of our design.

10. RECOMMENDATIONS

Several recommendations should be considered before the seat is produced. These recommendations refer to the seat attachment, composite material, and other miscellaneous details of the design.

For the attachment of the seat to the frame of the car, a study should be done on the best attachment method. We are unsure whether current attachment methods will work for the design or not due to the new frame shape. If possible, the current attachment method should be used since that would be most cost-effective. But other alternatives should be explored in order to determine which would fit best and also reduce concentrated stresses along the bottom of the frame as well.

A different method for attaching the back of the seat to the rest of the seat should be used. Currently the attachment consists of two support bars completely attached to the back and bottom of the seat. This method makes the seat back unable to adjust and it also creates high concentrations of forces at the joints. Instead, the attachment should be adjustable and should be made in such a way that it reduces stresses in the attachment locations. It will likely have to be a material that is different from that of the frame (steel or aluminum) due to the stresses in the joints.

More research needs to be done for the composite material. We determined that flax fibers and the SOMG resin would be the strongest of the bio-based components but have not been able to determine whether the two materials are compatible enough for the composite to have the calculated strength. Procurement of both materials and the creation and testing of the composite is recommended in order to determine whether the composite has adequate strength.

Every corner and edge on the model's frame has a fillet on it in order to reduce stress concentrations. Fillet size should be analyzed more in order to determine the optimal size for stress reduction and also geometry. The shape of the frame limits the size of fillets in certain areas while combinations of fillets can also limit the size. It is best to do a study to figure out which sizes and combinations of fillets optimally reduce stresses in corners.

Ergonomics experts should be consulted before the seat is put into production. We designed the chair to be visually appealing and modeled it after objects that we believed to be ergonomic. The ergonomics team should look at our work and make appropriate changes to insure that the ergonomics are acceptable.

We have learned from our research that the Indratech foam in our design is susceptible to moisture damage. Testing should be done to make sure that the cushion covers provide adequate protection for the foam.

The whole design needs to be put through durability testing before it is produced. This was not the focus of our project so we do not have results, but it should be considered in the future.

11. SUMMARY AND CONCLUSIONS

In order to create a design that meets all of the requirements set forth by Lear Corporation, we created a list of engineering specifications. The design that we have made uses new materials that are environmentally friendly to meet those requirements. We have defined an environmental story, "Make a mark, leave no trace," which helped to guide us through the design process.

We created a survey, which was completed by potential customers to gather information on our target demographic. This information helped us in the concept generation process. We also completed a problem decomposition to better understand the functions of our project. A morphological chart helped us to organize all of our design ideas and Pugh charts helped us to select the best one. We then modified this design to create an alpha design.

CAD software was used to model our final design. We used this software to complete a force analysis and choose finalized dimensions. This was done while choosing materials in order to assure that the seat meets requirements. The materials were picked in order to follow the environmental story.

Elements of the final design include cushions that are easily removable for cleaning or customization. The frame of the seat is composed of a special composite of flax fiber and soybean oil that has been invented just for this purpose. Recyclable foam and bamboo fabric are used for the cushions. These features were demonstrated with several prototypes that the team constructed.

Once the design was finished, we distributed another survey to gather feedback. It showed that the majority of people thought that our design was environmentally friendly and followed the environmental story that we created. A public demonstration was also given and positive feedback was received.

With the design completed, this report and the prototypes will be delivered to Lear for review.

12. ACKNOWLEDGEMENTS

There were many people who contributed to our project. Lear Corporation, especially Eric Partington, was very helpful during the whole design process. Professor Diann Brei, Professor Greg Hulbert, Professor Sridhar Kota, Professor Jyoti Mazumder, Dr. Lalit Patil, Professor Steve Skerlos, and Ms. Esra Suel all contributed to instructing the team.

Dr. Patil was our closest advisor and deserves extra recognition. He was instrumental in completing the project.

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14. APPENDICES

14.1 Appendix A: Notes from meeting with Lear representatives, 1/15/08.

100% Recyclable Automotive Driver Seat

Seat design
Competing values in seat design:

1) Design innovation
2) Maintain physical loads (meet government regulations)
3) Keep costs low

Our focus will be on the design innovation component. Cost is not a focus, although we should keep our material selection reasonable. Meeting the government regulations is a very complicated problem, so we will focus on just three requirements:

1) Front load
2) Rear load
3) Side load

These regulations can be found in the following federal papers: FMVSS 202a, 207, 210, and 213. Eric will send us this information to help us along.

Since the meeting, we have adjusted these requirements. We are no longer concerned with the side load and are now concentrating on the seatbelt anchor point. The required loads were provided by Eric.

This leaves design innovation as our main goal. The final product needs to be "green," which has become an industry buzzword. This can be done by creating an environmental story that focuses on the seat features. The other half is creating an effective design aesthetic.

The design should be lighter than standard seats, which means less than 20 kg.

Environmental Story
So far "green" vehicles have focused on advanced power plants only. In the future other components will be "green" as well, such as the interior.

Environmentally friendly can mean recyclable, renewable resources, and fuel efficient. We should focus on an element and make this the central point of the environmental story. From this point we can work towards a design and confirm that the seat meats structural requirements.

Current seats are not focused on environmental concerns. It is unknown how much of current seats are recyclable. This is a new area and it is important for us to come up with as many ideas as we can.

We want something that we think will work. It does not have to be achievable in a short time frame.

Design Aesthetic

Start by looking at other products, like furniture. This will give us a feeling for "green" design. We can use future technology, since this is a pilot study. A good starting point is to select some materials and design around them.

We will add an industrial design student to our team to help with the design aesthetic. It is important that the designs instantly convey the "green" message. Consumers must recognize the seat as environmentally friendly without being told.

We should brainstorm to find a list of ideas that mean "green" to us. This will be a good list of things to implement into the design.

Target Demographic

We can't focus on everyone, because that assures failure. Our target will be young adults like us, and the seat will be made for a small/medium sized car. Lear will provide data about the target demographic, and we can also conduct a survey ourselves. This will tell us about the balance between "green" technology and appearance that the customers are interested in.

Deliverables

- The main deliverable is the design of a future driver seat which has an environmental message. The seat is the focus, not the manufacturing chain, but we can look at this as well if we have time.
- The prototype could be many different things, from a board of material swatches to a 1/3 scale seat. We will focus on the actual design for now and concentrate on a prototype later in the project.
- The following items are not required for this project: cost analysis, seatbelt location, car frame attachment, any movable components.
- Comfort is not a focus, but we should consider it.

Schedule

January 22/24 – Design Review 1 (define requirements of project)
February 19/21 – Design Review 2 (concept, drawings, initial analysis)
March 18/20 – Design Review 3 (final concept and design)
April 1 – Design Review 4 (first presentation of prototype)
April 10 – Public Demonstration (final presentation)

Summary

The design is our main goal! We want something new and exciting that can be displayed at industry shows. We will also arrange a visit to the Lear facility before Design Review 2.

14.2 Appendix B: Complete Survey Results.

1. What percentage of a product needs to be environmentally friendly for you to consider it "green"?

	Response Percent	Response Count
0	0.0%	0
25	4.0%	4
50	29.0%	29
75	**39.0%**	39
100	28.0%	28
answered question		**100**
skipped question		**0**

2. Rank the following on how important each item is when choosing an environmentally-friendly item, with 1 being the least important, and 4 being the most important.

	1	2	3	4	Response Count
Uses renewable resources	16.0% (16)	29.0% (29)	14.0% (14)	**41.0% (41)**	100
Is easily recyclable	17.0% (17)	24.0% (24)	**34.0% (34)**	25.0% (25)	100
Uses recycled materials	30.0% (30)	**32.0% (32)**	28.0% (28)	10.0% (10)	100
Is biodegradable	**37.0% (37)**	15.0% (15)	24.0% (24)	24.0% (24)	100
answered question					**100**
skipped question					**0**

3. When purchasing an environmentally friendly product, how do you want it to appear?

	Response Percent	Response Count
Standard (such as a Honda Civic Hybrid)	**55.0%**	55
Slightly Different (such as a Toyota Prius)	35.0%	35
Radically Different	10.0%	10

3. When purchasing an environmentally friendly product, how do you want it to appear?

(such as an Auto Show concept car)

answered question	**100**
skipped question	**0**

4. Rank the following factors on how important they are when purchasing an environmentally friendly product, with 1 being least important, and 4 being the most important

	1	**2**	**3**	**4**	**Response Count**
The product design looks "green"	**78.0% (78)**	9.0% (9)	1.0% (1)	12.0% (12)	100
The actual environmental impact	8.1% (8)	20.2% (20)	18.2% (18)	**53.5% (53)**	99
Performance is similar to or better than a non-"green" product	4.0% (4)	18.2% (18)	**53.5% (53)**	24.2% (24)	99
Price is similar to a non-"green" product	9.0% (9)	**52.0% (52)**	28.0% (28)	11.0% (11)	100
				view Other (please specify)	3
				answered question	**100**
				skipped question	**0**

5. Rank the following color sets, where 1 is the set that looks least environmentally friendly, and 5 is the set that looks most environmentally friendly.

	1	**2**	**3**	**4**	**Response Count**
Animal Prints	**36.0% (36)**	25.0% (25)	34.0% (34)	5.0% (5)	100
Natural Tones	6.0% (6)	1.0% (1)	12.0% (12)	**81.0% (81)**	100
Metallics	15.0% (15)	36.0% (36)	**41.0% (41)**	8.0% (8)	100
Neons & Bright Colors	**43.0% (43)**	38.0% (38)	13.0% (13)	6.0% (6)	100
				view Other (please specify)	7

5. Rank the following color sets, where 1 is the set that looks least environmentally friendly, and 5 is the set that looks most environmentally friendly.

answered question	**100**
skipped question	**0**

6. Do the following design elements appear environmentally friendly?

	Yes	No	Sort Of	Response Count
Aerodynamic	**69.7% (69)**	9.1% (9)	21.2% (21)	99
Thin	**56.6% (56)**	14.1% (14)	29.3% (29)	99
Sleek	**56.6% (56)**	17.2% (17)	26.3% (26)	99
Airy	**55.1% (54)**	22.4% (22)	22.4% (22)	98
Transparent	30.3% (30)	**42.4% (42)**	27.3% (27)	99
Curvy, Smooth Lines	**55.6% (55)**	17.2% (17)	27.3% (27)	99
Warm and cozy	35.7% (35)	**40.8% (40)**	23.5% (23)	98
Sexy	23.5% (23)	**48.0% (47)**	28.6% (28)	98
Simple design	**76.8% (76)**	11.1% (11)	12.1% (12)	99
		answered question		**99**
		skipped question		**1**

7. What does "Environmentally Friendly" mean to you?

	Response Count
	view 70
answered question	**70**
skipped question	**30**

14.3 Appendix C: Complete set of concepts.

Concept 1: Ambient lighting, exposed frame, lumbar support

Concept 2: Holes, aluminum, memory foam

Concept 3: Simple, steel, interrogation chair

Concept 4: Bright color, recycled foam, recycle symbol

Concept 5: Bamboo, recycled foam, stitching

Concept 6: MIB pod chair, Rubber, exposed frame

Concept 7: Lily pads, styrofoam, animal print

Concept 8: Lava lamp, fur, balsa

Concept 9: Rope lights, green tea, steel

Concept 10: Whoopie cushion, sponge, springs

Concept 11: Hand chair, sponge, silk

Concept 12: Lips, water pads, hydroformed

Concept 13: Banana chair, memory foam, fur

Concept 14: Bicycle, cork, backpack seat belt

Concept 15: MIB pod chair, latex, ceramic

Concept 16: Lily pads, pleating, cardboard

Concept 17: Lava lamp, bamboo, potato

Concept 18: Microfleece, wood, simple

Concept 19: Banana chair, holes, potato

Concept 20: Rope lights, temperature control, deploying side restraint

Concept 21: Lip chair, ambient lighting, water pad

Concept 22: Fabric support, drive number, rouching

Concept 23: Lava lamp, bright colors, ambient lighting

Concept 24: Leather, air, rubber

Concept 25: Bicycle, bamboo, exposed frame

Concept 26: Neoprene, integrated shell, cotton

Concept 27: Bean bag, drive number, recycled shredded tires

Concept 28: Banana chair, patchwork, hemp

Concept 29: Translucent, holes, fur

Concept 30: Cardboard, simple, cement

Concept 31: Synthetic fiber, fabric support, Indratech

Concept 32: Lily pad, wood, temperature control

Concept 33: Indratech, backpack seatbelt, banana chair

Concept 34: Rope light, soy foam, simple

Concept 35: Balsa, cork, composting chair

Concept 36: bicycle chair, composting chair, pleating

Concept 37: Hydroformed, seat belt guide, springs

Concept 38: Ceramic, air, bean bag

Concept 39: Air, Drive Number, holes

Concept 40: Ambient lighting, exposed frame, holes

14.4 Appendix D: Validation survey results.

1. These are computer images of our final design for an automotive driver's seat. Do you think it looks environmentally friendly in comparison to a standard automotive driver's seat?

	Response Percent	Response Count
Yes	**53.1%**	17
No	9.4%	3
Maybe	37.5%	12
answered question		**32**
skipped question		**0**

2. Do you think these images fit our environmental message of "Make a mark, Leave no trace"?

	Response Percent	Response Count
Yes	**56.3%**	18
No	18.8%	6
Maybe	25.0%	8
answered question		**32**
skipped question		**0**

3. The fabric covers for the seat will be easily removable for customization, cleaning, and easy disposal. Do you think this is environmentally friendly?

	Response Percent	Response Count
Yes	**50.0%**	16
No	21.9%	7
Maybe	28.1%	9
answered question		**32**
skipped question		**0**

4. Does this match our message?

	Response Percent	Response Count
Yes	**50.0%**	16
No	28.1%	9
Maybe	21.9%	7
answered question		**32**
skipped question		**0**

5. The seat is made of an advanced bio-based composite for the frame (biodegradable), a recycled foam for the cushions (recyclable), and bamboo fabric for the seat coverings (biodegradable). Do you think this is environmentally friendly?

	Response Percent	Response Count
Yes	**93.8%**	30
No	0.0%	0
Maybe	6.3%	2
answered question		**32**
skipped question		**0**

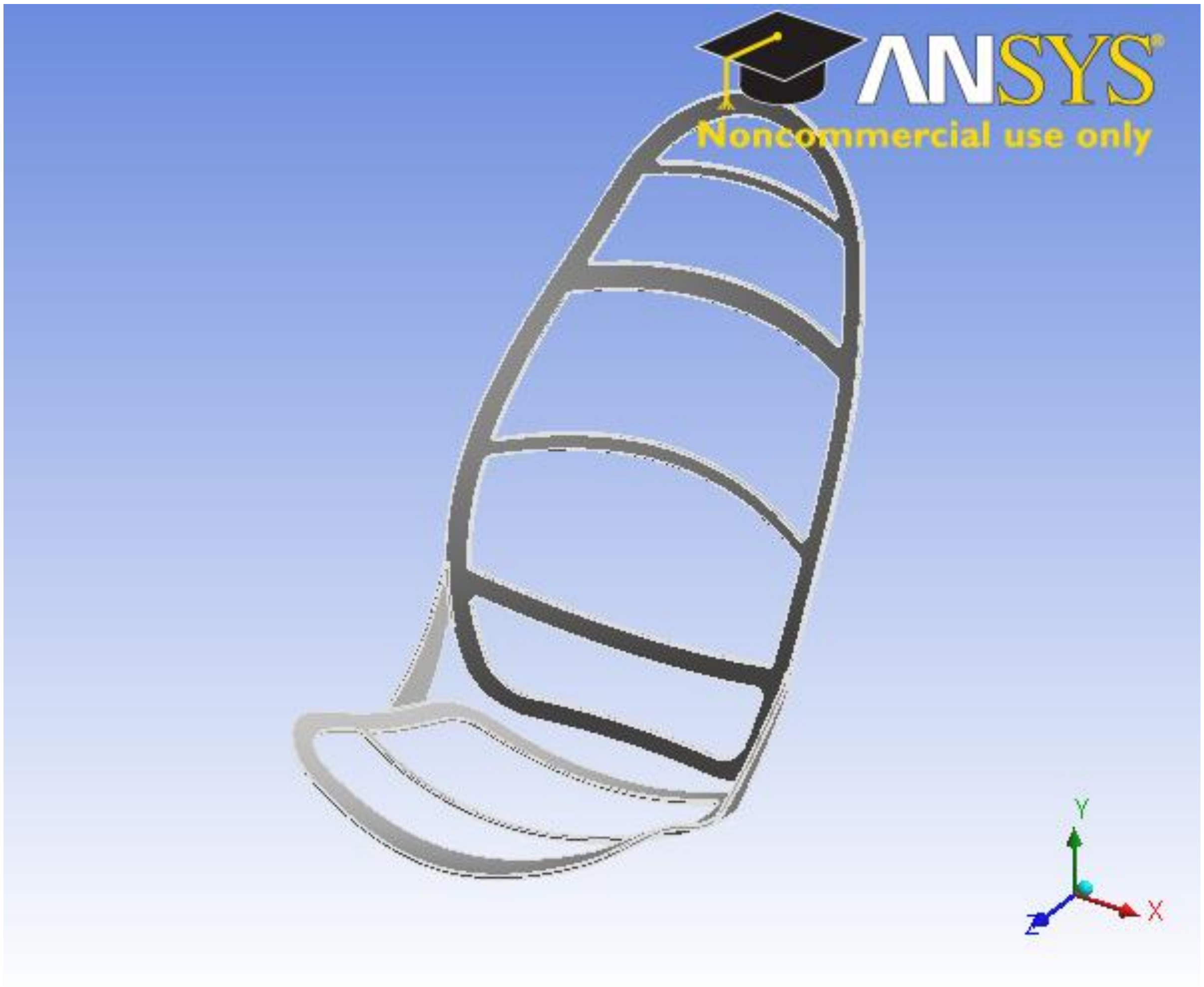
6. Does this match our message?

	Response Percent	Response Count
Yes	**90.6%**	29
No	0.0%	0
Maybe	9.4%	3
answered question		**32**
skipped question		**0**

14.5 Appendix E: Stress analysis results.

Project

First Saved	Thursday, March 20, 2008
Last Saved	Thursday, March 20, 2008
Product Version	11.0 Release



Contents

Units

TABLE 1

Unit System	Metric (m, kg, N, °C, s, V, A)
Angle	Degrees
Rotational Velocity	rad/s

Model

Geometry

TABLE 2
Model > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	\\storage\home\windat\desktop\03SeatPara.x_t
Type	Parasolid
Length Unit	Meters
Element Control	Program Controlled
Display Style	Part Color
Bounding Box	

Length X	0.89969 m
Length Y	1.351 m
Length Z	1.3058 m
Properties	
Volume	6.5249e-003 m³
Mass	51.22 kg
Statistics	
Bodies	1
Active Bodies	1
Nodes	243643
Elements	121051
Preferences	
Import Solid Bodies	Yes
Import Surface Bodies	Yes
Import Line Bodies	Yes
Parameter Processing	Yes
Personal Parameter Key	DS
CAD Attribute Transfer	No
Named Selection Processing	No
Material Properties Transfer	No
CAD Associativity	Yes
Import Coordinate Systems	No
Reader Save Part File	No
Import Using Instances	Yes
Do Smart Update	No
Attach File Via Temp File	No
Analysis Type	3-D
Mixed Import Resolution	None
Enclosure and Symmetry Processing	Yes

TABLE 3
Model > Geometry > Parts

Object Name	*Part 1*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Material	Structural Steel
Stiffness Behavior	Flexible
Nonlinear Material Effects	Yes
Bounding Box	
Length X	0.89969 m
Length Y	1.351 m
Length Z	1.3058 m
Properties	
Volume	6.5249e-003 m³
Mass	51.22 kg

Centroid X	0.38035 m
Centroid Y	0.45106 m
Centroid Z	-5.6622e-002 m
Moment of Inertia Ip1	14.372 kg·m²
Moment of Inertia Ip2	5.8365 kg·m²
Moment of Inertia Ip3	17.838 kg·m²
Statistics	
Nodes	243643
Elements	121051

Mesh

TABLE 4
Model > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Advanced	
Relevance Center	Coarse
Element Size	Default
Shape Checking	Standard Mechanical
Solid Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Initial Size Seed	Active Assembly
Smoothing	Low
Transition	Fast
Statistics	
Nodes	243643
Elements	121051

TABLE 5
Model > Mesh > Mesh Controls

Object Name	*Body Sizing*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	7.5e-003 m
Edge Behavior	Curv/Proximity Refinement

Static Structural

TABLE 6
Model > Analysis

Object Name	*Static Structural*
State	Fully Defined
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Options	
Reference Temp	22. °C

TABLE 7
Model > Static Structural > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Nonlinear Controls	
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Output Controls	
Calculate Stress	Yes
Calculate Strain	Yes
Calculate Results At	All Time Points
Analysis Data Management	
Solver Files Directory	\\storage\home\windat\desktop\ME450 Stress Analyses\03SeatPara Simulation Files\Static Structural\
Future Analysis	None
Save ANSYS db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No

TABLE 8
Model > Static Structural > Loads

Object Name	*Displacement*	*Force*
State	Fully Defined	

Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	2 Edges
Definition		
Define By	Components	
Type	Displacement	Force
X Component	0. m (ramped)	0. N (ramped)
Y Component	0. m (ramped)	0. N (ramped)
Z Component	0. m (ramped)	-2500. N (ramped)
Suppressed	No	

FIGURE 1
Model > Static Structural > Displacement

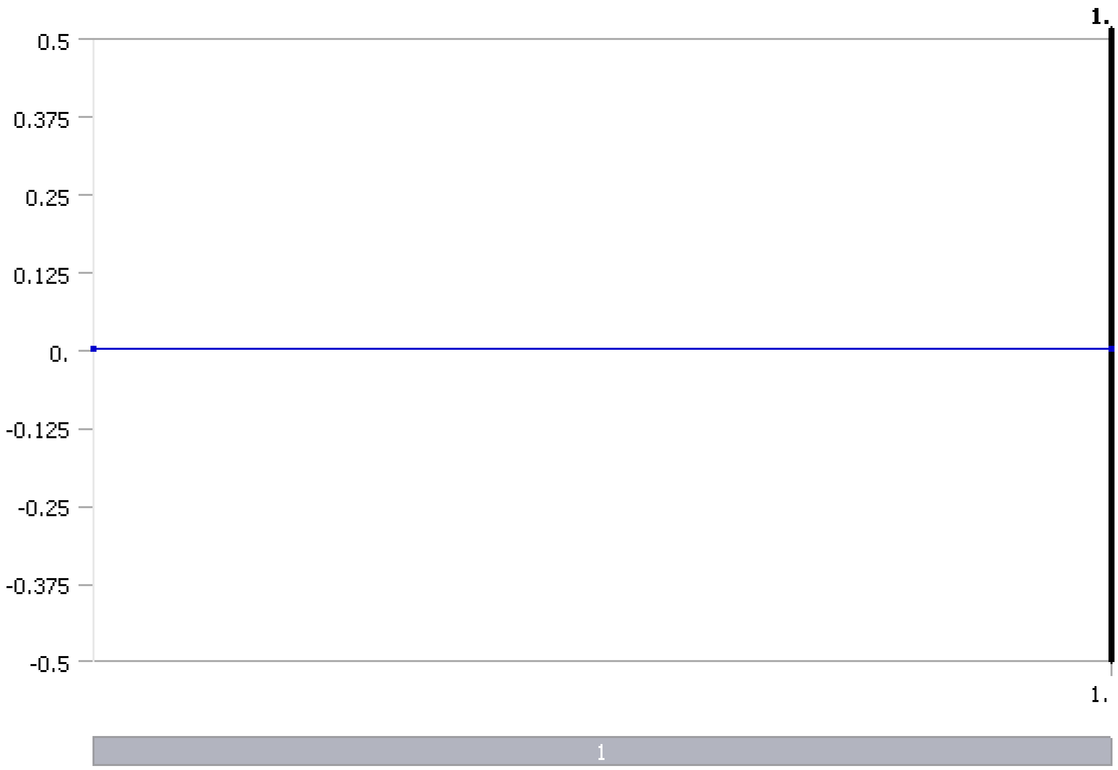
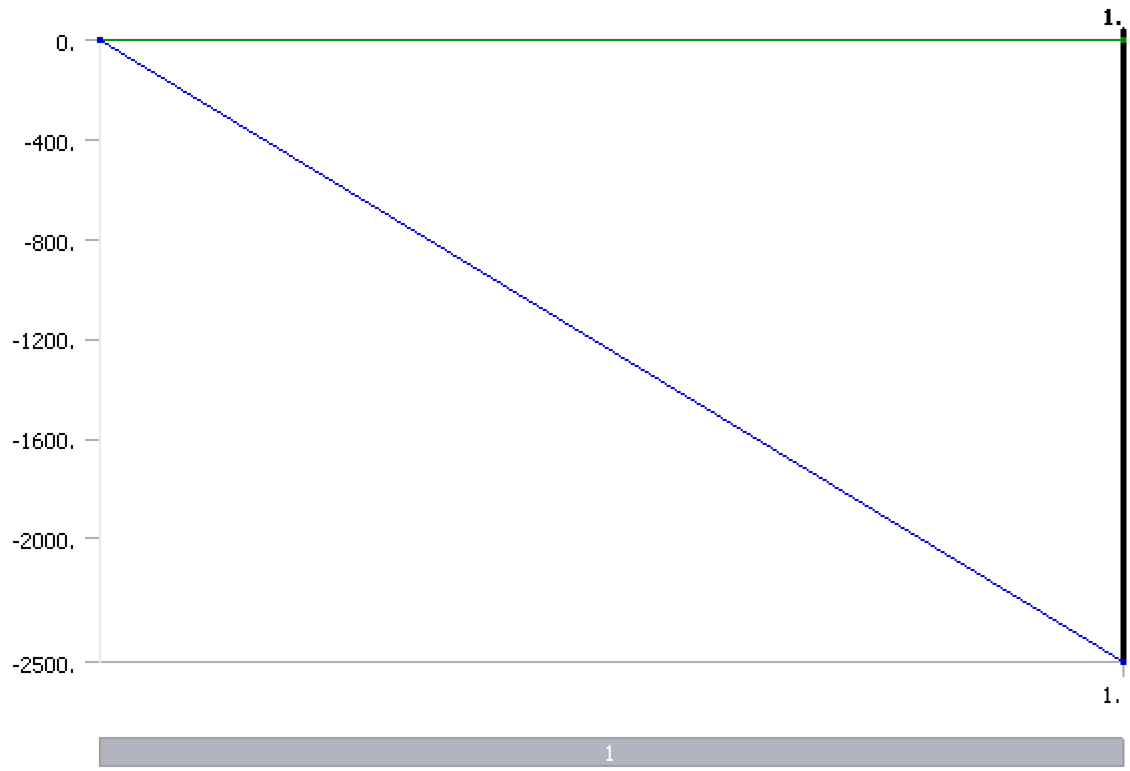


FIGURE 2
Model > Static Structural > Force



Solution

TABLE 9
Model > Static Structural > Solution

Object Name	*Solution*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.

TABLE 10
Model > Static Structural > Solution > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All

TABLE 11
Model > Static Structural > Solution > Results

Object Name	*Directional Deformation*	*Maximum Principal Stress*
State	Solved	
Scope		

Geometry	All Bodies	
Definition		
Type	Directional Deformation	Maximum Principal Stress
Orientation	Z Axis	
Display Time	End Time	
Results		
Minimum	-2.033e-003 m	-2.3207e+007 Pa
Maximum	7.045e-005 m	1.3275e+008 Pa
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

Model 2

Geometry

TABLE 12
Model 2 > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	\\storage\home\windat\desktop\03SeatPara.x_t
Type	Parasolid
Length Unit	Meters
Element Control	Program Controlled
Display Style	Part Color
Bounding Box	
Length X	0.89969 m
Length Y	1.351 m
Length Z	1.3058 m
Properties	
Volume	6.5249e-003 m³
Mass	5.2199 kg
Statistics	
Bodies	1
Active Bodies	1
Nodes	243643
Elements	121051
Preferences	
Import Solid Bodies	Yes
Import Surface Bodies	Yes
Import Line Bodies	Yes
Parameter Processing	Yes
Personal Parameter Key	DS
CAD Attribute Transfer	No
Named Selection Processing	No

Material Properties Transfer	No
CAD Associativity	Yes
Import Coordinate Systems	No
Reader Save Part File	No
Import Using Instances	Yes
Do Smart Update	No
Attach File Via Temp File	No
Analysis Type	3-D
Mixed Import Resolution	None
Enclosure and Symmetry Processing	Yes

TABLE 13
Model 2 > Geometry > Parts

Object Name	*Part 1*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Material	BLAH
Stiffness Behavior	Flexible
Nonlinear Material Effects	Yes
Bounding Box	
Length X	0.89969 m
Length Y	1.351 m
Length Z	1.3058 m
Properties	
Volume	6.5249e-003 m³
Mass	5.2199 kg
Centroid X	0.38035 m
Centroid Y	0.45106 m
Centroid Z	-5.6622e-002 m
Moment of Inertia Ip1	1.4647 kg·m²
Moment of Inertia Ip2	0.5948 kg·m²
Moment of Inertia Ip3	1.8179 kg·m²
Statistics	
Nodes	243643
Elements	121051

Mesh

TABLE 14
Model 2 > Mesh

Object Name	*Mesh*
State	Solved
Defaults	
Physics Preference	Mechanical

Relevance	0
Advanced	
Relevance Center	Coarse
Element Size	Default
Shape Checking	Standard Mechanical
Solid Element Midside Nodes	Program Controlled
Straight Sided Elements	No
Initial Size Seed	Active Assembly
Smoothing	Low
Transition	Fast
Statistics	
Nodes	243643
Elements	121051

TABLE 15
Model 2 > Mesh > Mesh Controls

Object Name	*Body Sizing*
State	Fully Defined
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	7.5e-003 m
Edge Behavior	Curv/Proximity Refinement

Static Structural

TABLE 16
Model 2 > Analysis

Object Name	*Static Structural*
State	Fully Defined
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Options	
Reference Temp	22. °C

TABLE 17
Model 2 > Static Structural > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s

Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Nonlinear Controls	
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Output Controls	
Calculate Stress	Yes
Calculate Strain	Yes
Calculate Results At	All Time Points
Analysis Data Management	
Solver Files Directory	\\storage\home\windat\desktop\ME450 Stress Analyses\03SeatPara Simulation Files\Static Structural (2)\
Future Analysis	None
Save ANSYS db	No
Delete Unneeded Files	Yes
Nonlinear Solution	No

TABLE 18
Model 2 > Static Structural > Loads

Object Name	*Displacement*	*Force*
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	2 Edges
Definition		
Define By	Components	
Type	Displacement	Force
X Component	0. m (ramped)	0. N (ramped)
Y Component	0. m (ramped)	0. N (ramped)
Z Component	0. m (ramped)	-2500. N (ramped)
Suppressed	No	

FIGURE 3
Model 2 > Static Structural > Displacement

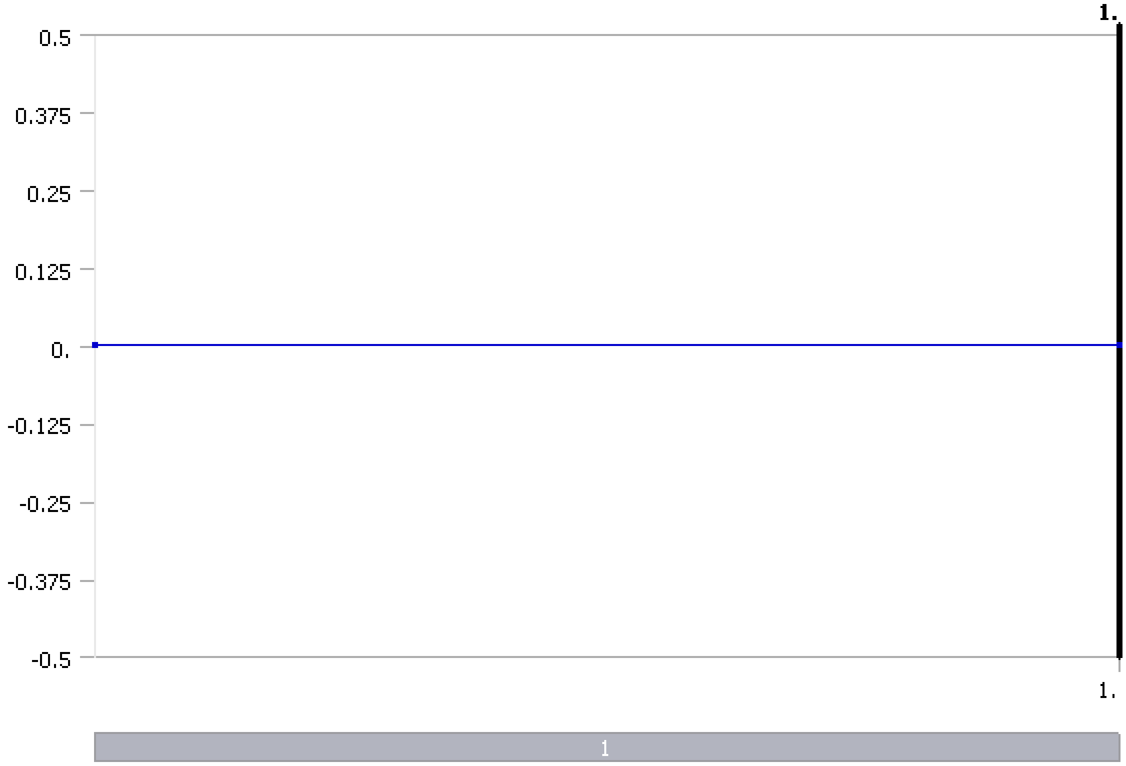
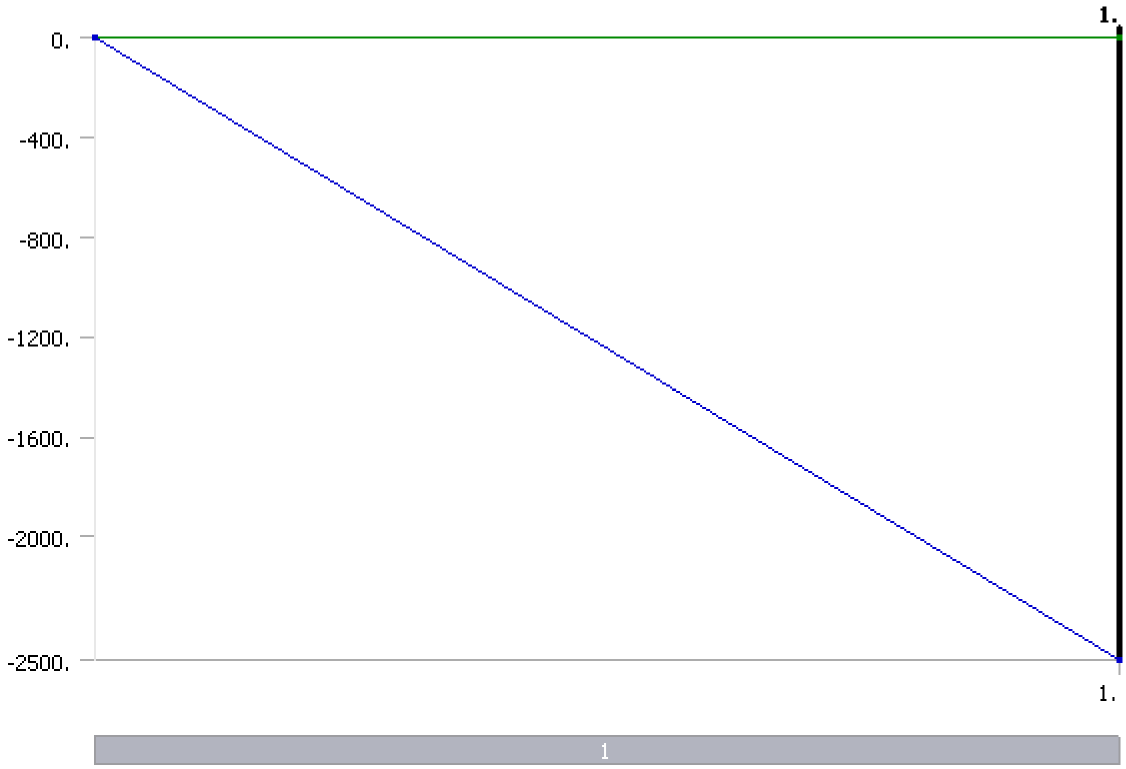


FIGURE 4
Model 2 > Static Structural > Force



Solution

TABLE 19
Model 2 > Static Structural > Solution

Object Name	*Solution*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.

TABLE 20
Model 2 > Static Structural > Solution > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All

TABLE 21
Model 2 > Static Structural > Solution > Results

Object Name	*Directional Deformation*	*Maximum Principal Stress*
State	Solved	
Scope		
Geometry	All Bodies	
Definition		
Type	Directional Deformation	Maximum Principal Stress
Orientation	Z Axis	
Display Time	End Time	
Results		
Minimum	-5.8927e-002 m	-2.3207e+007 Pa
Maximum	2.042e-003 m	1.3275e+008 Pa
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

Material Data

Structural Steel

TABLE 22
Structural Steel > Constants

Structural	
Young's Modulus	2.e+011 Pa
Poisson's Ratio	0.3

Density	7850. kg/m³
Thermal Expansion	1.2e-005 1/°C
Tensile Yield Strength	2.5e+008 Pa
Compressive Yield Strength	2.5e+008 Pa
Tensile Ultimate Strength	4.6e+008 Pa
Compressive Ultimate Strength	0. Pa
Thermal	
Thermal Conductivity	60.5 W/m·°C
Specific Heat	434. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	1.7e-007 Ohm·m

FIGURE 5
Structural Steel > Alternating Stress

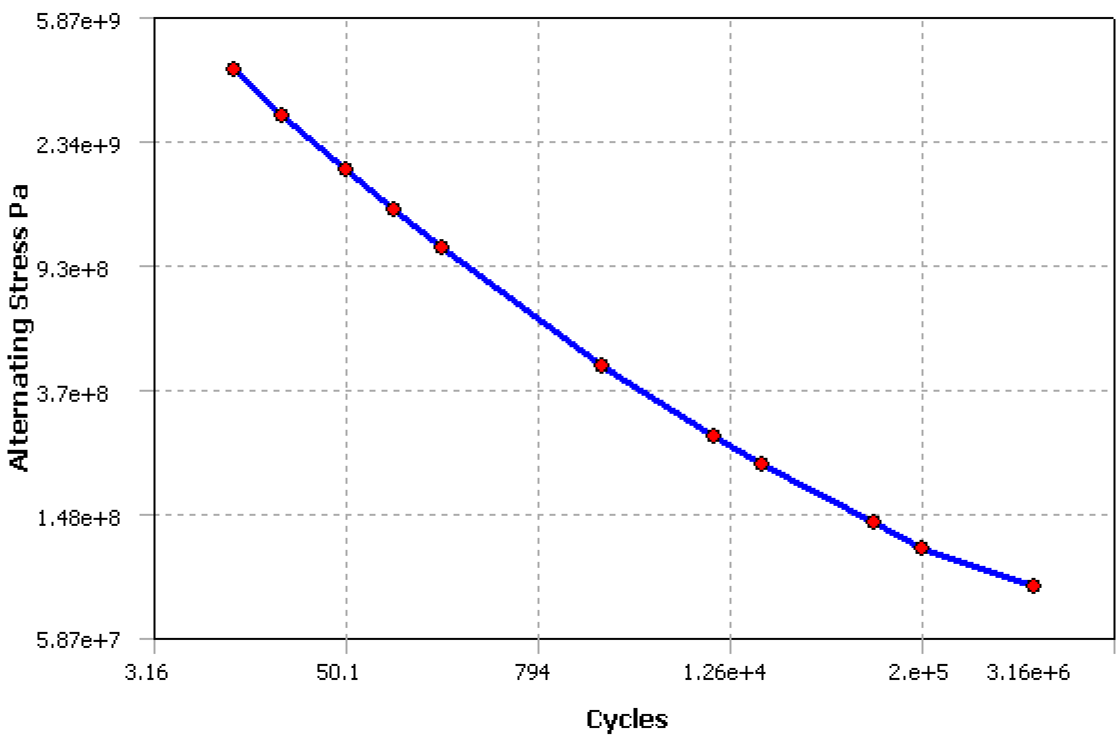


TABLE 23
Structural Steel > Alternating Stress > Property Attributes

Interpolation	Log-Log
Mean Curve Type	Mean Stress

TABLE 24
Structural Steel > Alternating Stress > Alternating Stress Curve Data

Mean Value Pa
0.

TABLE 25
Structural Steel > Alternating Stress > Alternating Stress vs. Cycles

Cycles	Alternating Stress Pa
10.	3.999e+009
20.	2.827e+009
50.	1.896e+009
100.	1.413e+009
200.	1.069e+009
2000.	4.41e+008
10000	2.62e+008
20000	2.14e+008
1.e+005	1.38e+008
2.e+005	1.14e+008
1.e+006	8.62e+007

FIGURE 6
Structural Steel > Strain-Life Parameters

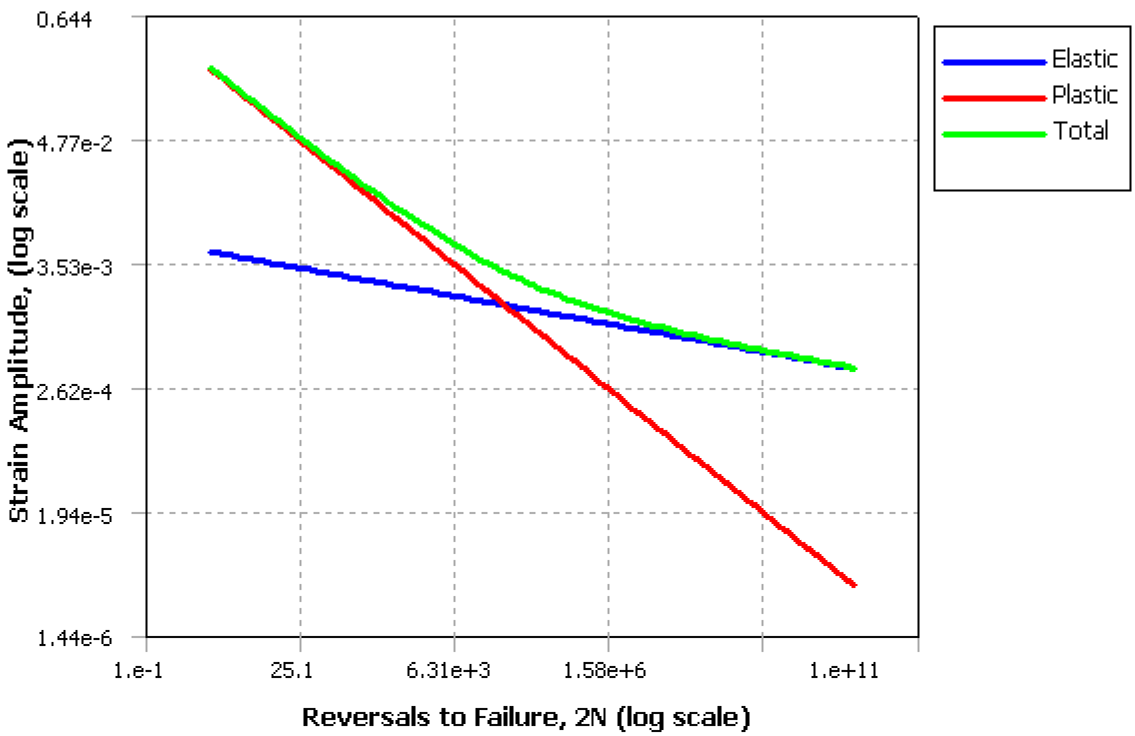


TABLE 26
Structural Steel > Strain-Life Parameters > Property Attributes

Display Curve Type	Strain-Life

TABLE 27
Structural Steel > Strain-Life Parameters > Strain-Life Parameters

Strength Coefficient Pa	9.2e+008
Strength Exponent	-0.106

Ductility Coefficient	0.213
Ductility Exponent	-0.47
Cyclic Strength Coefficient Pa	1.e+009
Cyclic Strain Hardening Exponent	0.2

SOMG-Flax

TABLE 28
SOMG-Flax > Constants

Structural	
Young's Modulus	6.9e+009 Pa
Poisson's Ratio	0.3
Density	800. kg/m³
Thermal Expansion	0. 1/°C
Thermal	
Thermal Conductivity	0. W/m·°C
Specific Heat	0. J/kg·°C
Electromagnetics	
Relative Permeability	0.
Resistivity	0. Ohm·m

14.6 Appendix F: Bill of Materials

The Bill of Materials is shown below.

Item	Quantity	Source	Material	Manufacturing Process	Function	Cost	Note
Rapid Prototyped 3D Model	1	UM 3D Lab	Plastic Rapid Prototyping Material	Rapid Prototyping	Communicate Design	$118.00	
Epoxy Resin	50 oz	Home Depot	Epoxy Resin	Hand Assembled	Demonstrate Composite	$14.97	
Bamboo Fiber	3 skeins	Knit-Around Yarn	Bamboo	Hand Woven	Demonstrate Composite	$16.75	
Square Mold (Paint Tray)	3	Home Depot	Plastic	-	Build Composite	$4.97	
Latex Gloves	4	Home Depot	Latex	-	Protect Team	$2.47	
Breathing Masks	2	Home Depot	Primarily Cotton	-	Protect Team	$3.11	
Indratech IPF (4ftx4ftx6in)	1	Indratech	Primarily Recycled Polyester	Hand Cut	Demonstrate Cushion	-	Provided for Free
Cloth	4 yards	Jo Ann Fabric	Cotton	Hand Stitched	Demonstrate Cushion	$15.00	
Wood Board (8ftx1inx2in)	1	ACE Hardware	Wood	Hand Assembled	Demonstrate Snap Attachment	$16.00	
Snap Attachments	15	ACE Hardware	Stainless Steel	Hand Assembled	Demonstrate Snap Attachment	$18.00	

14.7 Appendix G: Description of Engineering Changes since Design Review #3.

The design process that we went through was very iterative, so we made some changes between Design Review #3 and the final design. The first change that we made concerned the size of the fillets on the seat. Originally, all of the fillets were created to have small radii as not to disrupt the visual appeal of the design. Stress testing with FEA revealed that there was too much stress in the filleted areas. In order to alleviate these stress concentrations, we increased the radii of the fillets. They were increased to be as large as possible without interfering with the design. The exact dimensions can be found in our CAD files.

Another change that had to be made was the thickness of the frame. The old design called for a thickness of 1/4 inch for the composite frame. After further analysis, this was found to be too thin. The thickness was doubled to 1/2 inch in order to increase the strength of the frame. This change was necessary in order to meet the strength requirements for the seat.

The location of the snaps was also changed for the final design. In Design Review #3 the team failed to rigorously define where the snaps would be attached. The final design shows exactly where the snaps will be located. This is an important change because it eliminates some of the vagueness of the old design.

14.8 Appendix H: Description of Design Analysis Assignments.

Assignment #1: Material Selection

Frame

The material selected for the frame is not in the CES database. Glass fiber/Epoxy is chosen to complete this assignment because it has similar properties as the selected bio-based composite material.

The function of the frame is to support loads. The desired frame material would have to be lightweight, environmentally friendly, durable, strong, and low cost. The constrains are

1. Density small than 10 000 kg/m^3
2. Renewable or recycle fraction greater than 85%
3. Above average fresh water resistance
4. Yield strength larger than 40MPa
5. Cheaper than 20 USD/kg

Constrains are loosely defined because a variety of materials can be chosen for the frame. The appropriate material indices are metal, wood (including bamboo), and composite (assuming they are renewable like our bio-based composite).

<u>Choice 1</u>
Carbon steel AISI 1015 (Normalized)
Advantage: The cheapest material that is suitable and passed all constrains.
Disadvantage: Heavy

<u>Choice 2</u>
Magnesium alloy AM 100A, T6
Advantage: The most lightweight metal that passed all constrains
Disadvantage: High CO2 footprint

<u>Choice 3</u>
Lignumvitae
Advantage: The strongest renewable material (Highest yield strength). It's relatively lightweight.
Disadvantage: Lower yield strength compare to metal

<u>Choice 4</u>
Carbon steel AISI 1340
Advantage: Good yield strength.
Disadvantage: Heavy

<u>Choice 5</u>
Epoxy (glass fiber)
Advantage: Relatively light weight

Disadvantage: Not recyclable (recycled fraction 1.8%~2.2%)

Assuming the bio-based composite material chosen has similar properties as epoxy (glass fiber) and uses renewable resource. It would be a strong renewable material that can be used as the frame material. This material would be preferred because the focus of our project is renewability. Other renewable material such as lignumvitae and bamboo are flammable and would not be suitable for our application. Flammability was not one of the constrains because we want to consider some renewable material. Constraining the materials to be non-flammable would make all renewable materials fail the selection.

Padding

This material selection process is done only for the purpose to complete the assignment. None of these materials are chosen because of their low recyclability.

The function of the padding is to support the loads adequately providing comfort to the driver. It would also have to be environmentally friendly, non-flammable, and durable. The constrains are

1. Minimum recycled fraction of 50%
2. Not flammable (including non-flammable, slow burning, and self-extinguishing)
3. Maximum service temperature greater than 100 degrees Celsius
4. Minimum service temperature lower than -50 degrees Celsius

The appropriate index is polymeric material.

<u>Choice 1</u>
Polycarbonate (copolymer, high-heat)

<u>Choice 2</u>
Polyamine/Nylon (type 46, unreinforced)

<u>Choice 3</u>
Polyarylsulfone (PAS-unflled)

<u>Choice 4</u>
Polysulfone (flame retarded)

<u>Choice 5</u>
Polybutylene terephthalate-unfilled (general purpose PBT)

The selected material is general purpose PBT because it’s the cheapest among the material that passed the constrains. It also has the least CO2 footprint which helps to reduce the environmental impact of our design.

Assignment #2: Design for Assembly

1) Assembly Efficiency of Original Design

1	2	3	4	5	6	7	8	9	Name of Assembly
Part ID number	Number of times operation carried out consecutively	Two-digit manual handling code	Manual handling time per part	Two-digit manual insertion code	Manual insertion time per part	Operation time (seconds) (C2*(C4+C6))	Operation cost (cents) (0.4*C7)	Figures for estimation of theoretical minimum number of parts	Environmentally Friendly Driver Seat
1	1	95	4	00	1.5	5.5	2.2	1	Seat Frame
2	25	10	1.5	39	8	237.5	95	25	Snap Screw
3	3	80	4.1	99	12	48.3	19.32	3	Cushion Cover
4	3	80	4.1	99	12	48.3	19.32	3	Zipper
5	25	10	1.5	90	4	137.5	55	25	Cover Snap
6	3	30	1.95	31	5	20.85	8.34	3	Padding

TOTAL	497.95	199.18	60
	Time	Cost	Parts

Efficiency = 3*Parts/Time = 3*60/497.95 = 0.361482

2) Study for Minimum Number of Parts
   a) Do parts move relative to each other?
   b) Must parts be made of different materials?
   c) Would combination of these parts prevent assembly or disassembly of other parts?
   d) Has servicing of the assembly been adversely affected?

Part Relations	Qa	Qb	Qc	Qd
Frame > Snap Screw	**No**	**No**	**No**	**No**
Snap Screw > Cover Snap	Yes	No	Yes	No
Cushion Cover > Cover Snap	No	Yes	No	No
Cushion Cover > Padding	Yes	Yes	Yes	No
Cushion Cover > Zipper	No	Yes	Yes	No

The above test shows that the frame and the snap screws (the half of the snap that is attached to the frame) can be combined into one part. The composite material should be strong enough that the snap screws can be molded into the frame, thus eliminating 25 parts from the total number of parts. The redesign will include the snap screws integrated into the frame.

3) Assembly Efficiency of Redesign

1	2	3	4	5	6	7	8	9	Name of Assembly
Part ID number	Number of times operation carried out consecutively	Two-digit manual handling code	Manual handling time per part	Two-digit manual insertion code	Manual insertion time per part	Operation time (seconds) (C2*(C4+C6))	Operation cost (cents) (0.4*C7)	Figures for estimation of theoretical minimum number of parts	Environmentally Friendly Driver Seat
1	1	95	4	00	1.5	5.5	2.2	1	Seat Frame
2	3	80	4.1	99	12	48.3	19.32	3	Cushion Cover
3	3	80	4.1	99	12	48.3	19.32	3	Zipper
4	25	10	1.5	90	4	137.5	55	25	Cover Snap
5	3	30	1.95	31	5	20.85	8.34	3	Padding

TOTAL	260.45	104.18	35
	Time	Cost	Parts

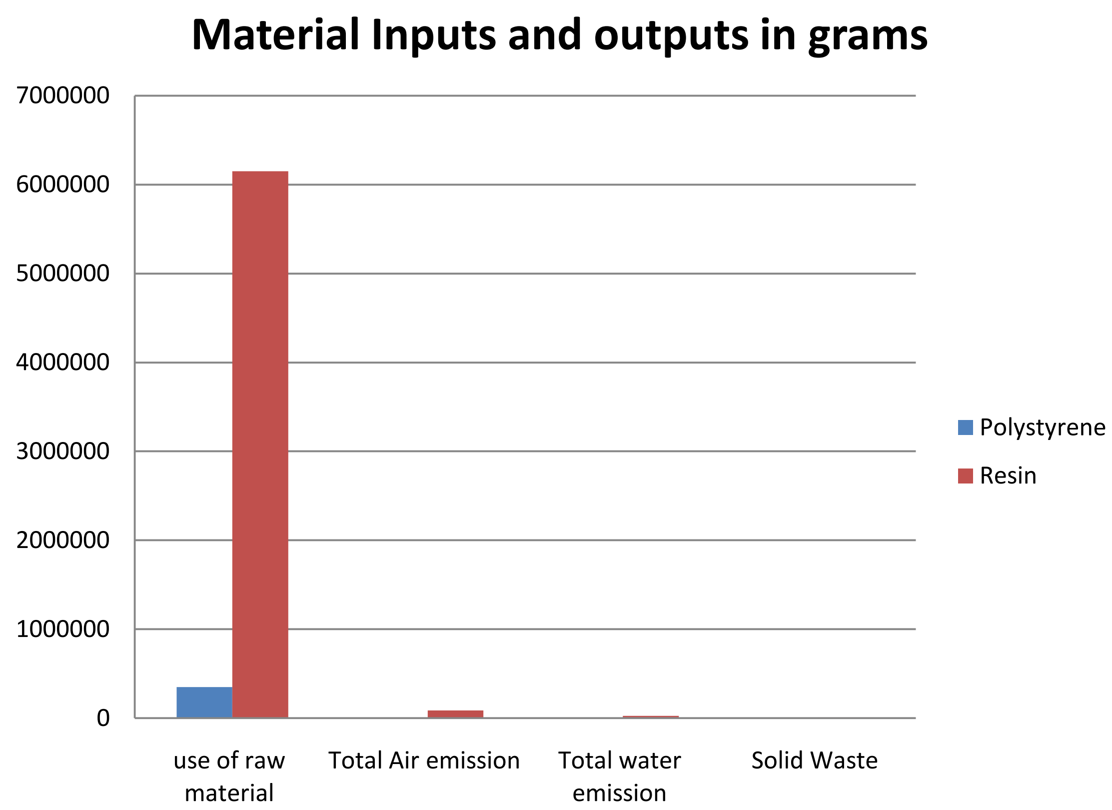
Efficiency = 3*Parts/Time = 3*35/260.45 = 0.403148

4) For Design For Assembly worksheets, see the above sections.
5) After completing the Design for Assembly worksheets, the possible changes to the design were to make the snap screws part of the frame. In other words, instead of the snap screws being separate parts to be attached to the frame, they are included in the mold and made into the frame out of the same composite material. This change increased the assembly efficiency by 4.2% and eliminated 25 parts from the overall assembly.

Assignment #3: Design for Environmental Sustainability
In this assignment, we compare the environmental impact of 15 kg of epoxy resin and 2kg of polystyrene.

The total air emission, water emission, use of raw material, and solid waste are listed in the table below.

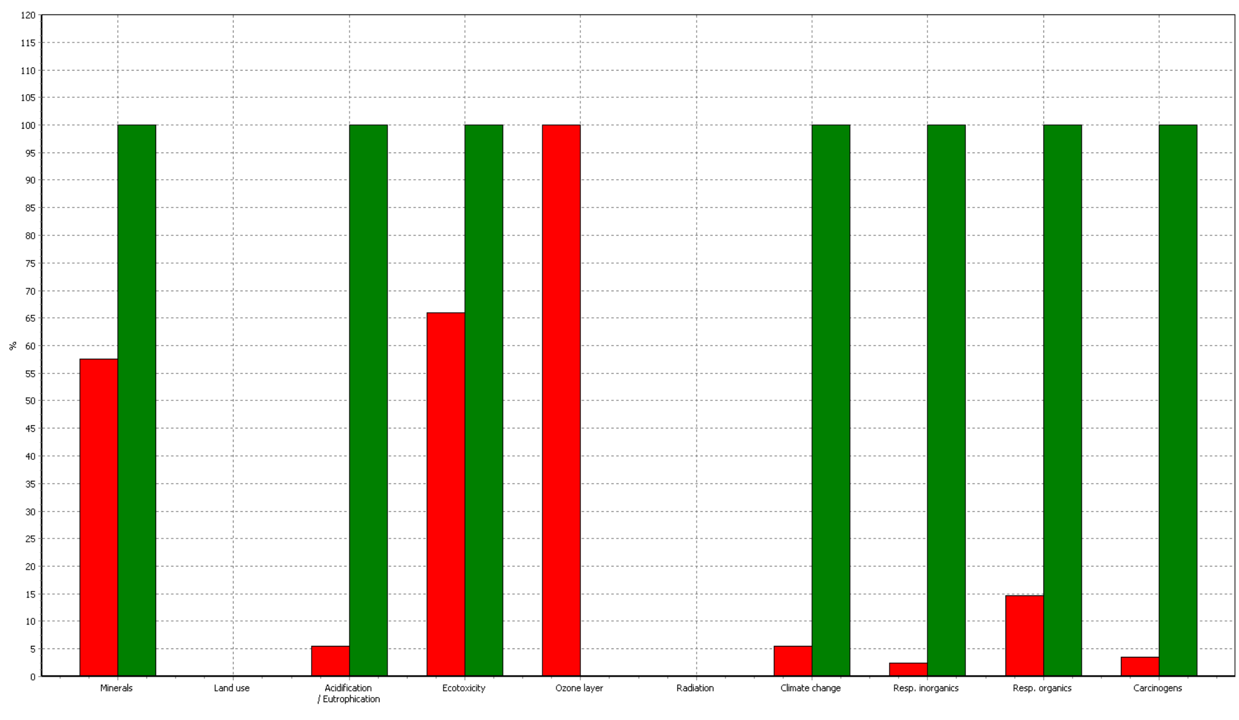
	Resin	Polystyrene
use of raw material (g)	6149475	348896
Tot Air emission (g)	87879	5261
Tot water emission (g)	23661	13
Solid Waste (g)	5922	1197



Epoxy has more impacts on carcinogens, resp. organics, resp. Inoprganics, climate change, ecotoxity, acidification, and minerals. EPS has more impact on the ozone layers.

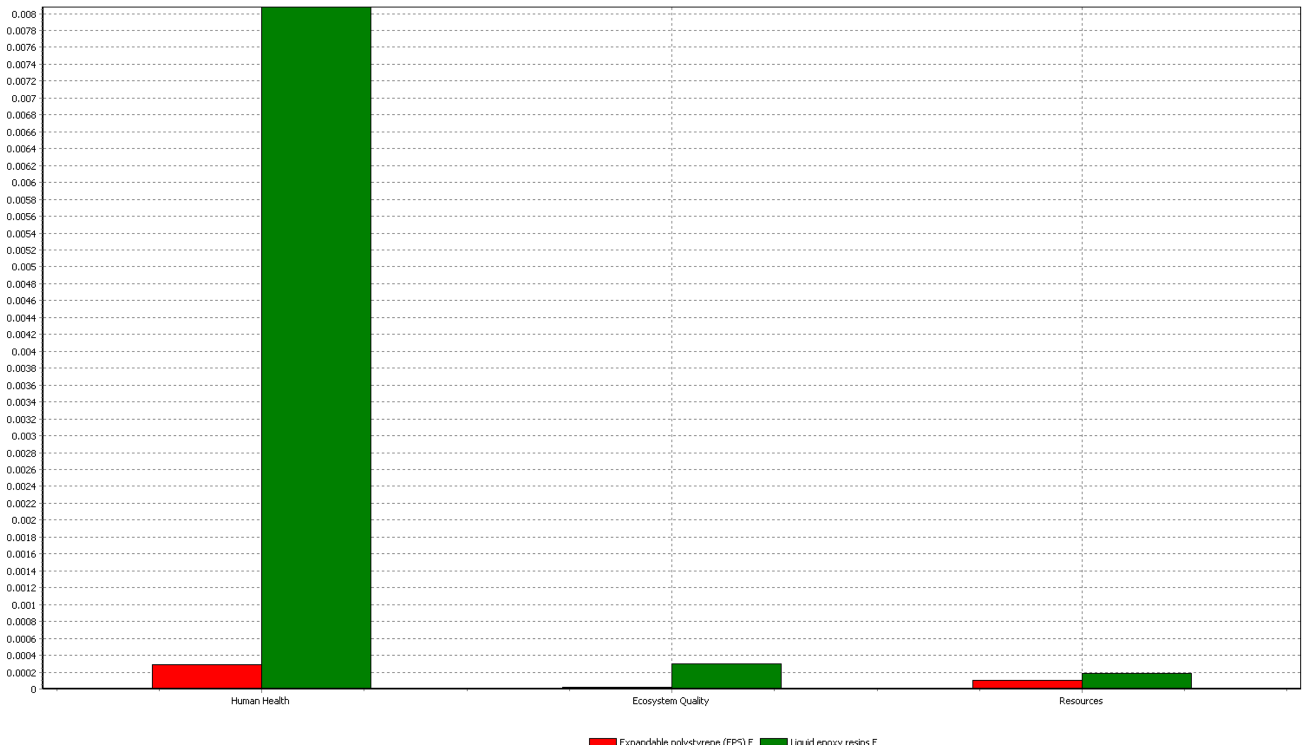
Impact category	Unit	Expandable polystyrene (EPS) E	Liquid epoxy resins E
Carcinogens	DALY	3.88054E-09	1.1279E-07
Resp. organics	DALY	1.27331E-08	8.71969E-08
Resp. inorganics	DALY	1.07256E-06	4.26988E-05
Climate change	DALY	1.31649E-06	2.38546E-05
Radiation	DALY	0	0
Ozone layer	DALY	1.02864E-10	0
Ecotoxicity	PAF*m2yr	0.103784875	0.157395032
Acidification/ Eutrophication	PDF*m2yr	0.07251496	1.335784057
Land use	PDF*m2yr	0	0
Minerals	MJ surplus	0.016007677	0.027820756

Table shows relative impact in different damage categories



Bar graph shows relative impact in different damage categories

Based on EI99, the most important damage categories are human health.



Normalized Score in Human Health, Eco-Toxicity, and Resource Categories

	Expandable polystyrene (EPS)	Liquid epoxy resins
Overall Points	0.186	4.55

Epoxy has a higher Eco99 points. At the end of the products lifecycle, epoxy is more likely to have more environmental impact because it has much more impact during the manufacturing phase. Very little impact would be contributed during the user phase and the end of the life cycle epoxy is believed to have more impact because we use so much more of it.

Based on this analysis, neither material would be suitable for out environmentally friendly driver seat project. Other materials with smaller environmental impact must be considered.

Assignment #4: Design for Safety

1. We used DesignSafe to help perform a risk assessment. The person riding in our seat is the user at risk in this analysis. The major risks found with DesignSafe are shown in the report on the next page.

2. The major risks identified with DesignSafe concern an impact with the seat. We have been planning for this failure from the beginning of the project because some of our engineering requirements have to do with impact forces.

We did not expect as many ergonomic risks as we found. This is a more serious problem than we expected. An ergonomics expert could make some redesigns to reduce these risks, but for now, our solution of using warning stickers is sufficient. That will help alleviate the risk for now.

3. There is a big difference between risk assessment and FMEA (Failure Modes and Effects Analysis.) FMEA is used to find the potential failing points of a design. All of the potential failures are ranked based on severity and probability of failure. The detection rate and effects of the failure are also considered. These ratings are used to create one metric, the Risk Priority Number (RPN.) Possible failures that have a high RPN are redesigned to reduce risk and make a better product.

Risk Assessment looks at possible hazards associated with using the design. Possible risks are found by brainstorming and they are assigned ratings based on level of severity and probability of occurrence. These risks are then ranked and the design changed to reduce the high risk areas. This is repeated until acceptable risk is reached. Acceptable risk will be different for every design.

4. It is impossible to design something to have zero risk. There will always be some element of risk with every design. Acceptable risk is the level that we strive to reach. This is the point where we cannot reasonably make the design safer. This means that the design is as safe as it can be without losing function or consuming lots of extra resources.

designsafe Report

Application:	Environmentally Friendly Driver Seat	Analyst Name(s):	Aaron Williams
Description:		Company:	Team 35
Product Identifier:		Facility Location:	University of Michigan
Assessment Type:	Detailed		
Limits:			
Sources:			

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	mechanical : crushing The seat could crush the occupant in the event of a crash	Slight Remote Unlikely	Low	substitute less hazardous material / methods	Slight Remote Unlikely	Low	
All Users All Tasks	mechanical : cutting / severing The seat could cut the occupant in the event of a crash	Slight Remote Unlikely	Low	substitute less hazardous material / methods	Slight Remote Unlikely	Low	
All Users All Tasks	mechanical : pinch point A user could get caught in one of the seat's holes	Minimal Remote Unlikely	Low	substitute less hazardous material / methods	Slight Remote Unlikely	Low	
All Users All Tasks	mechanical : fatigue Fatigue could cause fracture of the seat	Serious Remote Unlikely	Moderate	substitute less hazardous material / methods	Serious Remote Unlikely	Moderate	
All Users All Tasks	mechanical : break up during operation Fracture could result from operating the automobile	Serious Remote Unlikely	Moderate	substitute less hazardous material / methods	Serious Remote Unlikely	Moderate	
All Users All Tasks	mechanical : impact Impact of the automobile could cause failure	Catastrophic Occasional Possible	High	substitute less hazardous material / methods	Catastrophic Occasional Unlikely	High	
All Users All Tasks	ergonomics / human factors : posture User sitting with improper posture could cause long term damage	Slight Frequent Unlikely	Moderate	warning label(s)	Slight Frequent Unlikely	Moderate	
All Users All Tasks	ergonomics / human factors : repetition This risk is increased with repeated use	Slight Frequent Unlikely	Moderate	warning label(s)	Slight Frequent Unlikely	Moderate	

User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
All Users All Tasks	ergonomics / human factors : duration Long time use will also increase risk	Slight Frequent Unlikely	Moderate	warning label(s)	Slight Frequent Unlikely	Moderate	
All Users All Tasks	noise / vibration : fatigue / material strength Noise and vibration is given for an automobile, which will cause fatigue	Serious Frequent Probable	High	substitute less hazardous material / methods	Slight Frequent Probable	High	

We faced this issue when working on our project. We had many requirements that were directly related to safety. We had to meet these requirements while still accomplishing other goals, which had opposite needs. For example, using more material in our frame would make it stronger, but in order to meet environmental requirements we had to cut down on the amount of material used. To satisfy both requirements we made sure that there was enough material for the design to be reasonably safe.

Assignment #5: Manufacturing Process Selection

1. Our sponsor is one of the biggest suppliers of automotive seats in the world. Although they produce many different designs, each one can be used in many different cars. If our seat was to be put into wide scale production, it could potentially be used in a large number of car models. Since Lear has so many car manufacturers as customers, it would be reasonable to expect a volume of around 100,000 seats to be produced.

2. The first process that we considered is for our flax fiber-soybean oil composite. To find this process, we looked at all of the composite forming processes. A key part of our composite is that the fibers are woven, not randomly arranged. This makes the composite stronger but also limits our manufacturing choices. Since we are making such a large volume of pieces, compression molding seems like a natural choice. This allows a large number of parts to be made cheaply.

Of the compression molding processes, cold press molding is the only one that allows woven composites. Another reason that this is a good process is because it is already widely used in the automotive industry. Finally, cold press molding is better for the environment than other molding processes because it uses a closed mold process. This is important for us because of the environmental focus of our project.

The next process that we considered is for our foam. The foam is produced in large blocks that need to be cut down to size for our cushions. We considered all machining processes to find the best one. Since the foam needs to potentially be cut in multiple directions, we chose to use a band saw. This allows for a high production volume and accurate cuts.