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Autonomous Vehicle Interior Design

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Memo to: Dr. Betsy Aller, EDMMS

From: Team AVID

Subject: Autonomous Vehicle Interior Design senior project completion

Introduction

Senior engineering design presentations were recently completed on December 3, 2019. This memo serves to outline the work completed in the Autonomous Vehicle Interior Design senior project. The Summary Project Report highlights the design process and development of the autonomous vehicle interior.

Project Information

Automotive companies are researching and creating self-driving technology for vehicles; however, they are not dedicating as many resources to their interior designs with which passengers will interact. Therefore, the crux of our project was to research, investigate, design, and create the interior for an autonomous vehicle, bearing in mind new creative possibilities that are not feasible in driver-dependent vehicles. The interior mockup was created by utilizing concept sketches from current automakers, a survey inquiring about what participants would like to see in autonomous cars, small-scale interior models, and manufacturing methods including: 3D printing, woodworking, welding, sanding, and more.

3D prints failed due to moisture in the filament which was resolved by drying it and changing the print settings. To accommodate a tight budget, seats were sourced from scrapyards and Amazon, and affordable building materials were obtained from Menards without compromising quality. Spatial issues where components interfered with each other were remedied by having students interact with the model to make appropriate spacing modifications, which was possible because most components were configurable.

The model was generally well-received by students, but spatial issues were the biggest concern. As automakers refine their autonomous vehicles, it is important that they design freely and creatively, keeping in mind packaging constraints to fit everything together. The work completed showed how difficult it is to develop a consumer product and how important it is to survey the consumer base when creating solutions.

Conclusion

The final model was created both in physical full-scale and a 3D Computer-Aided Design digital representation. To continuously improve the interior, it is important to periodically receive more consumer feedback and adjust as necessary. We'd like to acknowledge our course coordinator Dr. Betsy Aller and advisor Mr. Middleton for their ongoing support and will take these lessons moving forward in our careers.

Autonomous Vehicle Interior Design

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Senior Design Summary Report

December 13, 2019

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Abstract

As technology in the automotive industry advances and self-driving vehicles become more commercially available, design concepts for their interiors must also be developed. Research was conducted on automotive design and autonomous technology, drawing inspiration from production and concept vehicles of the past, present, and future. A survey was conducted to gauge possible consumer needs. Hand sketches, small-scale models, and a Computer-Aided Design (CAD) model was produced. A full-size model was developed using various material-forming processes, including 3D printing, woodworking, clay sculpting, and metal machining. The interior was designed with consideration for safety, comfort, and technological advancements to satisfy the needs of the consumer.

Introduction

The current state of the automotive industry is approaching a fully electric and autonomous mode of transportation. With the prospect of a "green future," automotive giants such as General Motors and Ford Motor Company have sought to keep up with competitors like Tesla Motors who have pushed for this change. Companies such as Uber and Lyft are considering replacing drivers with autonomous ride-shares. Modern automobiles have features including assisted parking, adaptive cruise control, and auto-pilot driving, which points to a future of self-driving vehicles on a computerized and sensory system. This project provides an understanding and visual representation of what the future of automobile interiors may incorporate when manual driving is not needed.

Project Objectives

Market research and a survey was conducted to explore ideas, create concept sketches, and develop models. This information was used to create the final deliverables: a CAD model with features of the car interior and a full-size, 5-passenger autonomous vehicle interior that demonstrates innovations which companies can consider for their own designs.

Keeping costs to a minimum was important in making the model. There was an allotted $1,000 budget for cost of supplies. Lightweight and affordable material was used to maintain ease of transportation and low cost.

The engineering design process was the framework used to approach each challenge. Redesigns and adjustments were made based on feedback. The team and advisor set specific criteria for the design, and after analyzing research data and homing in on the target market, representational models of an autonomous vehicle interior were developed.

Summary

Now that vehicles are shifting toward an automated drive system, designers must seek new possibilities for automotive interiors. The engineering design process calls for defining the problem, researching the market, designing and selecting solutions, and redesigning as necessary.

Background

Vehicles are used every day to transport innumerable passengers and goods. As populations increase and urban areas expand, the need for fast and reliable transportation grows. Efficient methods of transportation must be developed in the best interest for people's time, money, and safety. One solution for this is the implementation of self-driving cars.

To establish an understanding of the development of self-driving cars and their interiors, the team examined several main topics: Safety standards, current autonomous interior designs, and consumer-market research. This technical research explores the possibilities for the future of automotive interior design envisioned for the industry.

Current Safety and Regulations

A better understanding of how to approach an autonomous vehicle interior design was gained by researching safety standards to establish more criteria. Very few states have implemented laws that are specific to autonomous vehicles. The Department of Transportation released documents for guidance and voluntary procedures; however, these are not laws, rather suggested guidelines written to remove obstacles and to streamline innovation (NHTSA, 2018).

The National Highway Traffic Safety Administration (NHTSA), under the U.S. Department of Transportation, released a framework titled *Preparing for the Future of Transportation: Automated Vehicles 3.0.* It underlines the prioritization of human life and safety on the road, citing statistics like how there's been 2.2 million fatal automobile crashes since 1966. Human error is the leading cause (94%) for these fatal accidents (NHTSA, 2018). This article also establishes a Level scale from 0 to 5 defining increasing levels of autonomous vehicle integration. Level 0 has no automation with full driver responsibility, and Level 5 has full automation with optional human control. Autonomous vehicles are encouraged to have redundant safety systems, provide feedback to the outside world like visible sensors for pedestrians and other drivers, and have the option for the user to take complete control of the vehicle at any given time. (NHTSA, 2018).

Considering the likely event that all autonomous vehicles follow the aforementioned guidelines, and coupled with a network in which vehicles communicate with each other, we narrowed our focus to a Level 5 autonomous vehicle, claiming that this vehicle will have near-zero chances for any unforeseen collisions and other safety hazards. External accidents with this proposed autonomous vehicle are out of the scope of the project.

The Future of Autonomous Interiors

Extensive research of future vehicles from current car manufacturers was conducted. Some of the concepts found included Bentley's 2036 design and Volvo's 360c vehicle. Based on several of these designs, it was concluded that desks, tables, ample storage, touchscreens, and display panels were some of the most critical features to include (Savov, 2018). Research also concluded that variable seating options were a popular choice among future concept designs (Wong, 2016). Seating options would allow for passengers to recline and sleep during long trips or face one another to create a more social experience. These findings were important for developing future designs and moving forward in creating the final deliverables.

Maximizing comfort, flexibility, and appeal of designs to consumers was key. Following the direction of current automakers, it was important to have the option of creating a premium and luxurious interior and attempting a functional and broadly appealing design that limits cost. The research conducted on current manufacturers conceptual designs, along with modern vehicles, provided for a unique vision of an interior that fits the current and near-future market.

Project Activities

After conducting research, structuring a plan for how to tackle such a large project was crucial to accomplishing our goals. This required generating various ideas for design features, asking end-users directly what *they* may want for their autonomous vehicle experiences, sketching ideas on paper, and bringing those ideas to life in small models. Creating the physical model required measurements from a real-world vehicle, designing fixtures and bases, and manufacturing components and arranging them to physically perform as desired for the large model. Constructive criticism from people around the college helped to redesign and correct issues as necessary.

Design Thinking

A Design Thinking exercise orchestrated by Mr. Middleton was held after finalizing research. Design Thinking is an activity in which participants are shown how to approach problems by conjuring up as many imaginative ideas as possible, no matter how unconventional and eccentric. This mitigates negativity, allows for maximum creativity, and stimulates thought to propose solutions when deadlines approach and a decision is required. The exercise was completed along with Mr. Middleton's other senior design team, and we were brought together to brainstorm ideas and give input on design concepts. The result was a list of potential features to contemplate and include in the interior design.

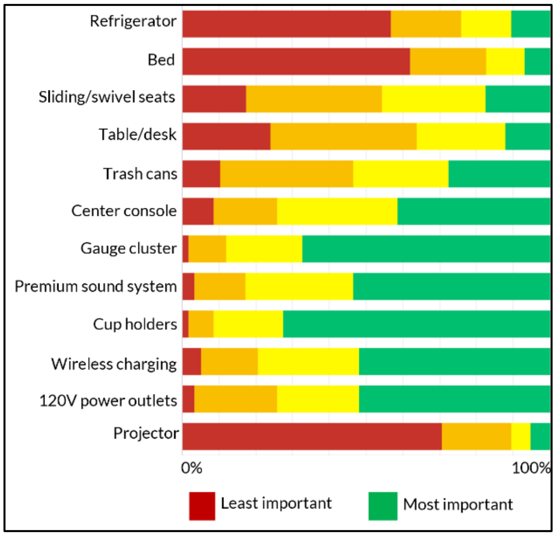
Survey and Results

To gain an understanding of consumers' wants from an interior, the team distributed a survey through Facebook's SurveyMonkey app with questions that included features from Design Thinking. Among the questions were: gender identity, age range, seating features, what type of commutes would the vehicle be used for, which interactive features were most important, and activities that might be done on a commute.

Most responses were female (59%), with the largest age group being 18-24 years old (34%). The second largest age group was 55-63 years old (29%), which was helpful because designs could address the needs of all age ranges based on these demographics.

Generally, results showed that people would use autonomous vehicles for both long and short distance travel. An overwhelming number of people desired adjustable interior lighting options. Top seating features included: cooled, heated, massage, and reclining chairs, configurable seating, leather material, and storage behind seats. Other key requests included cupholders, a gauge cluster to see the vehicle's status, and wireless charging with 120V power outlets. Table 1 shows these features associated with a popularity bar chart.

Table 1: Importance of Features in an Autonomous Vehicle



Trash cans, projector screens, refrigerators, and a bed were among things that were not important to respondents. These results contradicted initial predictions but were useful in recognizing that the team's design inputs did not always reflect the wants and needs of the consumer. Due to monetary restrictions, we did not capture the needs of all the survey requests, such as adjustable lighting or heated seating. Compromises were made to meet other needs which were more feasible, such as the reclining front seats, storage underneath the backseats, wireless charging, and 120V outlets.

Concept Sketches and Small-Scale Models

2D concept design sketches of the interior, its accessories, and seats were created to understand the design elements each member wanted to implement in the final design. Using survey requests and other manufacturer's concept sketches as a basis, sketch designs were created by taking creative liberties and including additional features which could improve the project. Some of the sketch features included translatable seats in the front-back direction, swivel seats, touchscreen controls, desks or tables, and storage compartments. Figures 1 and 2 represent some of the team's drawings which detail some of these design features.

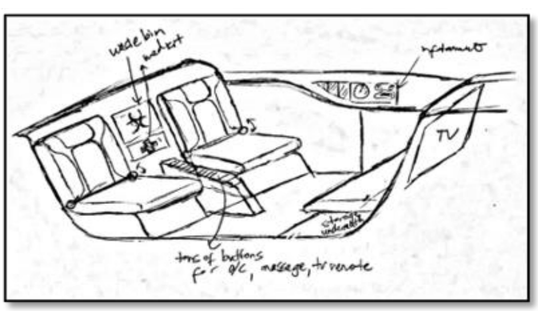


Figure 1: Concept sketch #1

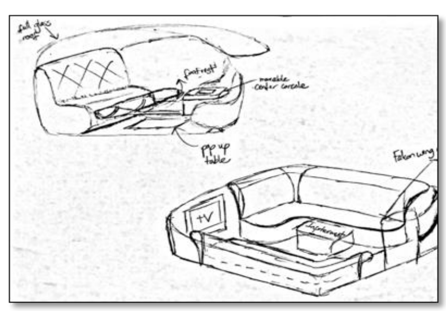


Figure 2: Concept sketch #2

While some sketches presented a more luxurious lounge feeling with passengers having the option to face one another, others were more traditional, including three-passenger backseats and two front seats. After completing several sketches, team members created their own individual scale models using the 2D drawings as inspiration. Putting the small models together gave a physical and visual representation of design ideas to add to the final build, gave a hands-on approach to manipulating and forming materials like foam and clay, and allowed for the consideration of spatial restrictions. Figures 3 and 4 show two of the total 10 scale models.

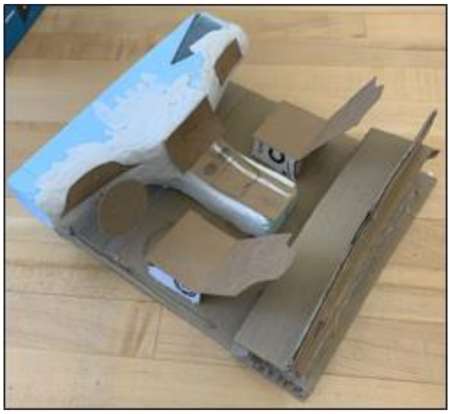


Figure 3: Scale model #1

Figure 4: Scale model #2

After exploring all sketches and scale models, specific characteristics of the small-scale models and sketches were identified to be later incorporated in the CAD model and final full-scale design.

Design and Manufacturing

Measurements were taken from a Honda Odyssey to determine how much space should be used in the build model. This was our choice for a reference vehicle due to the large amount of space it would provide, enabling more creative design. Based on measurements, dimensional sketches were created for the base and support structures that would serve as documentation for the required amount of material. This design accounted the challenge of moving such a massive project outside of the project room, so a split platform design with caster wheels was created. Figure 5 and 6 show the sketches created.

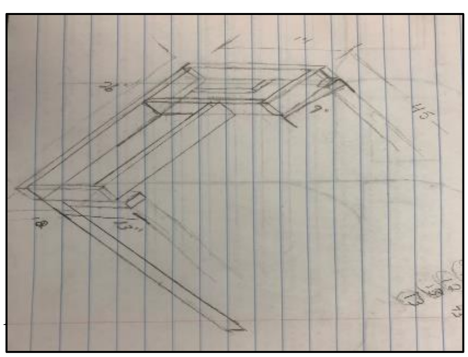


Figure 5: Dimensional sketch #1

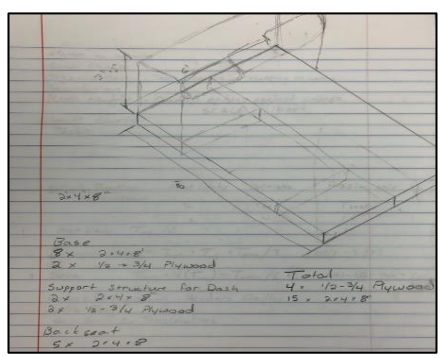


Figure 6: Dimensional sketch #2

Initial manufacturing steps

After material quantities were calculated and gathered, the team began building structures that would serve as a wood frame to build upon. Furthermore, the team acquired a backseat and two front seats. Cost-effective solutions were sought out for obtaining the seats that would meet functional requirements. Backseats were sourced from a Jeep found in a local scrapyard for $50. Desk chairs were purchased for $60 each from Amazon to serve as front seats. Figures 7 and 8 show the base structure along with frame mounts.

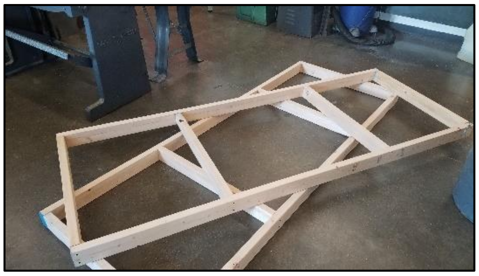


Figure 7: Base wooden frame

Figure 8: Base with backrest mounted

Manufacturing processes

Various manufacturing processes contributed to finalizing the physical interior model. Plywood sheets and 2”x4” studs were cut using a table saw provided in the student projects lab. They were also drilled to make slots for joining with wood screws, smoothed with a belt sander, and/or cut using a knee mill. Stock metal materials were cut, turned, and welded together. Ultimaker 3D printers were leveraged to produce parts such as the backseat armrest control panels, cupholders, and the wireless charging encasement. Working with large sheets of 2” thick foam involved cutting with hot wires, sanding by hand with drywall sandpaper to make rounds and smooth surfaces, gluing with hot glue guns, and cutting with handsaws.

Various issues arose during manufacturing. Warping of the wood material due to ambient moisture and temperature caused dimensional inaccuracies but were not significant enough to require a redesign. Repeated print failures due to moisture in the filament were relieved by drying the filament. Additionally, the printer settings were fine-tuned in order to minimize future print failures.

Manufactured components

The model consisted of the following modular components: a separable platform, center console, backseat, dashboard, and two front seats. All these components were free to move if needed.

The center console was developed using a wooden frame and foam with a compartment on top for storage. A functioning wireless charging pad and 120V outlets were integrated to the center console and connect to a power strip. A table was also constructed with foam sheets and affixed to the center console, which could be useful for completing work on a commute or the center of a social space.

The backseat was mounted to a simple box frame and was bolted down at locations where the original manufacturer designed the seat's bracket bolt holes. The frame was constructed out of several wood studs cut to size, bolts, washers, and foam panels which were shaped as armrests which each contained a cupholder and mockup control panel. A storage solution using thin foam boxes were created in a drawer-like, pullout fashion beneath the left and right backseat passengers.

The dashboard was mostly a wooden frame with shaped foam. Adding curvature to the dashboard was difficult to make using only foam, so clay was added to form those complex features for aesthetic purposes. The mockup gauge cluster and display screens on the left and right side of the dashboard were made with thin black foam sheets and pasted pictures. The center screen was created using an LCD computer screen that can be controlled from an external motherboard. It was mounted into the foam dashboard using screws through the screen casing. In a production vehicle this would also be a touchscreen, but this was the selected solution to demonstrate a powered digital display.

Stock metal material such as rods, rails and bearings were obtained from a machining lab to create the computer chair fixture. The fixture allows the two front seats to recline, fully rotate, adjust vertically, and translate front-to-back which conforms to the survey's respondents' request for configurable seating.

All foam and wood support structures were coated twice with a lavender acrylic paint that highlighted components and contrasted well with the dark grey carpeted platform.

Adhering to the Design Process

Several redesigns were required in manufacturing the components. The center console had an issue where the front passenger's knees would bump into its vertical panel in the first design, therefore preventing a full rotation. Per the design process, this was a solution that would not satisfy the criteria set by the team, so the center console was modified to have space underneath where passengers could swing their knees through. Storage in the console was sacrificed but allowed the total interior design to function as intended. Furthermore, the original center console design caused spatial issues in the front seats where passenger's arms and legs interfered with the dashboard. The redesign of the center console solved this problem as well, giving those passengers more space in the forward-backward directions.

Changing one front seat fixture was necessary when it was discovered that welding material got caught and solidified in the wheel well. The right seat stopped abruptly when the bearings rolled halfway through the rails, thus not meeting the criteria of a configurable seat. To resolve this issue, the fixture was completely dismantled, purged of the weld material that caused the problem, and was finally rewelded together.

Lastly, the dashboard was redesigned because the original was very planar and mundane. Therefore, adjustments were made using more foam, foam cutting, and clay shaping in order to command more attention to the component.

Computer-Aided Design (CAD)

3D models of the interior components – including the full assembly rendering – were created using CAD software concurrently with physical model construction up through completion. Rapid design changes in the digital model determined if certain designs were feasible before making physical modifications. This allowed for efficiency in confirming those designs, improvements, and aesthetic integration. Using Creo Parametric 6.0, all team members contributed to developing sections and features of the interior design that were included in the physical full-size build.

Feedback Clinic

Students at the engineering campus were invited to interact with the model so that recommendations and design changes could be gathered. Participants saw room for improvement with vehicle control, requesting that all passengers have equal access to adjusting things such as the radio, Bluetooth connections, cabin heating and cooling, etc. Several students also disliked the storage option underneath the backseat because the drawer-style storage compartment interfered with the passenger's legs and feet. Along the same lines of critiquing, other students thought the middle backseat passenger's feet would collide with the center console upright support post. On the other hand, many students were excited about the functional wireless charging and power outlets. The gaming-style computer chairs and mockup triple touchscreens on the dashboard were also praised for aesthetics.

Budget and Cost of Activities

Mr. Middleton set the project budget at $1,000. CAD design, survey creation and distribution, use of manufacturing equipment, and research were completed through the university's open resources, free of charge. The backseats and two front desk chairs summed to $170. Materials including wood, fasteners, foam, and gluing agents summed to a total of $300. Items such as wireless charger and power outlets were purchased for minimal cost online and in retail stores. Lastly, purchase of a portable hot wire cutter for foam shaping was $30. Completion of the project was achieved without exceeding the budget as shown in Table 2.

Table 2: Cost of supplies

Activity	Cost
Online Surveys	$0
Seats	$170
Purchasing of foam, wood, & gluing agents	$300
Wireless charger	$10
120V outlets	$20
Foam shaping supplies	$30
Total	$530

Project Results

As per the design criteria defined by the team and advisor, sketches, small models, a CAD rendering, and a full-scale model were completed. Final deliverable results show a conceptualized design for a Level 5 autonomous vehicle interior. The Computer-Aided Design model and full-scale model are shown in Figures 9 and 10.

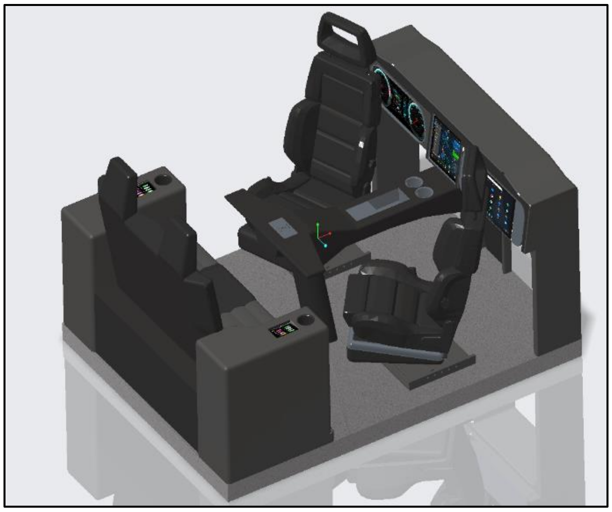


Figure 9: CAD model of interior

Figure 10: Full-scale interior build

Conclusion

Per the engineering design process, the team successfully completed all tasks required for this senior design capstone. First, the problem was defined: Currently, automakers are focusing more on developing autonomous technologies and not so much on new ways to interact with automotive interiors. Research was conducted on the issue and a survey was distributed to gauge consumer demand. Conceptual sketch designs were created for idea exploration. A build plan was formulated and executed efficiently. A feedback clinic was held for evaluation, and design changes were made where needed. As a result, representative interior models for a Level 5 autonomous vehicle were developed.

This project has demonstrated there are innovative ways to redefine a passenger's relationship with a vehicle's interior. As vehicle autonomy becomes standardized, travel will become more efficient and safer. Because of this, passengers may focus their energy on other activities while on commute rather than driving.

Finally, this project has shown a direction that automakers may take regarding the future of the automotive industry. The implementation of self-driving vehicles would benefit society by expediting travel time, improving safety, and allowing for easier commuting experiences. Autonomous vehicles can revolutionize transportation and can positively affect change around the world.

Recommendations

A primary recommendation is for future teams to have an industry mentor when tackling industry-based projects. Although guidance from the advisor and our team members' experience helped complete all tasks, a mentor would have given proper insight for automotive interior development. Moreover, we recommend teams conduct ergonomic research when designing for organic interactive environments. This facilitates converting a design from small-scale to large-scale. Lastly, we recommend seeking out how to acquire financial assistance – including grants or sponsorships from a local company – to have more options when making purchases to include in a design.

Acknowledgements

We would like to thank and acknowledge Dr. Betsy Aller and Mr. David Middleton for their continued support throughout this project and for helping us stay accountable and dedicated to completing it.

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