

# INTEGRATING SMART TEXTILES INTO AUTOMOTIVE APPLICATION OF UPHOLSTERY IN VEHICLE INTERIORS FOR THEIR DEVELOPMENT INTO THE THIRD LIVING/ WORKSPACE

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*PAPER ABSTRACT: The purpose of this study is to investigate design opportunities for industrial designers in the field of automotive interiors, with a focus on the integration of smart textiles. The research examines current trends and innovations in automotive interior design and explores ways in which smart textiles are used. Through a combination of literature review and interviews, the study aims to identify key design considerations and potential challenges when incorporating smart textiles into automotive interiors. The research suggests various opportunities in the automotive field that would greatly benefit from the application of smart textiles. The findings of this study provide valuable insights for industrial designers and the automotive industry and contribute to the ongoing conversation around the future of automotive design.*

*Automotive interiors, smart textiles, smart fabrics, interior innovation, third living space, ergonomics, user experience.*

## 1. INTRODUCTION

The automotive industry has been changing drastically in the last decade with the advent of new technology and with it the evolution of the drivers' mindset. This has led to a change from seeing vehicles as a mode of transport from one destination to another to now being another living space or workspace, each tailored specifically to your needs (e.g., a personalized space that is customizable and feels like an extension of your home). This research paper includes a market analysis of current interior upholstery techniques, an overview of Smart Textiles (ST) and their various applications and investigates the needs of shared vehicles and vehicles as third living/ working spaces. Finally, it also identifies key opportunities for ST in the automotive industry. ST has great application in providing user comfort, especially in terms of heat control and noise cancelation although it is rarely applied outside of specific fields. ST has become increasingly used in architecture, fashion, packaging, and more, but there is a lack of exploration in the realm of automotive interiors. Using ST and combining them with AI and smart technologies that are being implemented in the automotive industry can create a positive and rich user experience.

The purpose of the study is to better understand the pain points and opportunities in current vehicle interiors that potentially helps find the application of ST. The methods for achieving these results include conducting secondary research, utilizing the databases and search engines available through the K-State Libraries, and semi-structured interviews.

## 2. LITERATURE REVIEW

The purpose of this literature review is to look at what the automotive industry is doing with interior design, specifically upholstery, and textiles. Analyzing the different trends in automotive to better understand the scope of the industry to make better judgments on the areas of focus. The research will help to draw conclusions and connect different areas outside of automotive, such as Smart Textile (ST), into the field to outline opportunities. This was done by using the K-State library and Google Scholar, with articles ranging from primarily 2017-2022 with a few exceptions ranging from 2000 to 2017. Keywords include but are not limited to Automotive interiors, smart textiles, smart fabrics, interior innovation, third living space, ergonomics, and user experience.

### 2.1 CURRENT INTERIOR UPHOLSTERY

Automotive has a wide variety of fabrics and textiles being used in different areas of the vehicle. Primarily interior furnishings are made of woven, warp-knitted, weft-knitted, tufted, non-woven, and laminated fabrics (Josh, 2019). There has been a recent exploration into the application of nanotechnology to combine it with well-known textiles to create more durable and cost-effective materials. This exploration has led the fields of botany and nanotechnology to unite and explore the concept of 'self-cleaning textiles' (Josh, 2019). The current trend in automotive interiors is towards convenience and adaptability while maintaining the luxuriousness of the material and quality of finish (You, 2006). Currently, automotive upholstery testing is geared towards testing the tension of different areas of the seat and calculating the best material to get the firmness the company desires (Wirsching, 2020). Even though the application of fabrics on the interiors of vehicles is not an underexplored topic, there is a lack of written research and empirical data on the subject. Looking at how the industry is starting to make substantial changes with the advent of driverless technology, there will only be more changes coming.

### 2.2 AUTOMOTIVE INDUSTRY TRENDS AND INTEGRATION OF SMART SENSORS IN ST

As the automotive industry begins to eliminate the steering wheel using autonomous vehicles (AV), vehicle interior suppliers are investing heavily in innovative solutions for

flexible seating, replaceable components, and smart surfaces. Many concerns arise with the evolution of shared vehicles, the first being durability. Due to heavy usage, shared vehicle interiors are subject to wear and damage that could be unappealing to some users. While shared vehicles present this challenge it opens an opportunity for easily replaceable components (e.g., seat cover and carpeting). The interior suppliers are also working on producing low-cost, replaceable, and recyclable trims. These trends could open the market for greater use of biodegradable materials (Modi, 2018). Previous interviews show that exterior appearance becomes less important in Automated, Connected, Electric, and Shared (ACES) vehicles and the personalization of interiors will be the next big thing for automakers and after-market suppliers. (Modi, 2018) As the industry progresses into a more human-centric experience rather than a driving-centric one, it creates room to develop a richer user experience inside of a car. By developing textile-based sensors, the focus is on enabling non-driving activities integrated into the car interior and supporting a richer experience. In a previous study functional prototypes implemented hand interactions (such as press and double tap gestures) on the leather or fabric of the steering wheel and the back of the headrest (Khorshandi, 2022). Investigating these textile sensors is a great opportunity for shared and living vehicle spaces.

### 2.3 VEHICLES AS A SECOND LIVING/ WORKSPACE

One of the biggest trends in the automotive industry right now is the movement towards vehicles being a living space not just transportation. Previous studies are even looking into how to personalize work-centered vehicles to specific jobs by making various instruments in the vehicle adjustable (e.g., steering wheel, control panel, pedals, and seat column) (Punte, 2000). A paper published by Bosch listed these 4 concepts as the future of the third living space. (Dattatreya, 2016)

- A space, which is going to redefine the existing boundaries between office, home, and automotive interiors;
- A space that is so personalized to your tastes, habits, and behavior that it will seem to appear to be an extension of yourself;
- A space that makes you feel safe and secure, as you are on the move; whether you are encountering situations along the road or at a standstill; and
- A space that offers you a seamless experience of all different devices in the car that interact with you in tandem and satisfy your needs.

Making vehicles human-centered has made many companies look into completely redesigning the interior of the vehicle, making the seating more flexible and having a centralized commune space. With so many technologies converging in the automotive sector simultaneously, there are substantial changes on the horizon and smart textiles, AI, and user comfort look to be the center of the movement.

## 2.4 OPPORTUNITIES FOR SMART MATERIALS

ST has many applications across fields. ST is described as textiles that can sense stimuli from the environment, react, and adapt to these stimuli can range from electrical, chemical, thermal, magnetic, and more. (Priniotakis, 2022) There are three main types of ST and the first is the passive one. This ST can only sense the environment and can serve as a sensor. The second type is active ST, and these can sense stimuli and react to them. These serve as an actuator. The third and final ST or so-called Very Smart Textiles can adapt their behavior to changing conditions. For a textiles structure to be considered “smart”, both the sensor and actuator need to be present unless supplemented by a CPU to run the exchange between components. When considering the functions of the materials, lightweight textile acoustic materials are known for their enhanced sound absorption properties. These electrospun nanofibers have the advantage of a high surface area-to-volume ratio. The mechanical performance and high porosity enhance their sound absorption capabilities and could be implemented into the automotive interior to reduce unwanted road noise. Piezoelectric nanofibers are known for converting mechanical energy into electricity and have a remarkable acoustic-to-electric conversion ability (Priniotakis, 2022). This acoustic-to-electric conversion could prove useful as a passive power source for Electric Vehicles. Along with acoustics ST has amazing thermal properties that have been explored in other applications such as architecture. Innovations in ST can also help the thermal properties of buildings, which impact the overall energy use of a building and the thermal comfort of its occupants (Priniotakis, 2022). These attributes are equally beneficial to the automotive industry, especially with a lean toward vehicle living spaces. However, with the rise of EVs and due to the thermal hazards of batteries, flame-retardant materials are likely to be preferred in many areas of the vehicle (Modi, 2018). This is where ST can be a great tool for the automotive industry.

## 2.5 FINDINGS

With the secondary research conducted, there have been some noticeable gaps in information on several automotive subjects. The biggest of which is the application of ST and the implementation of AI into the interior. Bringing all these technologies together will make vehicles take a huge step towards the third living space so many companies are working towards. ST is great at providing user comfort. With materials that can react and change the environment around users, it lends the users a more comforting experience. With a growing interest in Shared Vehicles and Car Living spaces it is vital to integrate these textiles into the vehicle environment. Much research can be found about the integration of ST in buildings; however, little research has been done on the opportunities of integrating Smart Textiles into Automotive Interiors. Doing this can provide many opportunities for automotive interiors, especially with the advent of the third living space.

### 3. INTERVIEW

#### 3.1 PURPOSE OF THE INTERVIEW

This study investigates the potential of smart textiles to enhance the user experience in shared vehicles. Conventional vehicles lack appropriate adaptations for the unique requirements of shared vehicles, including frequent turnover of passengers and drivers, increased wear, and tear on the vehicle due to high usage, greater potential for messes and spills, need for easy and efficient cleaning and maintenance, limited storage space for personal belongings, and limited privacy for passengers. Through conducting interviews with people who use shared vehicle systems, the study aims to gain insights on how to better design the interiors of vehicles with the application of smart textiles in a shared vehicle. The research questions for this interview include: 1) what are the common issues faced by passengers when using shared transportation, and how can they be addressed to enhance the user experience? 2) what are the most important controls for passengers when using shared transportation, and how can they be optimized for ease of use and safety? and 3) how much time and effort do users typically invest in cleaning and repairing shared vehicles, and are there any design solutions that could reduce this burden?

#### 3.2 METHODOLOGY

A series of semi-structured interviews were conducted in person and online via Zoom. The interviews granted significant responses regarding the various issues within shared vehicle interiors among users and providers. The interview questions for the shared vehicle service providers include 1) experience with shared transportation, 2) types of shared transportation used, 3) issues with the shared vehicle system, 4) important controls for passengers, 5) standout issues with vehicle interior, 6) personal time spent cleaning/repairing a vehicle, 7) any interest in further investigating opportunities within shared vehicle spaces. The interview questions for the shared vehicle users include 1) experience with shared transportation, 2) types of shared transportation used, 3) issues with the system, if any, 4) most important controls for passengers, 5) issues that stand out about the vehicles used, specifically the interior, 6) personal time spent cleaning/repairing the vehicle, and 7) any opportunities to improve shared vehicle spaces for a better experience. See the appendix for more details.

#### 3.3 DATA COLLECTION

The interview participants were recruited by the following inclusion criteria: 1) Used or provided a shared vehicle service and 2) interested in providing their experience. The interview participants were recruited via email/in-person contact and determined based on their level of experience within their field. The interview took about 10 minutes. The interview plan was reviewed and approved by the Institutional Review Board (IRB) at Kansas State University (IRB protocol number 11620).

### 3.4 DATA ANALYSIS

In total, three participants who are users and providers of shared vehicle systems completed the interview. A detailed thematic analysis was conducted to analyze and report the data. Multiple themes emerged as a result: Cut Resistant Fabrics in Shared Vehicle Design, Cleanliness-Enhancing Fabrics for Vehicle Interiors, and Passenger Experience with Touch-Sensitive Textiles in Public Transportation.

### 3.5 RESULTS

**Cut Resistant Fabrics in Shared Vehicle Design:** PA 1 notes that the number one reason for seat reupholstery on the bus is cuts and tears in the vinyl cover. PA 2 does not enjoy how the fabric of the Kansas City buses get worn down and starts to look shabby. PA 3 does not enjoy how some Uber/Lyft or other shared car services can have holes or cuts in the upholstery.

**Cleanliness-Enhancing Fabrics for Vehicle Interiors:** PA 1 likes how easily the vinyl upholstery repels spills and how almost everything is easily wiped from the surface. PA 2 commented that Kansas City public transportation seats are gross and is not sure how often they get clean. The fabric that is used does not seem easy to clean, and stains are obvious. Vinyl is not used on Kansas City buses, the material used is similar to felt. PA 3 does not enjoy how Uber/Lyft can often feel unclean, “with trash, crumbs, and stains in the car you can tell it is used by a lot of people. It is almost like they are sacrificing cleanliness for comfort.”

**Passenger Experience with Touch-Sensitive Textiles in Public Transportation:** PA 1 does not believe the passenger needs integrated controls for this service. PA 2 noted that it would be nice to have more understandable signage and an easier way to signal when you are getting off and which door you intend on leaving from. PA 3 suggested the idea of having temperature control and radio suggestion control in a shared car space.

### 3.6 FINDINGS

Based on the interview, participants enjoy the ease of shared vehicle spaces but dislike the feeling of being unclean or uncomfortable. The most common dislikes were sacrificing cleanliness and durability for comfort making this form of transportation a less desirable choice. There is no way to completely resolve these issues without any drawbacks, but we believe some of the issues could be resolved with ST. Opportunities include ceramic-coated smart textiles which have reliable protection from cuts and tears as well as an elevated level of comfort making them perfect for use in public shared vehicle spaces. Also, in terms of cleanliness, designers can explore using ST that are easy to clean and maintain. This could include materials with antimicrobial properties that resist bacteria and other germs. Additionally, designers could integrate features such as self-cleaning fabrics or coatings that repel dirt and stains that reduce the need for manual cleaning. As for touch-sensitive textiles, designers can explore integrating smart textiles that provide easy-to-use controls for passengers. This could include temperature control, lighting, and media controls that are seamlessly integrated into the fabric and the display of the vehicle. Additionally, designers could integrate smart textiles

that provide visual cues for passengers, such as real-time information about the next stop or which door to exit from.

#### **4. DISCUSSION**

The literature review highlights a gap in information regarding the application of smart textiles in vehicle environments. Incorporating ST into vehicle interiors can enhance the overall user experience, particularly in shared vehicles and car living spaces. The integration of ST and AI can bring vehicles closer to the third living space that many companies are striving to achieve. Overall, further research is needed to explore the potential benefits of ST in automotive interiors.

While the interview provides valuable insights for the application ST based on the shared vehicle systems, the interviews with the service providers are not completed before the deadline of this paper. Future studies should include larger interview pools including both providers and users to further investigate the positive and negative points of shared vehicle interiors. Also, the interviews were conducted in an indoor space that the participants are comfortable with. Future studies should further experiment in a physical context with real materials to get a better understanding of how these textiles affect users.

#### **5. CONCLUSION**

This research has shown that while the concept of ST in automotive interiors is gaining traction, it is not yet being implemented to its full potential. However, the potential benefits of ST in automotive interiors are significant. By incorporating these innovative materials into vehicle interiors, manufacturers can create safer, more comfortable, and more functional spaces for passengers and drivers. Key findings from the interview show that shared vehicle spaces are preferred but have become a worse option because the level of cleanliness and wear is not up to their standards. Product opportunities should focus on this area and applying stronger more resistant fabrics to these spaces. Also, smart materials with antimicrobial properties or self-cleaning fabrics can reduce the need for manual cleaning. ST with temperature control, lighting, and media controls could also improve the user experience in a shared car. This study provides valuable insights into how ST can be used to improve shared vehicle spaces and highlights the potential benefits for manufacturers and consumers.

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## **APPENDIX**

### **SHARED VEHICLE PROVIDERS**

#### **BACKGROUND QUESTIONS**

- What is your age group?
- How do you identify?
- How long have you been using a shared car service?
- Warm-Up Questions
- Have you had a pleasant experience with shared transportation?
- What types of shared transportation have you used?
- Main Questions
- What are some issues you have with the system, if any?
- What controls are most important for passengers?
- Are there any issues that stand out about the vehicles you use, specifically the interior?
- How much personal time do you spend cleaning/ repairing your vehicle?
- Cool-Off Questions
- Has this interview made you want to further investigate opportunities within shared vehicle spaces?

### **SHARED VEHICLE USERS**

#### **BACKGROUND QUESTIONS**

- What is your age group?
- How do you identify?
- How long have you been using a shared car service?
- Warm-Up Questions
- Have you had a pleasant experience with shared transportation?
- What types of shared transportation have you used?
- Main Questions
- What are some issues you have with the system, if any?
- What controls are most important for passengers?
- Are there any issues that stand out about the vehicles you use, specifically the interior?
- How much personal time do you spend cleaning/ repairing your vehicle?
- Cool-Off Questions
- Has this interview made you want to further investigate opportunities within shared vehicle spaces?