

# ENVIRONMENTAL DESIGN

4<sup>th</sup> International Conference on Environmental Design

9-11 May 2024

*A cura di  
Mario Bisson*

# ENVIRONMENTAL DESIGN

Conference proceedings of the  
4<sup>th</sup> International Conference on Environmental Design

Environmental Design : IV<sup>th</sup> International Conference on Environmental Design  
A cura di Mario Bisson

Proceedings ( reviewed papers) of the IV<sup>th</sup> International Conference on Environmental Design,  
Mediterranean Design Association | [www.mda.center](http://www.mda.center) | [info@mda.center](mailto:info@mda.center)  
9-11 May 2024, Ginosa, Italy

Progetto grafico ed impaginazione: Federico De Luca e Giulia Alvarez  
Immagine di copertina: Federico De Luca  
ISBN 978-88-5509-634-8  
Copyright 2024 by MDA - Mediterranean Design Association  
Palermo University Press | Finito di stampare nel mese di Maggio 2024

## President Scientific Committee

Dr. Federico Picone	Prof.ssa Lina Ahmad - College of Arts and Creative enterprises Zayed University, Abu Dhabi - UAE
<b>Scientific Director</b>	Prof. Tiziano Aglieri Rinella - IUAV Venezia, Italy Prof. Giuseppe Amoroso - Politecnico di Milano, Italy Prof. Venanzio Arquilla - Politecnico di Milano, Italy
Prof. Mario Bisson	Prof. Antonino Benincasa - Libera Università di Bolzano, Italy Prof. Alessandro Biamonti - Politecnico di Milano, Italy Prof. Mario Bisson - Politecnico di Milano, Italy
<b>Industry Relations Manager</b>	Prof.sa Cristina Boeri - Politecnico di Milano, Italy Prof.sa Monica Bordegoni - Politecnico di Milano, Italy Prof.sa Daniela Calabi - Politecnico di Milano, Italy Prof.sa Rossana Carullo - Politecnico di Bari, Italy
Dr. Giorgio De Ponti	Prof. Mauro Ceconello - Politecnico di Milano, Italy Prof. Giovanni Maria Conti - Politecnico di Milano, Italy
<b>Organization</b>	Arch. Riccardo Culotta, Italy Prof.sa Clice De Toledo Sanjar Mazzilli - Faculdade de Arquitetura e Urbanismo da USP, Brasil
Giulia Alvarez	Ing. Giorgio De Ponti - Politecnico di Milano, Italy
Andrea Cavaliere	Prof.sa Barbara Del Curto - Politecnico di Milano, Italy
Federico De Luca	Prof. Dincyrek Ozgur - Eastern Mediterranean University, Cyprus
Alessandro Ianniello	Prof.sa Elisabetta Distefano - Università degli Studi di Palermo, Italy
Crispino Lanza	Prof. Luca Donner - American University in the Emirates, United Arab Emirates
Benedetta Meretti	Prof. Michele Fiorentino - Politecnico di Bari, Italy
Stefania Palmieri	Dr. Luca Fois - Politecnico di Milano, Italy
Dario Russo	Prof. Claudio Gambardella - Università della Campania Luigi Vanvitelli, Italy Prof.sa Franca Garzotto - Politecnico di Milano, Italy Prof. Luca Guerrini - Politecnico di Milano, Italy Prof.sa Sandra Hipatia Nuñez Torres - Universidad Técnica de Ambato, Ecuador Dr.sa Lisa Hockemeyer - Politecnico di Milano, Italy Prof. Alessandro Ianniello - Delft University, Netherlands Prof. Lorenzo Imbesi - Università la Sapienza - Roma, Italy Prof. Matteo Ingaramo - Politecnico di Milano, Italy Prof. Tomasz Jelenski - Cracow University of Technology Poland Prof. Andres López Vaca - Universidad Internacional SEK, Ecuador Prof. Giuseppe Lotti - Università degli Studi di Firenze, Italy Prof. Carlo Martino - Università la Sapienza Roma, Italy Prof.sa Diana Navas - PUC - San Paulo, Brasil Prof. sa Valentina Nisi - University of Madeira, Portugal Prof. Nuno Jardim Nunes - University of Lisbon, Portugal Prof. sa Stefania Palmieri - Politecnico di Milano, Italy Prof.sa Frida Pashako - Epoka University - Tirana, Albania Prof. Pier Paolo Peruccio - Politecnico di Torino, Italy Prof.sa Silvia Piardi - Politecnico di Milano, Italy Prof.sa Savita Raje - Maulana Azad National Institute of technology Bopal, India Prof. Pinto Reaes - Università LUSIADA lisbona portogallo, Portugal Prof.sa Francesca Rizzo - Politecnico di Milano, Italy Prof. Garcia Rubio Ruben - Tulane university- New Orleans, USA Prof. Dario Russo - Università degli Studi di Palermo, Italy Prof.sa Francesca Scalisi - Università degli Studi di Palermo, Italy Prof. Antonio Scontrino - Bowling Green State University, USA Prof. Marco Sosa - Zayed University, United Arab Emirates Prof. Cesare Sposito - Università degli Studi di Palermo, Italy Prof. Paolo Tamborrini - Università di Parma, Italy Prof. Toufic Haidamous - American University in the Emirates, United Arab Emirates Dr. Diego Vainesman - New York, Usa Prof. Sonsoles Velais - Tulane University- New Orleans, USA Prof. Min Wang - China Central Academy of Fine Arts, China Prof. Cui Wei - Beijing Institute of Fashion Technology, China Prof. Francesco Zurlo - Politecnico di Milano, Italy



## INTRODUCTION

11 Environmental Design

Mario Bisson  
Politecnico di Milano, Italy

## SUSTAINABLE DEVELOPMENT

15 RAISE ecosystem: urban design for accessible and inclusive Smart Cities

Francesco Burlando<sup>1</sup>, Federica Maria Lorusso<sup>2</sup>, Claudia Porfirione<sup>1</sup>  
<sup>1</sup>University of Genoa, Italy  
<sup>2</sup>University of Campania Luigi Vanvitelli, Italy

27 Culture, meaning, value and sustainability: A terminological analysis

Piera Losciale  
Politecnico di Bari, Italy

37 Bio-inspired design: A systemic and interdisciplinary design approach to increase the sustainability of processes and products

Lucia Pietroni, Mariangela Francesca Balsamo, Giuliana Flavia Cangelosi  
University of Camerino, Italy

49 Eco-sea design. Transdisciplinary products and services for sustainability in seaside contexts

Ivo Caruso<sup>1</sup>, Vincenzo Cristallo<sup>2</sup>  
<sup>1</sup>Università degli Studi di Napoli Federico II, Italy  
<sup>2</sup>Politecnico di Bari, Italy

63 Fashioning a Sustainable Future: Navigating Zero-Waste Practices in Textile Chain

Maria Antonia Salomè  
Università degli Studi di Firenze, Italy

75 The black hole of the fashion system:  
The contribution of design to the sustainable transition of the fashion system

Elena Pucci  
Università degli Studi di Firenze, Italy

87 Digital art direction and sustainable communication for fashion in Italy: A literature review

Filippo Maria Disperati<sup>1</sup>, Elisabetta Cianfanelli<sup>2</sup>  
<sup>1</sup>Università degli Studi della Campania "Luigi Vanvitelli", Italy  
<sup>2</sup>Università degli Studi di Firenze, Italy

97 Fast Fashion. Sustainability and the negative psychological and social impacts for consumers

Giovanni Maria Conti  
Politecnico di Milano, Italy

105 Mixed reality for addressing boredom at work: grounds and perspectives for PhD

Francesco Musolino, Michele Fiorentino  
Politecnico di Bari, Italy

113 Design as a Catalyst for Sustainability Bridging Disciplines in the Anthropocene

Dario Russo  
Università degli Studi di Palermo, Italy

125 Evolving practices in sustainable communication design: An integrated approach

Francesca Scalisi, Dario Russo  
Università degli Studi di Palermo, Italy

## SOCIAL INNOVATION

- 141 Urban lifestyle in twenty years.  
Forecasts from a Young Generation of Interior Designers  
*Luca Guerrini*  
*Politecnico di Milano, Italy*
- 159 Design as a catalyst for rural regeneration:  
Insights from a Research through Design study  
*Alessandro Ianniello<sup>1</sup>, Riccardo Palomba<sup>2</sup>*  
<sup>1</sup>*TU Delft, The Netherlands*  
<sup>2</sup>*IUAV, Italy*
- 175 The role of the communication design for the Mediterranean enhancement and development. The representative case studies map  
*Chiara Tuttolani*  
*Politecnico di Bari, Italy*
- 179 From concepts to open products:  
The experience of a design hackathon for inclusive open-source products  
*Federica Caruso, Venanzio Arquilla*  
*Politecnico di Milano, Italy*
- 191 ReMade Community Lab, Design explorations in a Proximity System  
*Susanna Parlato*  
*Università degli Studi di Napoli Federico II, Italy*
- 203 Utensilia© to design. On the “process by which people go about producing things”  
*Rossana Carullo*  
*Politecnico di Bari, Italy*
- 215 Color loci placemaking: Color and processes of place appropriation  
*Cristina Boeri*  
*Politecnico di Milano, Italy*
- 225 Editorial Design and the Influence of Racism on Black Representation in Brazilian Magazines and Newspapers: The Panorama Before and after George Floyd and João Alberto Silveira Freitas  
*Gustavo Orlando Fudaba Curcio, João Vitor Pereira Moura*  
*Universidade de São Paulo, Brasil*
- 241 Playing as a cultural dissemination strategy. Eco-bab:  
Designing collaborative, playful and educational experiences  
*Nicolò Ceccarelli, Nada Beretić*  
*University of Sassari, Italy*
- 253 Functionality and significance in the design of tourist and community interaction structures in the Colta Lagoon  
*Sandra Núñez<sup>1</sup>, Claudia Balseca<sup>1</sup> and Eliska Fuentes<sup>2</sup>*  
<sup>1</sup>*Universidad Indoamérica, Ecuador*  
<sup>2</sup>*Universidad Técnica de Ambato, Ecuador*
- 261 A Journey into Social Innovation through the Tombolo of Mirabella Imbaccari From History to Project Perspectives and the First Workshop of the Community Foundation of Messina via the Tombolo Academy  
*Luca Fois, Camilla Guerci*  
*Politecnico di Milano, Italy*
- 273 Urban interiors. The domestic space and the city/the street as a living room  
*Tiziano Agieri Rinella*  
*IUAV, Italy*

## TECHNOLOGY APPLICATIONS

- 293 The 'New Morphologies':  
When Technology Becomes Gender-Neutral

Matteo O. Ingaramo, Martina Labarta  
Politecnico di Milano, Italy

- 305 UX Design in The Context of Navigation Aid Equipment Maintenance.  
A new approach to Monitoring and Control System Design

Elie Barakat<sup>1</sup>, Venanzio Arquilla<sup>2</sup>, Maximilian James Arpaio<sup>1</sup>  
<sup>1</sup>Thales Italia Spa, Italy  
<sup>2</sup>Politecnico di Milano, Italy

- 317 Enhancing User Experience in Autonomous Driving Levels 4 and Above:  
A Novel Seat Concept for Motion Sickness Mitigation.

Venanzio Arquilla, Shangyi Bai  
Politecnico di Milano, Italy

- 333 Digital Manufacturing of Tactile Maps to Improve Accessibility at Archaeological Sites

Alfonso Morone, Edoardo Amoroso  
Università degli Studi di Napoli Federico II, Italy

- 347 TREELOGY: Preserving Urban Forests through IoT Monitoring Data of Greenery

Alfonso Morone, Mariarita Gagliardi, Silvana Donatiello  
Università degli Studi di Napoli Federico II, Italy

- 361 Research into the exterior walls of residential buildings in the context of  
sustainable construction based on bio-based materials and waste

Alberto Reaes Pinto, Marlene Canudo Urbano, Carlos Oliveira Augusto  
CITAD / Universidade Lusíada, Portugal

- 377 Design, cultural heritage and technologies:  
New forms of dialogue between the user and museum spaces.

Giuseppina Castaldo, Mario Buono, Elena Laudante  
Università degli Studi della Campania "Luigi Vanvitelli", Italy

- 389 Environmental Impact of Wood, Steel, and Concrete in Residential Buildings

Sonsoles Vela, Ruben Garcia Rubio  
Tulane University, USA

- 409 A sustainable territorial development

Luca Bullaro  
Universidad Nacional de Colombia, Colombia

## HEALTHCARE AND WELLNESS

- 419 Textures design for Augmentative and Alternative Communication (AAC)  
for people with deaf-blindness and multi-sensory impairment

Denise Dantas<sup>1</sup>, Lia Sossini<sup>1</sup>, Barbara Del Curto<sup>2</sup>  
<sup>1</sup>Universidade de São Paulo, Brazil  
<sup>2</sup>Politecnico di Milano, Italy

- 431 Design against cancer. Topics and projects for a new culture of prevention.

Erminia Attaianese, Ivo Caruso, Carla Langella  
Università degli Studi di Napoli Federico II, Italy


- 443 Thriving children's perceptual learning through educational environments  
color and material design

Elisa Longoni<sup>1</sup>, Michele Zini<sup>2</sup>, Barbara Camocini<sup>2</sup>  
<sup>1</sup>Politecnico di Milano, Italy  
<sup>2</sup>ZPZ Partners, Italy

- 
- 455 Enhancing Healthcare Systems: Redefining Strategies and Stakeholder Engagement for Community Care Service Evolution  
*Federico De Luca, Daniela Sangiorgi*  
*Politecnico di Milano, Italy*

## **POLICY AND GOVERNANCE**

- 467 The Project of ethical visions for new enterprises in the South  
*Rosa Pagliarulo*  
*Politecnico di Bari, Italy*
- 475 REMANUFACTURING ITALY. The role of design in the manufacturing chains of the southern contexts, for the development of territorial cultural heritage, between local archetypes and global connections.  
*Domenico Colabella*  
*Politecnico di Bari, Italy*

- 
- 479 Re-Made in ... Locally. The empowerment of regional practice  
*Lisa Hockemeyer<sup>1,2</sup>, Anna Santi<sup>2</sup>*  
*<sup>1</sup>Kingston University, UK*  
*<sup>2</sup>Politecnico di Milano, Italy*

- 493 Green design for resilient urban pathways  
*Davide Bruno<sup>1</sup>, Felice D'Alessandro<sup>2</sup>*  
*<sup>1</sup>Politecnico di Milano, Italy*  
*<sup>2</sup>Università degli Studi di Milano, Italy*

## **ALTERNATIVE FUTURES**

- 507 Design and Literature for Education: Academic and Pedagogical Transdisciplinary Integrated Lab as Innovative Project for Graduate Programmes  
*Michaella Pivetti<sup>1</sup>, Diana Navas<sup>2</sup>*  
*<sup>1</sup>Universidade de São Paulo (USP), Brasil*  
*<sup>2</sup>Pontifícia Universidade Católica de São Paulo (PUC-SP), Brasil*

- 521 What if interactive artifacts would disrupt human relations?  
*Andrea Di Salvo*  
*Politecnico di Torino, Italy*

- 533 The (Un)Sustainable Future - Design and Resignification of Materials and Processes  
*Maria João Barbosa, Benedita Camacho, Diogo Frias Riobom, Bernardino Gomes*  
*CITAD / Universidade Lusíada, Portugal*

- 
- 549 Shaping the future of automotive design: The automotive experience design lab  
*Venanzio Arquilla, Giorgia Ballabio*  
*Politecnico di Milano, Italy*

- 561 Defining garment quality for user experience design in metaverse: The outerwear case study  
*Dario Gentile, Michele Fiorentino*  
*Politecnico di Bari, Italy*

- 571 Research through Design in Multisensory Narrative Dimensions  
*Clice de Toledo Sanjar Mazzilli*  
*University of São Paulo, Brazil*

- 585 Anthropogenic Narratives. Imagination and Anti-Disciplinarity for the Communication of Non-Human Perspectives  
*Francesco E. Guida<sup>1</sup>, Martina Esposito<sup>1</sup>, Enrico Isidori<sup>2</sup>*  
*<sup>1</sup>Politecnico di Milano, Italy*  
*<sup>2</sup>Università degli Studi di Napoli Federico II, Italy*

## MADE IN...

- 601 Design storytelling e microstorie del Made in Italy:  
Nuovi modelli di sostenibilità e innovazione nel distretto produttivo murgiano  
*Vincenzo Paolo Bagnato, Antonio Labalestra*  
*Politecnico di Bari, Italy*
- 609 Values, Identity, Stereotypes  
*Daniela Anna Calabi, Francesco Ricciardi*  
*Politecnico di Milano, Italy*
- 622 From territories to communities. A new perspective for Made in Italy.  
*Iole Sarno*  
*Università degli Studi di Napoli Federico II, Italy*
- 627 MADE IN AItaly.  
The Identities of Fashion Design in the Era of Artificial Intelligence.  
*Andrea Quartu*  
*Università degli Studi della Campania "Luigi Vanvitelli", Italy*
- 633 Food, Design, and Territory:  
The Valorization of Manna in the Madonie area.  
*Benedetto Inzerillo, Samuele Morvillo*  
*Università degli studi di Palermo, Italy*
- 641 Made in Italy. Values, Identity, and Relationships  
*Mario Bisson, Daniela Anna Calabi, Stefania Palmieri*  
*Politecnico di Milano, Italy*



# Enhancing User Experience in Autonomous Driving Levels 4 and Above: A Novel Seat Concept for Motion Sickness Mitigation.

Venanzio Arquilla, Shangyi Bai  
venanzio.arquilla@polimi.it, shangyi.bai@mail.polimi.it

Politecnico di Milano, Italy

---

**Keywords:**  
*Automotive UX  
Motion Sickness Mitigation  
Future Cockpit  
Automotive Seat Design*

## Abstract

The rapid advancement of technology, particularly in autonomous driving, has brought about a profound transformation in the automotive industry. This paper introduces a research-driven strategy aimed at tackling emerging challenges related to non-driving activities in autonomous vehicles, with a specific focus on mitigating motion sickness. Recognizing the growing prevalence of light usage in the cockpit and the expected rise in non-driving engagements, this study underscores the urgent necessity for innovative solutions. Through comprehensive research on future mobility trends, levels of driving automation, and user experiences, this paper proposes a novel automotive seat concept tailored to alleviate motion sickness arising from increased non-driving activities in autonomous vehicles.

The proposed seat design features a wrap-around structure to facilitate enhanced privacy and flexibility in both personal and group activities. A key component of this solution is the Anti-motion Sickness Light Warning System, strategically integrated into the seat's backrest. Leveraging ISELED technology, this system offers real-time synchronization with autonomous driving systems, issuing light warnings to passengers prior to unexpected movements, thereby minimizing the likelihood of motion sickness. While demonstrating promising outcomes, the paper acknowledges certain limitations. These include the necessity for further exploration of interactive elements within the seat design, research to exploit the potential of advanced lighting effects using ISELED technology and ergonomic considerations for the seat itself. By shedding light on the impact of autonomous driving on user experiences, this study contributes to the ongoing discourse and underscores the pivotal role of technology in shaping the future of automotive design.

## Introduction

In recent years, vehicle interior lighting has undergone significant advancements owing to rapid technological progress and evolving user preferences. The 2022 Mercedes-Benz EQS integrates innovative lighting solutions throughout its interior. With up to 13 strategically positioned functional lights (see Figure 1), this model not only enriches the driving and passenger experience but also underscores the pivotal role of lighting in automotive design.

Currently, lighting design has shifted from being supplementary to essential within the cockpit, significantly enhancing the driving and passenger experience. This trajectory is expected to continue, with future automotive lighting applications becoming even more innovative and diverse.



Figure 1. Interior of Mercedes-Benz EQS 2022 (Drive, 2022)

## Literature Review

The literature review of this paper primarily focuses on future mobility and cockpit design. It commences by examining future transportation scenarios and delves deeply into potential changes in cockpit configurations.

### 1. Future Mobility

The future of mobility will witness significant changes in the role of automobiles, particularly with the emergence of autonomous vehicles. The discussions are summarized in three main aspects: driving automation, new contexts, and new scenarios.

#### Driving Automation

Autonomous driving technology has witnessed rapid advancement, necessitating standardized taxonomy and definitions to classify the various levels of automation. Society of Automotive Engineers International has established a widely recognized standard with its classification of autonomous driving into five levels (SAE International, 2021).

Table 1. SAE J3016 Levels of Driving Automation (SAE International, 2021)

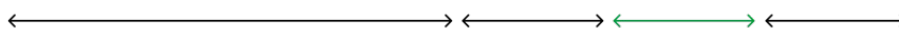


## SAE J3016™ LEVELS OF DRIVING AUTOMATION™

Learn more here: [sae.org/standards/content/j3016\\_202104](https://www.sae.org/standards/content/j3016_202104)

Copyright © 2021 SAE International. The summary table may be freely copied and distributed AS-IS provided that SAE International is acknowledged as the source of the content.

	SAE LEVEL 0™	SAE LEVEL 1™	SAE LEVEL 2™	SAE LEVEL 3™	SAE LEVEL 4™	SAE LEVEL 5™
What does the human in the driver's seat have to do?	You <b>are</b> driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You <b>are not</b> driving when these automated driving features are engaged – even if you are seated in “the driver’s seat”		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	



Achieved

Transition

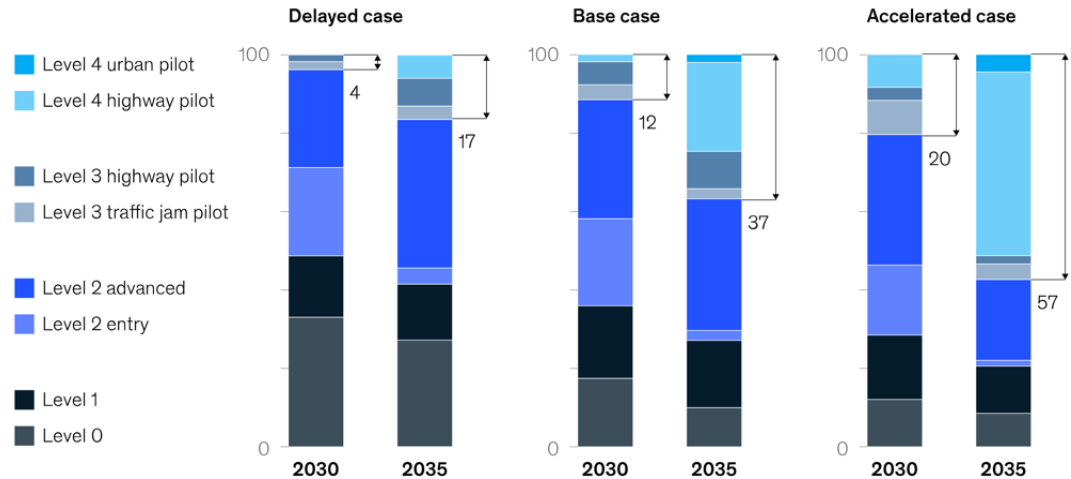
Practical

Unrealistic

Table 2. Estimated passenger vehicles sold with autonomous-driving technologies installed, % (McKinsey, 2023)

Through the comparison of various levels of autonomous driving technologies and assessing the current market adoption, the author contends that Levels 0 to 2 autonomous driving have nearly achieved widespread application in real-world scenarios. Even Level 3 autonomous driving, despite its capability to take over most driving tasks from human drivers, still requires human drivers to remain fully engaged in vehicle operation, presenting a technical challenge (see Table 1).

Estimated passenger vehicles sold with autonomous-driving technologies installed, %



Through the comparison of various levels of autonomous driving technologies and assessing the current market adoption, the author contends that Levels 0 to 2 autonomous driving have nearly achieved widespread application in real-world scenarios. Even Level 3 autonomous driving, despite its capability to take over most driving tasks from human drivers, still requires human drivers to remain fully engaged in vehicle operation, presenting a technical challenge (see Table 1).

Table 2 illustrates the projection that vehicles will ultimately achieve SAE Level 4, or driverless control under certain conditions (McKinsey, 2023). Level 4 autonomous driving has found extensive applications, particularly in the field of autonomous taxis, highlighting its broader potential as a future mainstream autonomous driving technology. The author holds high expectations for the significant potential that Level 4 autonomous driving technology can demonstrate in future transportation scenarios.

**New Context**

In the evolving landscape of future mobility, the role of automobiles is poised for significant transformations. Autonomous vehicles, in particular, will redefine concepts of ownership and sustainability, leading to new behavioral patterns, evolving demands, and the emergence of innovative urban mobility systems centered around vehicles.

One relevant concept in recent years is Mobility as a Service (MaaS), which embodies a novel idea that redefines our perception and engagement with mobility. It can be seen as a concept, a contemporary phenomenon accompanied by emerging behaviors and technologies, or even as a revolutionary transport solution that seamlessly integrates various modes of transportation and mobility services (Jittrapirom, P. et al., 2017).

Additionally, a new approach known as “Mobility as a Feature (MaaF)” considers mobility services as inputs into a broader activity-based paradigm of service delivery. It acknowledges that transport and travel stem

from broader needs, emphasizing the importance of integrating non-transport services to effectively meet these needs (Hensher, D. A., & Hietanen, S., 2023).

The emergence of both Mobility as a Service (MaaS) and Mobility as a Feature (MaaS) is poised to profoundly impact the future landscape of mobility. The convenience of this ecosystem will further reduce the demand for private transportation, blurring the boundaries between private and public transportation, presenting a unique scenario for future mobility.

### **New Scenario**

Dannemiller, K. A. et al. (2023) introduced intriguing concepts - travel-based activities (TBAs) and activity-based travel (ABT). This represents the first comprehensive exploration of the kinds of activities that individuals are likely to pursue when relieved from the task of driving in the era of fully automated vehicles (AVs). They refer to such activities as travel-based activities or TBAs. The results indicate that the highest impact of AVs will likely be on the number of long-distance trips, with such trips increasing.

## **2. Future Cockpit**

Given the changes in future mobility, the role of the future cockpit becomes flexible and diverse with the advent of the driverless era. Therefore, there are four challenges to be faced when researching and designing the future cockpit: privacy, safety, activities, and driving experiences (Kun, A. L. et al., 2016). Among them, the latter three are the most widely concerned.

### **Driving and Safety**

Under the premise of L4 autonomous driving, artificial intelligence can address most driving safety concerns for humans. However, three main security issues persist: Taking over Requests (TORs), visualization of speed, and lane change decisions (Shah, A. H., & Lin, Y., 2020). This emphasizes the necessity of traffic warning systems in the era of autonomous driving. Even though driving behaviors are no longer the primary focus, passengers still require access to pertinent traffic information in specific situations.

### **Driving and Activities**

The study of non-driving behavior of drivers and passengers under L4 autonomous driving conditions primarily focuses on two main aspects: individual behavior and group interaction.

For individual behaviour, several surveys have highlighted some primary activities, including sleeping, listening to music, browsing mobile phones, reading, and admiring the scenery outside the window (Hecht, T. et al., 2020; Parida, S. et al., 2020; Pfleging, B. et al., 2016; Pollmann, K. et al., 2019; Russell, M., 2011).

What's more, group interactions in the context of autonomous driving primarily revolve around communication (Ive, H. P. et al., 2015). However, it's important to note that there is still a relatively limited amount of research in this area. Nevertheless, these studies lay the foundational groundwork for subsequent design endeavors.

### **Driving Experience**

In the era of L4 autonomous driving, the driving experience, also known as the ride experience, presents two significant aspects that deserve attention: psychological experience and physical experience.

Psychologically, when users are no longer in control of the car's operations, understanding the vehicle's intentions becomes essential for them to feel safe and secure. Löcken, A. et al. (2016) point out that the transition

Table 3. Frequency and severity of motion sickness for adults while watching video or reading in a moving conventional vehicle (Sivak, M., & Schoettle, B., 2015)

from human drivers to automation raises complex issues. One of the key challenges, particularly in Level 3 automation, is the “Increasing complexity” of the automation systems. With the growing complexity of automation, it becomes harder for drivers to understand and monitor the car’s actions.

Measure	Activity	
	Viewing video	Reading
Frequency: <i>Often, usually, or always</i>	15%	26%
Severity: <i>Moderate or severe</i>	15%	32%

Physically, it is posited that an increasing number of non-driving activities will make motion sickness a more significant concern in self-driving vehicles compared to traditional, human-driven vehicles (Sivak, M., & Schoettle, B., 2015) (see Table 3). This expectation arises from the fact that the three primary factors contributing to motion sickness, namely conflicts between vestibular and visual inputs, the inability to predict the direction of motion, and the absence of control over the direction of motion, are heightened in self-driving vehicles. However, it’s worth noting that the frequency and severity of motion sickness are influenced by the specific activities that individuals engage in while in the vehicle, rather than the act of driving itself.

## Design Opportunity

In the context of driving automation, considerable attention has been given to the sense of safety, and various solutions have emerged. However, in the context of Level 4 autonomous driving, non-driving activities are poised to significantly expand and diversify within the cockpit, potentially leading to increased occurrences of motion sickness among passengers. Therefore, the author contends that motion sickness arising from non-driving activities in the era of autonomous driving presents a promising design opportunity.

### 1. Motion Sickness

#### Causes

Spencer Salter et al. (2019) underscore the increasing prevalence of rearward-facing seats in automated vehicles (AVs). However, adopting a rearward orientation in AVs may compromise the passenger experience, particularly with regard to motion sickness. Meanwhile, Michael J. Griffin and Kim L. Mills (2002) noted that the direction of motion (fore-and-aft or lateral) did not significantly impact the occurrence of motion sickness.

Michael J. Griffin and Maria M. Newman (2004) further emphasize the importance of the visual scene in motion sickness within cars. They recommend mitigating motion sickness by providing visual information while deepening understanding of the various factors influencing its occurrence or relief.

In addition, research by Ouren X. Kuiper et al. (2020) indicates that unpredictable motion induces motion sickness more significantly compared to predictable motion. These findings suggest that motion sickness arises from the disparity between sensed and expected motion, rather than simply being unprepared for the motion.

#### Existing Solutions

Addressing motion sickness stemming from the aforementioned causes,

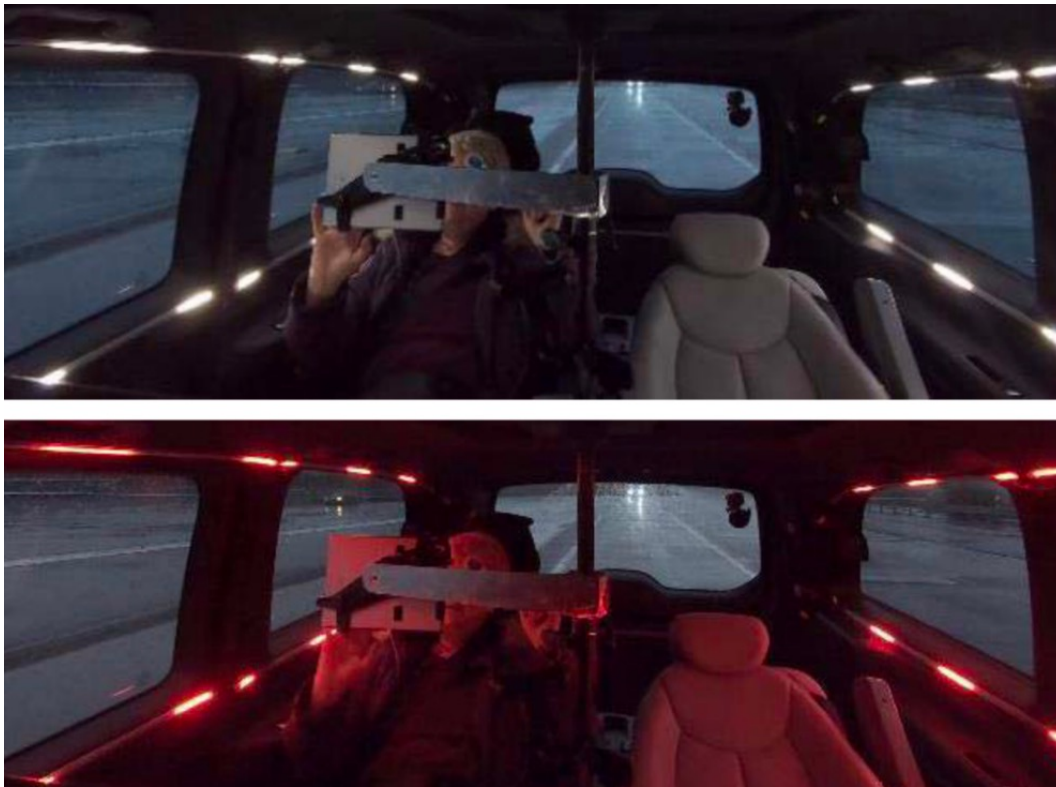


Figure 2. Illustration of prototypical LED feedback system (Bohrmann, D. et al., 2022)

several potential solutions have emerged. For instance, Dominique Bohrmann et al. (2020) explored the efficacy of active seat belt retractions as a countermeasure against motion sickness. Millard F. Reschke et al. (2006) attempted to alleviate motion sickness-related gastrointestinal symptoms and motor disorders while inhibiting vestibular-autonomic pathways by using stroboscopic light synchronized to the motion pattern.

It is noteworthy that Bohrmann, D. et al. (2022) demonstrated, through a prototypical LED feedback system visualizing longitudinal driving dynamics in the passenger's peripheral visual field (see Figure 2), that integrating peripheral visual information in automated vehicle experiences could potentially enhance users' situation awareness and reduce the occurrence of motion sickness.

In summary, the prevalence of motion sickness is expected to rise significantly with the widespread adoption of autonomous driving, attributed to unique seating orientations and unpredictable motions. While various methods exist to alleviate motion sickness, providing users with visual stimuli that align with their expectations and anticipated motion appears the most promising and practical approach. Light, therefore, emerges as a favorable medium to intervene in this process.

## 2. User Research

To gain a deeper understanding of the characteristics of individuals suffering from motion sickness and to identify the final target demographic for the design, the author developed the following questionnaire and distributed it to a broad spectrum of respondents (see Table 4).

**Research on Motion Sickness Phenomenon**

1. Your gender [single choice question] \*  
 Male  
 Female

2. Your age  
 [Enter a number from 15 to 60]\*  
 \_\_\_\_\_

3. Do you often get motion sickness? [Single choice question] \*  
 Yes  
 No (please skip to the end of the questionnaire and submit your answer sheet)

4. In which scenario are you more likely to get motion sickness?  
 [Single choice question] \*  
 Long-distance travel  
 Short commute  
 Others \_\_\_\_\_ \*

5. Your travel companions are usually [single-choice question] \*  
 Family  
 Companion  
 Friends  
 Traveling alone  
 Others \_\_\_\_\_ \*

Depends on option 1 of question 4

6. What type of vehicle do you usually ride in [Single choice question] \*  
 Car  
 SUV/MPV  
 Others \_\_\_\_\_ \*

7. What do you usually do on a car ride? [Multiple choice questions] \*  
 Listen to music  
 Playing with mobile phone  
 Chat with peers  
 Diet  
 Call  
 Look at the scenery  
 Others \_\_\_\_\_ \*

8. What may cause you to get motion sickness [Multiple choice questions] \*  
 Closed space/poor ventilation  
 Poor shock absorption/poor road conditions  
 Many turns/many stops  
 Seat comfort  
 Seating position  
 Others \_\_\_\_\_ \*

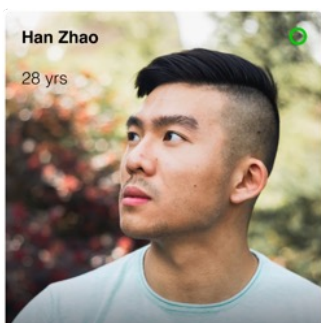
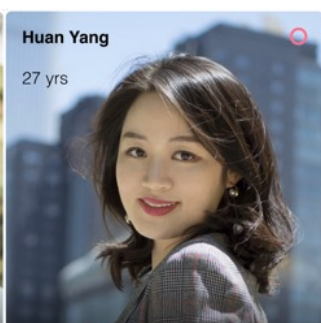
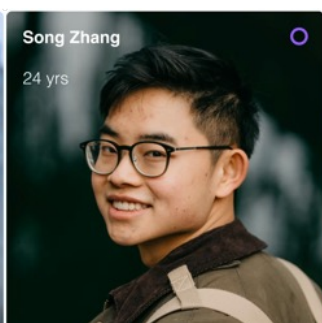
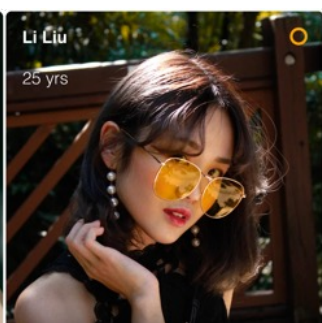
Table 4. Research on motion sickness phenomenon

A total of 117 questionnaires were collected for this survey, with 71 of them deemed valid. The research results indicate that the majority of surveyed individuals experience motion sickness during long-distance trips (59.15%) with family (42.86%) or friends (30.95%), primarily due to unpredictable traffic conditions (71.83%). This offers the author a clear design focus and scenario, which will be reflected in the construction of user profiles and user journeys in the next phase.

### 3. Design Approach

Table 5. Persona in long-distance travel with friends (Photo retrieved on Unsplash)

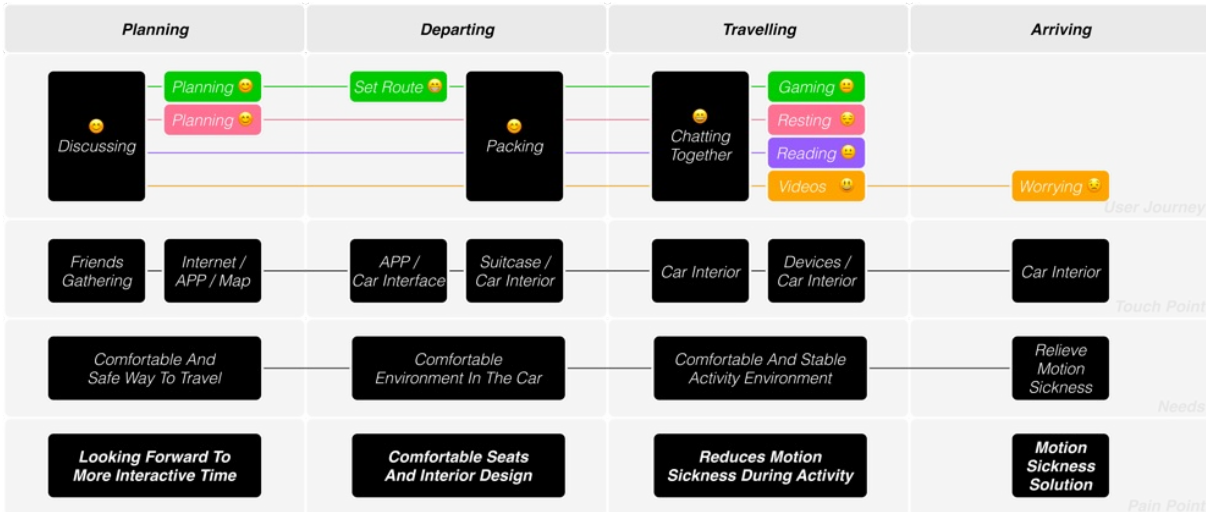
Based on the research findings, the author has chosen the scenario of long-distance travel with friends to create personas (see Table 5) and user journeys for the target users.

 <p><b>Han Zhao</b> 28 yrs</p> <p>Han Zhao is a 28-year-old adventurous traveler who enjoys exploring new places and outdoor activities. He is known for his upbeat personality and is the driver for this road trip.</p>	 <p><b>Huan Yang</b> 27 yrs</p> <p>Huan Yang is a 27-year-old nature enthusiast with a love for photography and wildlife. She's the group's designated navigator and often suggests scenic routes.</p>	 <p><b>Song Zhang</b> 24 yrs</p> <p>Song Zhang is a 24-year-old music enthusiast with a laid-back personality. He often provides entertainment during the journey with his guitar skills.</p>	 <p><b>Li Liu</b> 25 yrs</p> <p>Li Liu is a 25-year-old foodie and adventurer who loves trying local cuisine and exploring new places.</p>
<p><b>Needs</b></p> <ul style="list-style-type: none"> <li>Handling the responsibility of <b>navigation and driving</b></li> <li>Managing discomfort due to <b>motion sickness while driving</b></li> <li>Balancing the <b>diverse interests and preferences</b> of the group.</li> </ul>	<p><b>Needs</b></p> <ul style="list-style-type: none"> <li>Experiencing <b>motion sickness</b>, affecting her photography and navigation duties.</li> <li>Coping with <b>limited seating comfort and legroom</b>.</li> <li>Balancing the desire for <b>scenic stops</b> with the group's need for breaks.</li> </ul>	<p><b>Needs</b></p> <ul style="list-style-type: none"> <li>Battling <b>severe motion sickness</b>, requiring medication and frequent breaks.</li> <li>Facing challenges in providing <b>entertainment</b> with music due to motion sickness.</li> <li>Seeking <b>comfortable seating and accommodations</b> during rest stops.</li> </ul>	<p><b>Needs</b></p> <ul style="list-style-type: none"> <li>Concern for her friends' motion sickness, especially <b>Song Zhang's</b> severe condition.</li> <li>Valuing opportunities to savor local cuisine.</li> <li>Ensuring her friends' comfort during rest breaks and accommodations while satisfying her own desire for adventure.</li> </ul>

Enhancing User Experience in Autonomous Driving Levels 4 and Above:  
A Novel Seat Concept for Motion Sickness Mitigation.

In the scenario of friends traveling together, it is crucial to consider both the need for privacy for individual passenger behaviors and the flexibility required for group interactions. However, paramount considerations remain the demand for comfortable seat configurations and the mitigation of potential motion sickness risks (see Table 6).

Table 6. User journey of long-distance travel with friends



The analysis suggests that the seat is the closest and most effective touch point with passengers. By offering flexible and comfortable seating options, combined with a well-designed lighting system, there is an opportunity to enhance the overall riding experience, including alleviating motion sickness.

Figure 3. Cockpit layouts research (Photo retrieved on Pinterest)





## Project

### 1. Space Design

In preparation for designing the seats, thorough research and analysis are essential to accommodate potential non-driving activities for both individuals and groups within Level 4 autonomous driving cockpits. Various cockpit layouts from existing and conceptual designs have been examined by the author (see Figure 3).



Figure 4. Graphical illustration of researched cockpit layouts

After compiling and organizing numerous relevant conceptual designs, the author meticulously categorizes and analyses them based on seat number, form, and layout (see Figure 4) with the aim of identifying designs that meet specified requirements.

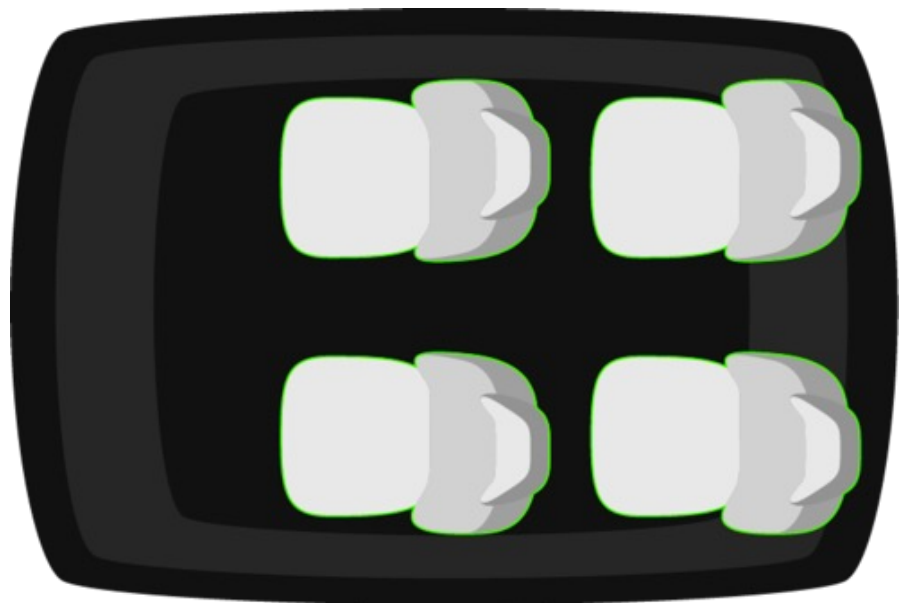


Figure 5. Final design decision of cockpit layout

Considering the configuration requirements of L4 autonomous driving (such as the retention of driver's seats), the selected design concept offers a balanced approach, enhancing traditional cockpit layouts by replacing fixed seating with four rotating seats (see Figure 5). This modification maintains

basic functionality while enabling seats to rotate 90 degrees sideways, facilitating group interactions and significantly reducing motion sickness risks. Such design ensures cockpit passengers' flexibility and potential for interaction.

Moreover, the uniform and interchangeable design of all four independent seats expands market possibilities, reduces maintenance and storage costs, and lowers potential manufacturing expenses.

## 2. Product Design



### Inspiration

Among various case studies, "The Egg chair" by Arne Jacobsen (1959) stands out as a significant source of inspiration (see Figure 6). This Danish design masterpiece, crafted through experimentation with wire and plaster in Jacobsen's garage, profoundly influences the author's design process. The enveloping shape of The Egg Chair not only ensures ample privacy and comfort but also provides an ideal location for integrating the lighting system in later stages.

Figure 6. The Egg Chair (Arne Jacobsen, 1959)

<b>single car seat,</b>	-----	<i>Product Definition</i>
<b>industrial design,</b>	-----	<i>Domain Definition</i>
<b>white color,</b>	-----	<i>CMF Constraint</i>
<b>Arne Jacobsen,</b>	-----	<i>Style Constraint</i>
<b>pure white background,</b>	-----	<i>Image Background</i>
<b>studio lighting,</b>	-----	<i>Lighting Configuration</i>
<b>right angle shot</b>	-----	<i>Camera Setting</i>
<b>--s 50</b>	-----	<i>Stylizing Strength</i>
<b>--c 0</b>	-----	<i>Chaos Strength</i>
<b>--ar 1:1</b>	-----	<i>Image Specification</i>
<b>--v 5.2</b>	-----	<i>Core Version</i>

Table 7. Prompt for references generation with Midjourney

### AI-facilitated Design

This project endeavors to explore how Artificial Intelligence Generated Content (AIGC) can optimize workflows for industrial designers. The chosen AI tool, the well-established Midjourney image generation platform, aids in generating a series of visual references.

The author utilizes the prompt “single car seat, industrial design, white color, Arne Jacobsen, pure white background, studio lighting, right angle shot” (see Table 7). Despite minimal design-related terms beyond image quality constraints, the inclusion of the somewhat biased term “Arne Jacobsen” ensures consistent and controllable style in the generated results, particularly concerning the later integration of the lighting system.



Figure 7. Generated references  
(Photo generated by Midjourney)

Ultimately, the author successfully generates numerous design references using Midjourney (see Figure 7). However, the existing cues proved insufficient for selecting and finalizing the design concept. The absence of consideration for the lighting system’s positioning in the generation process suggests utilizing this constraint to refine and approach the final design concept.

### Design Refinement

Given the necessity for the lighting system to coexist with passengers’ non-driving activities and convey specific informational content, the precise placement is paramount.

Referencing Spector, R. H. (1990), who introduced the concept of peripheral vision, it’s noted that signals appearing within passengers’ peripheral vision are still noticeable. Additionally, research by Strasburger, H. et al. (2011) highlights humans’ ability to reconstruct and interpret compressed and distorted information perceived peripherally, facilitating appropriate information delivery during focused non-driving activities.

Consequently, three potential locations for the light—near the head, shoulder, and body—were identified to effectively convey driving information to passengers (see Figure 8).

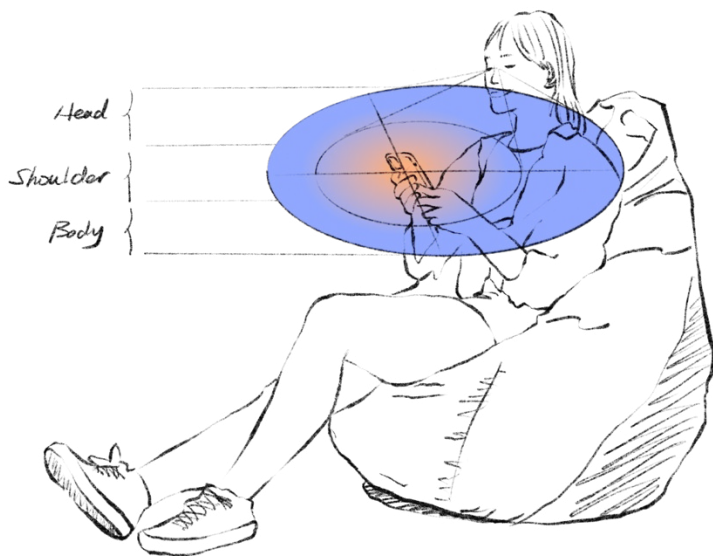


Figure 8. Potential location for lighting system

### HOODIE - Seat Design for Motion Sickness

As a result, the author developed HOODIE, a car seat designed to mitigate motion sickness resulting from Level 4 autonomous driving (see Figure 9). Enveloping passengers within a large shelter enhances privacy while the anti-motion sickness light warning system, integrated into the shelter, reduces motion sickness occurrences through preemptive warnings.



Figure 9. HOODIE - Seat Design for Motion Sickness

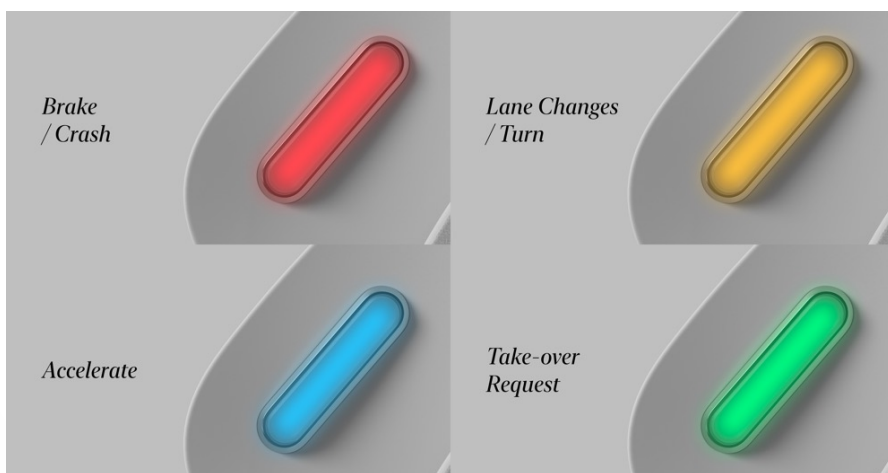
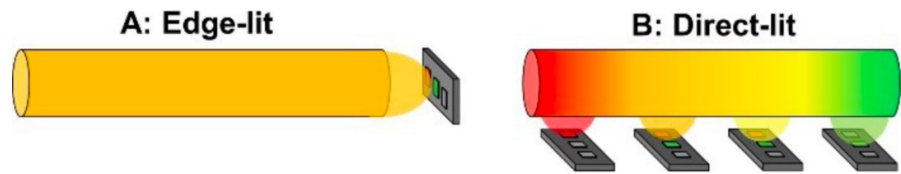


Figure 10. Examples of anti-motion sickness light warning system

The anti-motion sickness light warning system alerts users before the autonomous driving system detects motion trends. For instance, red lights indicate braking or imminent collision, while yellow lights signal lane changes or turns (see Figure 10). Furthermore, warnings are provided for accelerations or take-over requests. This design also addresses passengers' security concerns regarding driving conditions.

Figure 11. Left (A): Static edge-lit system. Right (B): Dynamic direct-lit system (Blankenbach, K. et al., 2019)



To ensure rapid light signal responsiveness to vehicle motion, the author selected ISELED technology (Blankenbach, K. et al., 2019) as the technical foundation. This technology addresses challenges associated with maintaining luminance and color uniformity across various temperature conditions in direct-lit light guides, which could synchronize effectively with in-car entertainment systems, offering rich lighting effects and potential for developing more complex animations (see Figure 11).

As previously discussed, HOODIE's cockpit layout features four independently rotatable seats, facilitating passengers' mobility and communication and supporting various scenarios. For instance, the four scenarios depicted in Figure 12 demonstrate passengers' ability to choose and configure seat layouts according to different situations, allowing for individual activities or face-to-face communication.

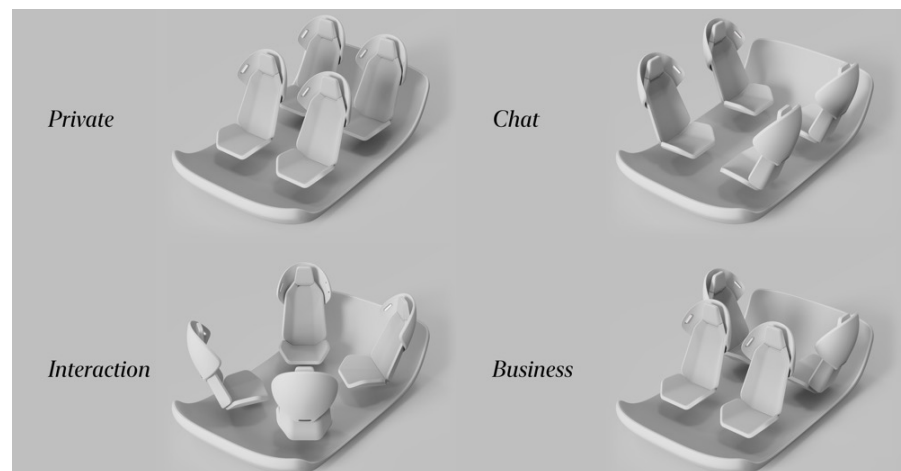


Figure 12. Flexible cockpit layouts in different scenarios

## Conclusion

In summary, extensive literature exploration supports the imminent widespread adoption of Level 4 autonomous driving technology, which will significantly impact urban transportation systems. The study underscores the potential for personal transportation in long-distance travel scenarios and addresses challenges posed by increased motion sickness through innovative solutions like HOODIE.

Moreover, by analysing automotive cockpit layouts, the study proposes a visionary concept tailored for Level 4 autonomous driving. This design features four independently swivelling seats, aiming to prevent motion sickness while accommodating diverse passenger activities.

## Limitation

While the proposed concept may mitigate motion sickness in future L4 autonomous driving, further exploration is needed regarding interactivity, ergonomics, market analysis, and user strategies to enhance implementation comprehensively. These areas present opportunities for future research and development, building upon this foundational exploration to create stronger and more effective solutions for motion sickness in autonomous driving scenarios.

## References

---

1. Blankenbach, K., & Isele, R. (2019). 57.1: Invited Paper: Automotive Interior Lighting: Challenges and Solutions for Uniformity. *SID Symposium Digest of Technical Papers*, 50(S1), 618–621. <https://doi.org/10.1002/sdtp.13589>
2. Bohrmann, D., & Bengler, K. (2020). Reclined Posture for Enabling Autonomous Driving. In T. Ahram, W. Karwowski, S. Pickl, & R. Taiar (Eds.), *Human Systems Engineering and Design II* (pp. 169–175). Springer International Publishing. [https://doi.org/10.1007/978-3-030-27928-8\\_26](https://doi.org/10.1007/978-3-030-27928-8_26)
3. Bohrmann, D., Bruder, A., & Bengler, K. (2022). Effects of Dynamic Visual Stimuli on the Development of Carsickness in Real Driving. *IEEE Transactions on Intelligent Transportation Systems*, 23(5), 4833–4842. <https://doi.org/10.1109/TITS.2021.3128834>
4. Dannemiller, K. A., Asmussen, K. E., Mondal, A., & Bhat, C. R. (2023). Autonomous vehicle impacts on travel-based activity and activity-based travel. *Transportation Research Part C: Emerging Technologies*, 150, 104107. <https://doi.org/10.1016/j.trc.2023.104107>
5. Egg™ Chair—Lounge chair with timeless design. (n.d.). Fritz Hansen. Retrieved 8 November 2023, from <https://www.fritzhanzen.com/en/categories/products/popular-series/egg>
6. Griffin, M. J., & Mills, K. L. (2002). Effect of frequency and direction of horizontal oscillation on motion sickness. *Aviation, Space, and Environmental Medicine*, 73(6), 537–543.
7. Griffin, M. J., & Newman, M. M. (2004). Visual field effects on motion sickness in cars. *Aviation, Space, and Environmental Medicine*, 75(9), 739–748.
8. Hecht, T., Feldhütter, A., Draeger, K., & Bengler, K. (2020). What Do You Do? An Analysis of Non-driving Related Activities During a 60 Minutes Conditionally Automated Highway Drive. In T. Ahram, R. Taiar, S. Colson, & A. Choplin (Eds.), *Human Interaction and Emerging Technologies* (pp. 28–34). Springer International Publishing. [https://doi.org/10.1007/978-3-030-25629-6\\_5](https://doi.org/10.1007/978-3-030-25629-6_5)
9. Hensher, D. A., & Hietanen, S. (2023). Mobility as a feature (MaaF): Rethinking the focus of the second generation of mobility as a service (MaaS). *Transport Reviews*, 43(3), 325–329. <https://doi.org/10.1080/01441647.2022.2159122>
10. Ive, H. P., Sirkin, D., Miller, D., Li, J., & Ju, W. (2015). 'Don't make me turn this seat around!': Driver and passenger activities and positions in autonomous cars. *Adjunct Proceedings of the 7th International Conference on Automotive User Interfaces and*

- Interactive Vehicular Applications, 50–55. <https://doi.org/10.1145/2809730.2809752>
11. J3016\_202104: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles - SAE International. (n.d.). Retrieved 21 April 2023, from [https://www.sae.org/standards/content/j3016\\_202104/](https://www.sae.org/standards/content/j3016_202104/)
  12. Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M. J. A., & Narayan, J. (2017). Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges. *Urban Planning*, 2(2), 13–25. <https://doi.org/10.17645/up.v2i2.931>
  13. Kuiper, O. X., Bos, J. E., Schmidt, E. A., Diels, C., & Wolter, S. (2020). Knowing What's Coming: Unpredictable Motion Causes More Motion Sickness. *Human Factors*, 62(8), 1339–1348. <https://doi.org/10.1177/0018720819876139>
  14. Kun, A. L., Boll, S., & Schmidt, A. (2016). Shifting Gears: User Interfaces in the Age of Autonomous Driving. *IEEE Pervasive Computing*, 15(1), 32–38. <https://doi.org/10.1109/MPRV.2016.14>
  15. Löcken, A., Heuten, W., & Boll, S. (2016). AutoAmbiCar: Using Ambient Light to Inform Drivers About Intentions of Their Automated Cars. Adjunct Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, 57–62. <https://doi.org/10.1145/3004323.3004329>
  16. Parida, S., Abanteriba, S., & Franz, M. (2020). Digital Human Modelling, Occupant Packaging and Autonomous Vehicle Interior. In T. Ahram, W. Karwowski, S. Pickl, & R. Taiar (Eds.), *Human Systems Engineering and Design II* (pp. 202–208). Springer International Publishing. [https://doi.org/10.1007/978-3-030-27928-8\\_31](https://doi.org/10.1007/978-3-030-27928-8_31)
  17. Pflöging, B., Rang, M., & Broy, N. (2016). Investigating user needs for non-driving-related activities during automated driving. Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia, 91–99. <https://doi.org/10.1145/3012709.3012735>
  18. Pollmann, K., Stefani, O., Bengsch, A., Peissner, M., & Vukeli, M. (2019). How to Work in the Car of the Future? A Neuroergonomical Study Assessing Concentration, Performance and Workload Based on Subjective, Behavioral and Neurophysiological Insights. Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, 1–14. <https://doi.org/10.1145/3290605.3300284>
  19. Reschke, M., Somers, J., & Ford, G. (2006). Stroboscopic vision as a treatment for motion sickness: Strobe lighting vs. shutter glasses. *Aviation, Space, and Environmental Medicine*, 77, 2–7.
  20. Russell, M., Price, R., Signal, L., Stanley, J., Gerring, Z., & Cumming, J. (2011). What Do Passengers Do During Travel Time? Structured Observations on Buses and Trains. *Journal of Public Transportation*, 14(3). <https://doi.org/10.5038/2375-0901.14.3.7>
  21. Salter, S., Diels, C., Herriotts, P., Kanarachos, S., & Thake, D. (2019). Motion sickness in automated vehicles with forward and rearward facing seating orientations. *Applied Ergonomics*, 78, 54–61. <https://doi.org/10.1016/j.apergo.2019.02.001>
  22. Shah, A. H., & Lin, Y. (2020). In-Vehicle Lighting and its Application in Automated Vehicles: A Survey. 2020 Fifth Junior Conference on Lighting (Lighting), 1–4. <https://doi.org/10.1109/Lighting47792.2020.9240585>
  23. Sivak, M., & Schoettle, B. (n.d.). MOTION SICKNESS IN SELF-DRIVING VEHICLES.
  24. Spector, R. H. (1990). Visual Fields. In H. K. Walker, W. D. Hall, & J. W. Hurst (Eds.), *Clinical Methods: The History, Physical, and Laboratory Examinations* (3rd ed.). Butterworths. <http://www.ncbi.nlm.nih.gov/books/NBK220/>
  25. Strasburger, H., Rentschler, I., & Jüttner, M. (2011). Peripheral vision and pattern recognition: A review. *Journal of Vision*, 11(5), 13. <https://doi.org/10.1167/11.5.13>
  26. The future of autonomous vehicles (AV) | McKinsey. (n.d.). Retrieved 17 December 2023, from <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected#/>

