

Safe by Design

INTERIOR DESIGN TO SUPPORT PERCEIVED SAFETY FOR AUTONOMOUS BUSES

Acknowledgements

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Abstract

ABSTRACT AND LIST OF ABBREVIATIONS

Autonomous buses offer benefits such as fewer traffic collisions and lower emissions, but public acceptance is limited by perceived safety: the subjective feeling of being unsafe. This project explores how interior design can support perceived safety in fully autonomous buses.

Research identified three core problems. A user survey (n=98) showed that passengers feel significantly less safe without a driver (safety score drops from 4.2 to 2.8 out of 5), mainly due to "no contact", "uncertainty", and "no control". Expert interviews with HTM, EBS and RET confirmed that passenger behaviour is the biggest concern in practice. Literature showed that predictability reduces stress and that visible staff presence is the most effective safety measure, but both disappear without a driver. Through this research three core problems were identified: support (passengers need to know they can get help), social safety (passengers need to feel safe around others), and uncertainty (passengers need to understand what the bus will do).

The design framework translated these insights into four themes: Overview & Comprehensibility, Control & Calm, Social Safety, and Accessibility & Inclusivity. Through ideation, six concepts were developed and evaluated against sixteen requirements and fourteen wishes. Two concepts were combined into the Heartbeat Bus, built around two core elements. The help ring provides a central point for route information and direct contact with a help centre. The breathing ceiling makes bus behaviour visible through gentle light signals. Supporting elements include large windows, mirrors, camera screens, emergency buttons, silent alarms, QR codes, and door lights.

Validation showed that 71% of respondents rated the redesigned bus as better than a normal autonomous bus, and 83% of final test participants would feel comfortable using it without a driver. A feasibility interview with BYD confirmed technical feasibility within 15 years. The concept meets all requirements and scores well on all wishes.

This project demonstrates that interior design can significantly address the psychological and social gaps left by the removal of the driver, uncertainty of the bus and behaviour of other passengers, offering a coherent, integrated solution that makes passengers feel safe, informed, and in control.

Keywords: perceived safety, autonomous buses, interior design, public transport, human-centred design, support, social safety, uncertainty

List of abbreviations	
HTM	Haagsche Tramweg-Maatschappij
EBS	Egged Bus Systems
RET	Rotterdamse Elektrische Tram
SAE	Society of Automotive Engineers
MRDH	Metropoolregio Rotterdam Den Haag
CPTED	Crime Prevention Through Environmental Design
BYD	Build Your Dreams

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Introduction

PUBLIC ACCEPTANCE

Cities are facing increasing challenges related to mobility, including congestion, environmental impact, and growing urban populations. To address these issues, transportation systems are evolving toward more sustainable and efficient forms of mobility (Hadid et al., 2025). Public transport plays a central role in this transition by providing shared mobility solutions that can move large numbers of people while reducing dependence on private cars.

At the same time, technological developments are transforming how transport systems operate. Autonomous vehicle technology is advancing rapidly because it offers significant potential benefits, including reduced traffic congestion, lower emissions, fewer traffic collisions, and greater mobility for people who cannot drive (Porter, 2025). Approximately 90% of all traffic collisions are caused by human error (Singh, 2015), and Waymo statistics show that robotaxis can reduce airbag deployments and injury-related crashes by over 80% (Kusano et al., 2025).

Consequently, autonomous driving is increasingly being explored within public transport. Self-driving shuttles and buses are currently being tested in several cities as potential components of future urban mobility systems (Editorial staff & Editorial staff, 2025).

While the technological development of autonomous vehicles continues to progress, their successful implementation depends not only on technical performance but also on public acceptance (Goldbach et al., 2022). One important factor influencing this acceptance is perceived safety, referring to passengers' subjective feeling of being safe while travelling (Raue et al., 2019).

This graduation project explores how interior design interventions could help support passengers' perceived safety in fully autonomous buses.

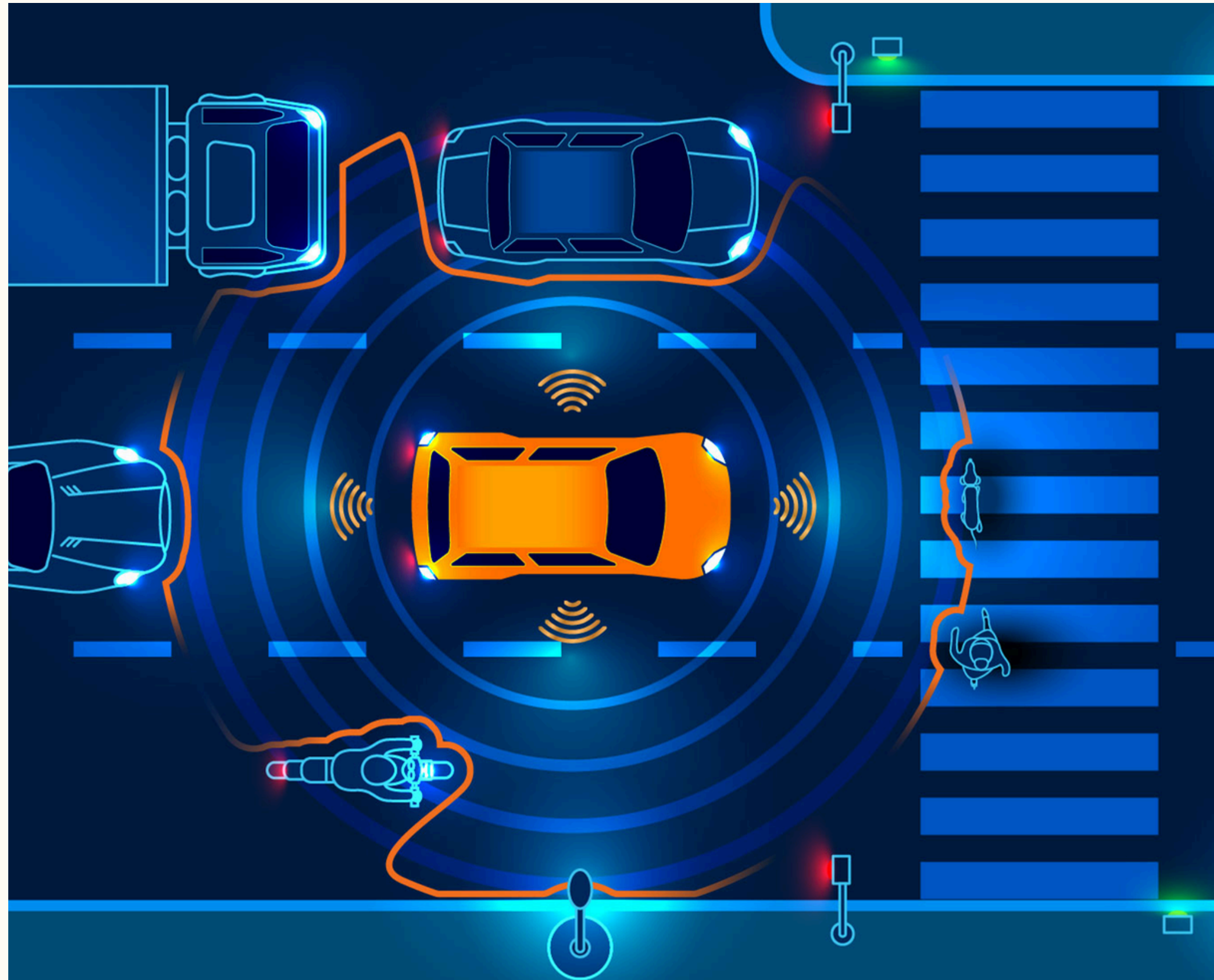


Figure 1: Autonomous vehicle using sensors. (Hub, 2020)

Context

AUTONOMOUS VEHICLE DEVELOPMENT

As autonomous vehicle technology continues to develop, its potential application within public transport is receiving increasing attention. Self-driving shuttles and buses are being explored as possible additions to future urban mobility systems. By operating without a human driver, these vehicles could improve operational efficiency and enable new forms of flexible public transport services.

However, the transition to autonomous buses also introduces changes to the passenger experience inside the vehicle. In conventional buses, the driver fulfils multiple roles beyond controlling the vehicle. The driver is a visible presence in the environment, providing assistance, supervision, and a point of contact for passengers during the journey (Indeed Editorial Team, 2025).

When the driver is no longer present, an important element of this travel experience disappears. Passengers may have

fewer opportunities to ask questions, receive help, or rely on a visible authority figure within the vehicle.

At the same time, feelings of safety already play an important role in how passengers experience public transport today. Situations such as travelling alone, sharing space with unfamiliar passengers, or navigating crowded environments can influence whether passengers feel comfortable during their journey (Trindade, 2024; Ceccato et al., 2022).

In autonomous buses, where direct human supervision may be reduced or absent, it becomes even more important to consider how passengers can still feel secure and supported while travelling. Besides, technological safety systems are safe already but still not fully trusted by people (Goldbach et al., 2022).

The physical environment inside the vehicle may influence

how passengers interpret and experience safety, elements such as visibility, lighting, and cleanliness influence the perceived safety (Trindade, 2024).

For this reason, this project focuses on interior design as a potential way to support passengers' perceived safety, complementing the existing technical safety systems that are already implemented in autonomous vehicles.

The project specifically focuses on autonomous buses rather than smaller autonomous shuttles. While many existing studies investigate small autonomous shuttle services (Debbaghi et al., 2025), buses operate in more complex and socially dynamic environments. They transport larger numbers of passengers, serve a wider variety of users, and involve more interactions between strangers in a shared interior space. These characteristics make perceived safety particularly relevant in bus environments.

Figure 2: Autonomous bus (Ridden, 2022)



Project outline

PROBLEM DEFINITION AND FOCUS OF THE PROJECT

This section describes the initial scope and direction of the project as defined before the research was conducted. The following chapters will present the research findings, after which the problem definition is refined.

INITIAL PROBLEM DEFINITION

Autonomous buses are expected to become part of future public transport systems, due to their advantages. As there are already safety concerns in public transport these days, the removal of the human driver introduces an extra challenge. In conventional buses, the driver does more than just drive. The driver is a visible point of contact, a source of help, an authority figure, and a reassuring presence for passengers.

When the driver is no longer present, passengers may feel uncertain, exposed, or unsafe. Their main worry may not only be about technical failures, but about the loss of human connection and social control too. This project started with the assumption that interior design could potentially compensate for some of these lost functions.

The initial research question was: **"How can interior design contribute to perceived safety in autonomous buses?"**

ASSIGNMENT

The goal of this graduation project is to design a set of interior design interventions that enhance perceived safety in fully autonomous buses. The final result is a concept package: a coherent collection of interior elements that work together to address the different factors that influence perceived safety. The package includes elements such as lighting, seating layout, sightlines, help points, and feedback systems.

The concept is presented in such a way that bus operators can choose which elements to implement in their own buses. This modular approach reflects current practice, where operators configure buses according to their specific needs and budget. As emerged from the interviews with HTM, EBS and RET, each operator has different priorities depending on the region, passenger demographics, and available budget. The concept package offers a flexible solution that can be adapted to different contexts.



Figure 3: Busdriver driving. (Contributor, 2018)

DOMAIN
 This project focuses on autonomous buses expected to become operational within the next **15 years**. This timespan is based on the interviews with bus operators, who indicated that fully driverless buses are still a future vision, not a short-term reality. The design concepts are based on technologies that exist today or are expected to be available within 15 years.

The project specifically addresses SAE Level 4 and Level 5 automation (Figure 4). Level 4 means the bus can perform all driving tasks under specific conditions without a human driver, but may have operational limitations (e.g., only on certain routes or in good weather). Level 5 means the bus can drive anywhere under any conditions without any human intervention. In both levels, there is no human driver present on board to assist passengers, provide social control, or answer questions. This makes perceived safety a critical design challenge, as the psychological and social functions of the driver must be compensated for by the interior design.

Why Level 4 and Level 5? This project does not investigate which level of automation passengers would accept. Instead, it starts from the assumption that fully driverless buses will become part of public transport. The design focuses on the most extreme scenario (no human presence on board) so that if the interior works in this case, it can also support lower levels of automation where staff is still present.

FOCUS WITHIN THE PROJECT

The project focuses entirely on the interior of the bus. This means looking at things like where the seats are placed, how the lighting is set up, whether passengers can see each other and the outside, how easy it is to ask for help, and what kind of feedback the bus gives when something happens. Materials and how easy the interior is to clean are also part of this. Everything that is inside the bus and that passengers can see, touch, or use is included.

The project is designed for fully autonomous buses (SAE Level 4 and 5), where there is no driver on board. However, the design does not assume that there will never be any staff present. In practice, there could still be occasional personnel on board, such as a steward, or frequent ticket inspections by controllers, similar to what happens in trains today. Staff could also be called in to intervene when incidents occur, as design and technology cannot replace a human in serious conflicts.

The interior design is therefore developed with the most extreme scenario in mind: a bus with no staff at all. If the interior can make passengers feel safe in this situation, it will

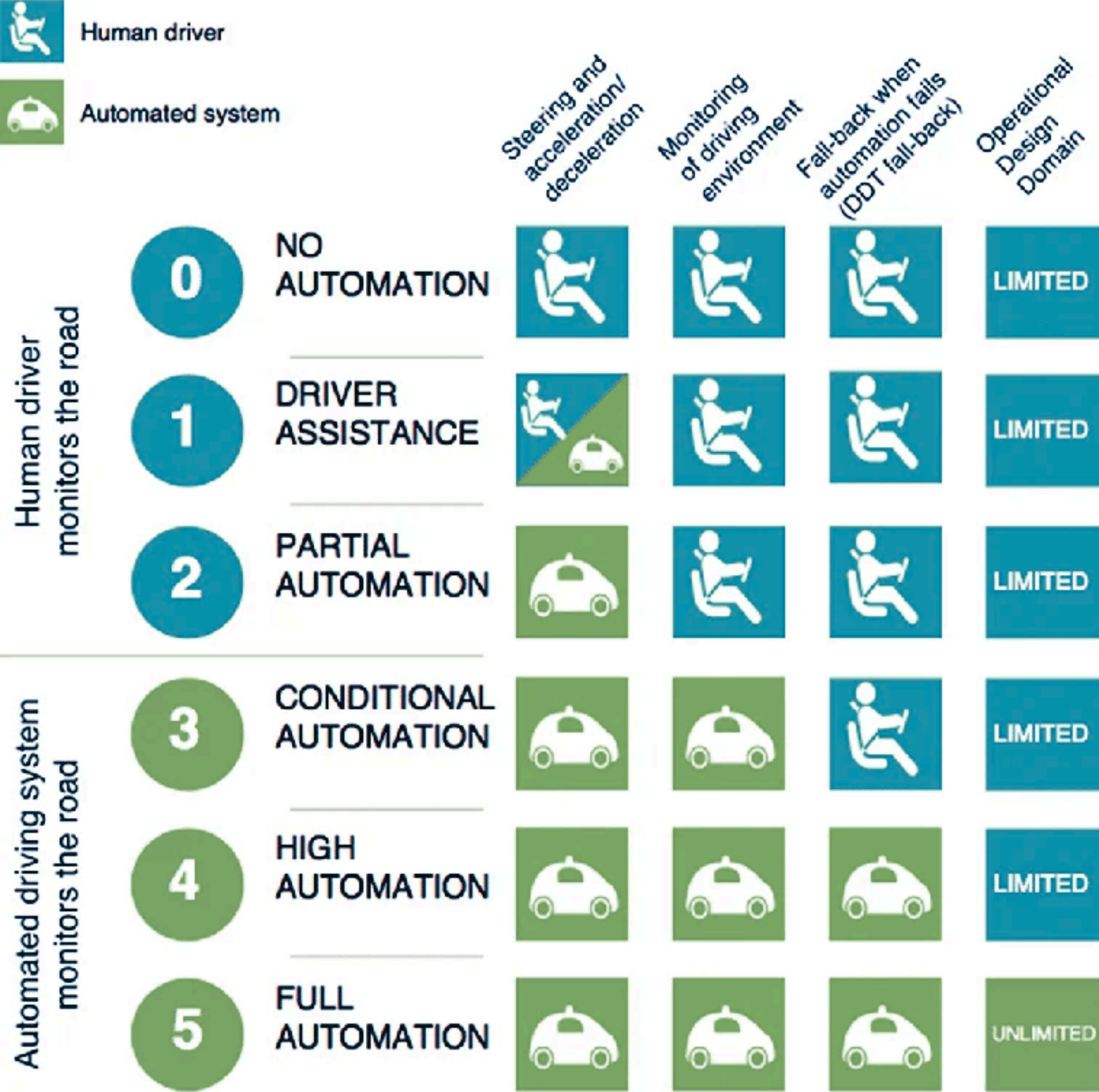


Figure 4: Levels of automation. (Serban et al., 2020)

also work when staff is present. This project will make suggestions of adding staff. This approach keeps the option open for operators to add personnel if they choose, while still ensuring that the interior itself supports perceived safety as much as possible.

OUT OF SCOPE

What is not included in this project is anything outside the

interior. The way the bus drives, the sensors and algorithms that make it stop or turn, the exterior paint or shape of the bus, and any smartphone apps or ticket systems are not part of the design. Changes to the road, such as special bus lanes or smart infrastructure, are also left out. Finally, this project does not look at business models or whether the design is profitable, although practical things like cost and maintenance are kept in mind.

Project approach

TRIPLE DIAMOND

This graduation project follows a Triple Diamond design process (Figure 5), which structures the work into three main phases: problem definition, solution discovery, and design development. Each phase consists of a divergent (exploring many possibilities) and convergent (narrowing down to a focus) step. The diagram below visualises this approach.

Phase 1: Problem definition

The first diamond focuses on understanding the problem. This phase diverges by exploring existing knowledge through a literature review, industry research, a user survey, and expert interviews with bus operators. It then converges into a clear problem definition and a set of design themes.

Phase 2: Solution discovery

The second diamond focuses on generating and selecting solutions. This phase diverges by brainstorming a wide range of ideas through How To's and C-box categorisation. It then converges by selecting the most promising concepts based on requirements and wishes.

Phase 3: Design development & validation

The third diamond focuses on refining the chosen concept. This phase diverges by developing detailed design iterations, including sketches, 3D models, and blender prototypes. It then converges into a validated final design through user testing and expert evaluation on feasibility.

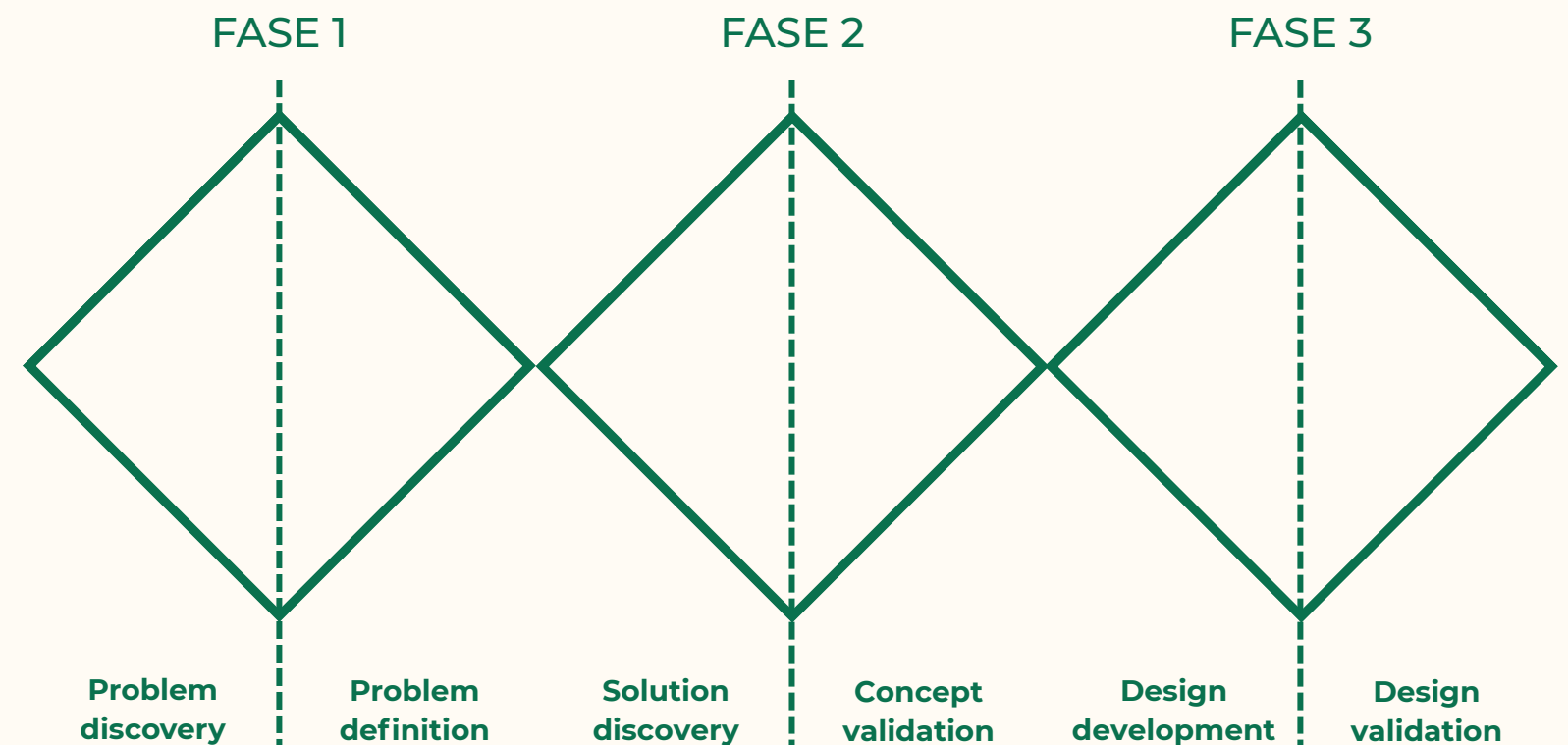


Figure 5: Triple diamond process of the project

METHODOLOGY

TRIPLE DIAMOND

The Double Diamond is a well-known design process model that describes two phases of divergence and convergence: problem definition and solution development. This project extends the Double Diamond to a Triple Diamond by adding a third diamond focused on design development and validation. This extension was necessary because the solution discovery phase (second diamond) generated six concept directions that needed further refinement before final validation. The third diamond allows for iterative prototyping and testing, which is essential for a project that aims to produce a validated design rather than only a conceptual proposal.

The research and design process uses several specific methods, drawn from the Delft Design Guide and other design research literature.

METHODS USED IN PHASE 1

- **Literature review:** Analysing existing academic research on perceived safety, trust, and autonomous vehicles. This provided the theoretical foundation for the project.
- **Industry and internet research:** Investigating current safety measures in public transport through online sources and operator websites.
- **User survey:** Collecting quantitative and qualitative data from 88 respondents about their experiences with safety in normal and driverless buses.
- **Semi-structured interviews:** Conducting expert interviews with HTM (product manager and innovation manager) and EBS (operations manager) to gain practical insights from bus operators.
- **Current bus interior research:** Research about current bus interior to get to know the measures and commonly used materials.

METHODS USED IN PHASE 2

- **How To's:** Generating a large number of ideas individually, then doing another session with another person. This method prevents groupthink and allows for independent thinking.
- **C-box** (Concept box): Categorising ideas on two axes (ease of implementation and impact on perceived safety) to identify the most promising directions.
- **Clustering:** Grouping ideas by function to identify overarching themes and strategies.
- **Requirements and wishes:** Developing a set of must-have requirements and nice-to-have wishes based on research findings.

METHODS USED IN PHASE 3

- **Sketching and 3D modelling:** Visualising the selected concept in detail.
- **Feasibility interview:** Interview with BYD to gain knowledge about the feasibility of the concept.
- **Prototyping:** Building digital prototypes to test specific elements of the design.
- **User testing:** Testing the prototype with potential passengers to validate whether the design actually improves perceived safety. This involves 360 pictures and renders, which allow participants to experience the autonomous bus interior without needing a physical prototype.
- **Evaluation:** Evaluating concept directions against multiple criteria to compare their strengths and weaknesses.
- **Scenario testing:** Testing the full concept through scenarios to evaluate the concept and find improvements or validations for future research.

STAKEHOLDERS

Several stakeholders are involved in or affected by the design of autonomous bus interiors (see Table 1). Understanding their roles and interests helps to frame the design decisions and ensures that the final concept is relevant and feasible. The table below summarises the main stakeholders, their roles, and their interests in this project.

Most of these stakeholders will not be directly involved in the design process, but their needs and constraints have been considered throughout the project.

STAKEHOLDER	ROLE	INTEREST IN PROJECT
Passenger	End users of the autonomous bus	Feel safe, comfortable, and in control during their journey. Need a bus interior that does not feel threatening or confusing.
Bus operators (HTM, EBS)	Run the bus services. Decide which buses to buy and how the interior is designed. They write the tender and choose the bus manufacturer.	Need cost-effective interiors that improve passenger satisfaction. Can choose to prioritise perceived safety in their tender.
Bus manufacturers (e.g. BYD, Mercedes-Benz)	Build the buses according to the operator's requirements. Respond to tenders.	Need clear, feasible requirements from operators. Will invest in interior quality only if the operator gives it enough weight in the tender (not just lowest price).
Transport authorities (e.g., MRDH)	Grant the concession to bus operators. Set the basic requirements public transport. Provide funding.	Decide whether perceived safety becomes a priority in the concession.

Table 1: Stakeholders and their role and interest in the project

Research

LITERATURE REVIEW

The literature review was conducted to understand which factors influence perceived safety in autonomous public transport. While technical safety and system reliability are essential, research consistently shows that the feeling of safety experienced by passengers is equally important for user acceptance (Raue et al., 2019; Rubagotti et al., 2022).

Perceived safety refers to the subjective feeling of being secure while travelling, which is influenced by cognitive, emotional, social, and environmental factors. Brosschot et al. (2016) indicates that even when objective safety risks are low, people may still feel unsafe if the environment does not provide clear signals of control, supervision, or predictability.

The literature review therefore focused on three main dimensions that influence perceived safety:

- Psychological factors
- Social factors
- Spatial factors

These three dimensions together shape how passengers interpret and experience safety in public transport environments.

Importantly, while psychological and social factors describe how people experience safety, spatial factors describe how the physical environment can influence and support these experiences. This makes spatial design particularly relevant for this project, as it offers potential design opportunities to support passengers' perceived safety in autonomous buses.



Figure 6: Literature. (ATLAS.ti, 2025)

PSYCHOLOGICAL FACTORS

Psychological factors influence how passengers cognitively and emotionally interpret a situation, see Figure 7 for a schematic view. Research shows that perceived safety is strongly related to trust, predictability, and emotional comfort.

Brosschot et al. (2016) explain that humans have a continuous stress response that is reduced only when the environment signals safety. When clear safety cues are absent, people remain in a heightened state of alertness even when no real danger is present. This means that environments that communicate safety can actively reduce stress and increase comfort.

From a **cognitive perspective**, people feel safer when situations are predictable and understandable. Predictable vehicle behaviour, clear spatial layouts, and visible supervision allow users to anticipate what will happen next and reduce uncertainty (Rubagotti et al., 2022).

When behaviour or systems are difficult to interpret, cognitive load increases and trust decreases.

Perceived safety is also shaped by **affective responses** such as comfort or anxiety. Environments that appear organised, controlled, and calm support relaxation, while unclear or chaotic environments can increase feelings of stress or vulnerability (Raue et al., 2019).

Human-centred design research links these responses to several fundamental psychological needs. Desmet and Fokkinga (2020) describe four needs that are particularly relevant in transport environments:

- Security – feeling protected from harm
- Comfort – feeling physically and mentally relaxed
- Autonomy – feeling in control of one’s actions
- Relatedness – feeling supported by others

These needs are currently partly fulfilled by the presence of a human driver. Research shows that drivers contribute to passengers’ feelings of security and relatedness by acting as a visible authority figure and source of assistance (Goldbach et al., 2022).

In autonomous buses, where the driver may no longer be present, these psychological needs may become less supported. As a result, passengers may experience higher levels of uncertainty and lower levels of trust.

Trust in automation is a dynamic attitude that is built and calibrated over time based on the history of the system’s performance. When the bus’s behavior is communicated through consistent, predictable patterns, passengers learn what to expect after only a few rides (Lee & Pitts, 2025).

For this project, these insights highlight that autonomous buses must not only be technically safe, but must also communicate safety and predictability to passengers.

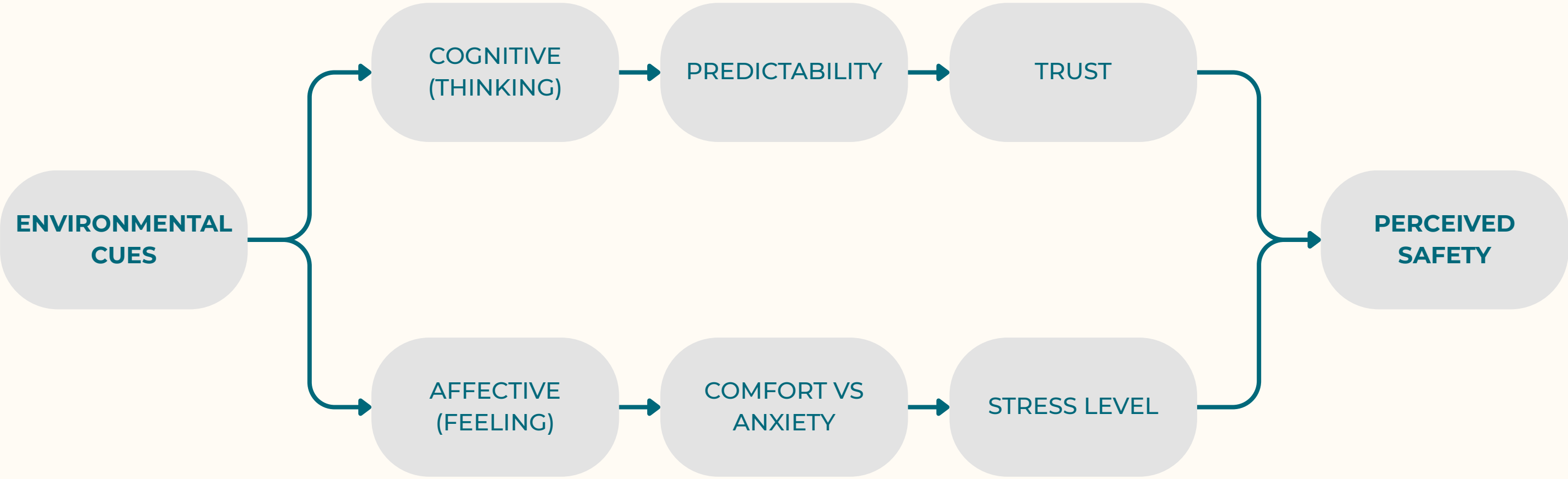


Figure 7: How an environment is interpreted through psycjological factors

SOCIAL FACTORS

In addition to psychological processes, perceived safety in public transport is strongly shaped by social dynamics between passengers and the presence of supervision.

Research shows that perceived safety problems already exist in current public transport systems. Stark and Meschik (2018) found that many women feel unsafe while travelling, which often leads to avoidance behaviour such as avoiding certain routes or travelling at specific times. These concerns are often related to social experiences rather than actual risk.

Ceccato et al. (2022) show that both very crowded vehicles and nearly empty vehicles can reduce perceived safety. Crowded environments increase the risk of unwanted social

interactions, while empty environments reduce the availability of help and social support. In both cases passengers may feel vulnerable.

The presence of visible staff plays an important role in reducing these concerns. Gekoski et al. (2015) found that staff presence is one of the most effective measures for increasing passengers' perceived safety in public transport. Staff provide supervision, authority, and assistance in case of incidents.

This becomes particularly relevant in the context of autonomous vehicles. If drivers or onboard personnel are removed, an important source of social reassurance disappears. Passengers may therefore experience increased uncertainty regarding supervision, help, and social control.

Research also shows that environmental cues influence how passengers interpret social situations. Trindade (2024) found that elements such as visibility, lighting, and cleanliness influence whether passengers feel safe among others. These cues help passengers assess their surroundings and understand whether the environment is controlled and monitored.

These findings highlight that perceived safety is not only an individual experience but is also shaped by how passengers perceive other people in the environment.

For autonomous buses, this suggests that the absence of a driver may amplify existing social safety concerns if no alternative forms of supervision or reassurance are provided.

Figure 8: Bus at night fully empty. (Dltigerbus, z.d.)

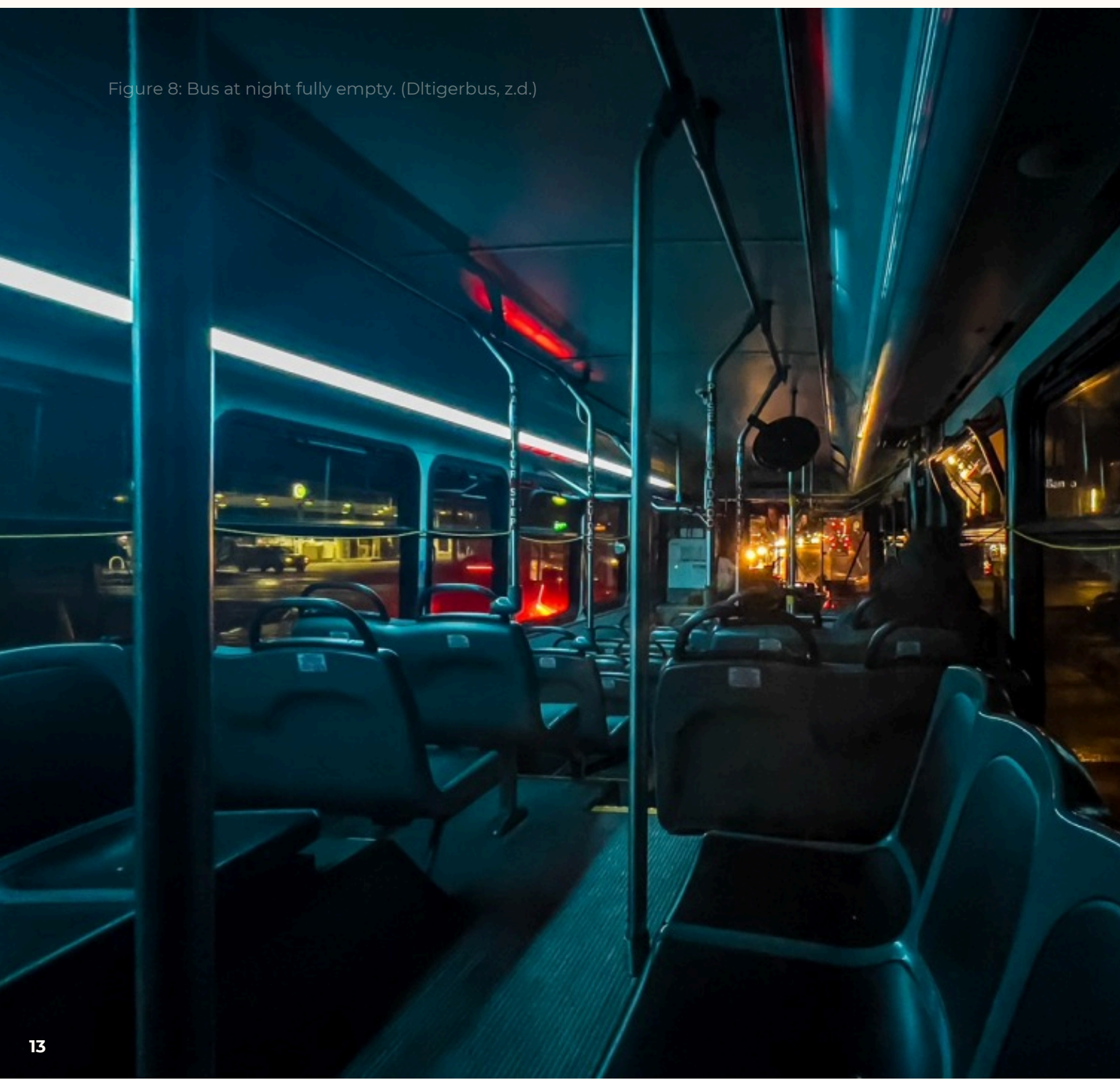


Figure 9: Crowded bus. (Baker, 2019)



SPATIAL FACTORS

While psychological and social factors describe how safety is experienced, spatial factors describe how the physical environment can influence these experiences.

The design of the interior environment plays a significant role in shaping passenger behaviour, movement, and perception. Elements such as layout, visibility, accessibility, and personal space can directly influence feelings of comfort, control, and trust.

Social norms are the unwritten rules that tell people what behaviour is normal and expected in a given environment. When a space clearly signals its intended use, people are more likely to follow that cue (Ryan-Christensen, 2026). This is also known as Clarity Reinforcement in CPTED: environments designed to communicate behavioural expectations encourage compliance (Lopez & Van Soomeren, 2026). For autonomous buses without a driver, making social norms visible through spatial design can help encourage prosocial behaviour.

Research on passenger behaviour shows that people make deliberate spatial choices inside public transport vehicles. Haferl (2025) found that passengers prefer specific positions in a vehicle depending on proximity to doors, handrails, or familiar locations. These choices help passengers anticipate their journey and increase their sense of control.

Accessibility is another important spatial factor. Jaydarifard et al. (2025) show that design features such as sufficient floor space, accessible boarding areas, and clear colour contrasts improve both safety and comfort for passengers with disabilities. Inclusive design therefore contributes not only to physical accessibility but also to perceived safety and autonomy.

Spatial design also affects control over personal space. Deng et al. (2025) found that passengers in shared autonomous vehicles value elements such as partitions, adjustable seating, and individual control over lighting or climate. These features help create personal zones within shared environments and increase feelings of protection and comfort.

In addition, movement and circulation patterns within the vehicle influence perceived safety. Clearly defined entry zones and movement paths reduce congestion and allow passengers to move through the vehicle more intuitively (Haferl, 2025). As said earlier, visibility and being able to assess the surroundings increases perceived safety (Trindade, 2024). Also, predictable movement patterns help passengers anticipate situations and reduce stress (Rubagotti et al., 2022).

- Overall, spatial design shapes perceived safety by (Figure 10):
- improving visibility and spatial understanding
 - supporting clear movement and circulation
 - providing control over personal space
 - ensuring accessibility for diverse users
 - creating calm and comfortable environments

These spatial characteristics influence both psychological experiences (such as trust and comfort) and social dynamics (such as awareness of others and supervision).

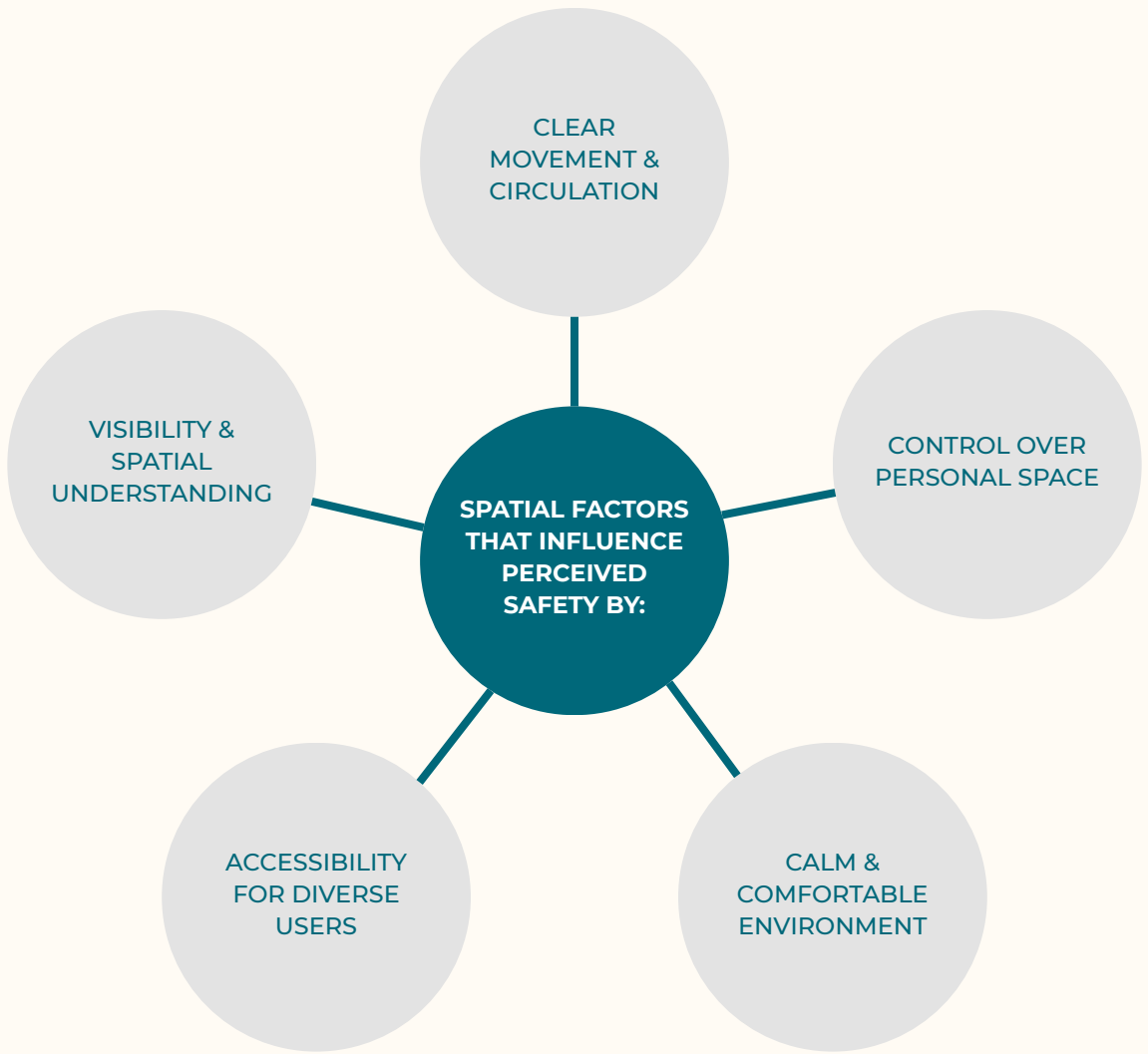


Figure 10: Spatial factors influencing perceived safety

RELEVANCE FOR THE DESIGN PROJECT

The literature review shows that perceived safety in autonomous public transport emerges from the impact of psychological, social, and spatial factors.

Psychological and social factors describe how passengers experience safety, including trust, emotional comfort, social dynamics, and the presence of supervision. However, these experiences are strongly influenced by the physical environment in which passengers travel.

Spatial design therefore becomes a critical design opportunity. By carefully shaping elements such as layout, visibility, lighting, circulation, and personal space, the interior environment can support passengers' psychological needs and social awareness. Interior design may play a key role in influencing the perceived safety.

At the same time, the literature reveals an important research gap. While many studies discuss trust, supervision, and social safety in autonomous transport, there is limited research that directly translates these insights into concrete vehicle design strategies.

This gap forms the foundation for the graduation project, which explores how human-centred interior design can support perceived safety in autonomous buses.

INDUSTRY/ INTERNET RESEARCH

In addition to the literature review, online and industry research was conducted to understand how perceived safety is currently addressed in public transport systems. The goal of this research was to identify which strategies are already implemented by transport operators and to understand whether perceived safety is primarily addressed through operational measures, technological systems, or environmental design.

Most available information from public transport providers focuses on security measures and operational policies, rather than interior design interventions. Safety is commonly addressed through surveillance, monitoring, and enforcement strategies aimed at preventing crime or responding to incidents.

Several measures are widely implemented across public transport systems.



Figure 11: Internet research in miro

SURVEILLANCE AND MONITORING

One of the most common safety measures is the use of CCTV cameras inside vehicles and at stations. These systems allow operators to monitor passenger behaviour and provide evidence in case of incidents. CCTV can also act as a deterrent for anti-social behaviour. “Increased awareness of bus camera systems can lead to more responsible behavior among both passengers and drivers” (Ellison, 2025).

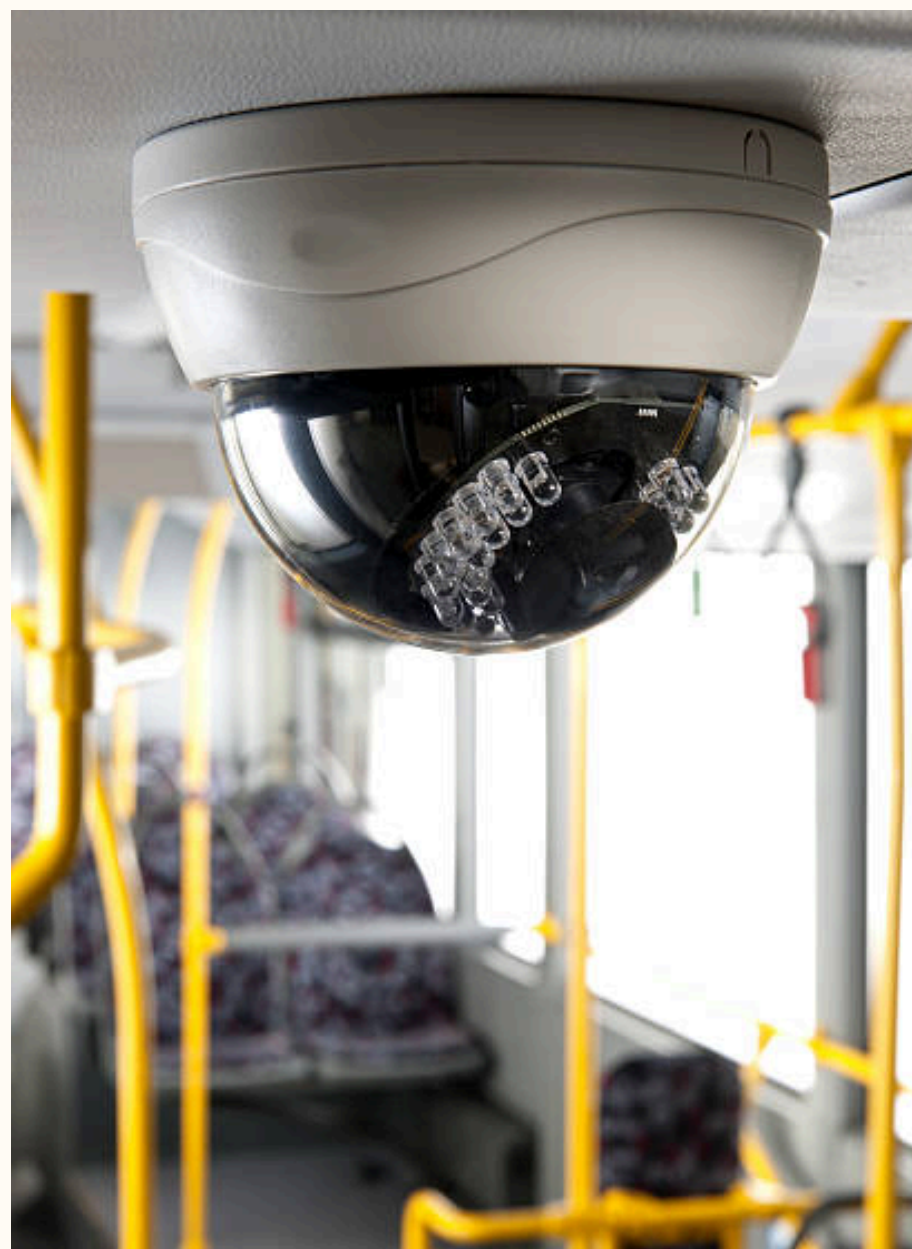


Figure 12: Surveillance camera in a bus. (Wachiwit, z.d.)

EMERGENCY COMMUNICATION SYSTEMS

Trams and trains include emergency buttons or intercom systems that allow passengers to contact the driver or control centre when necessary. These systems provide a way to request assistance in case of emergencies or unsafe situations (Rules On Public Transport, z.d.). However, some buses only have one spot, the wheelchair place, where this button is located, and most of the time there is not even an emergency button.

Although these features offer functional support, they are primarily reactive. Passengers may only interact with them when something already feels unsafe, rather than these systems continuously contributing to a feeling of safety. However, the feeling of having support at reach is reassuring (Bolzmacher et al., 2026). These systems should be “designed explicitly, briefly, timely, distinguishable from regular on-trip information, and address auditory and visual sensory channels alike.” (Mirnig et al., 2020).



Figure 13: SOS button in a NS train

STAFF PRESENCE AND ENFORCEMENT

Public transport operators also rely on ticket inspectors in trains and cardreaders in buses to scan your ticket (Connexxion, 2023), where passengers should enter only through the front passing the driver (Safe Bus, z.d.). Also security personnel, and transport staff in public transport maintain order and provide assistance. Staff presence is often considered one of the most effective ways to increase passengers' perceived safety (Gekoski et al., 2015).

The driver plays a particularly important role in this context. In addition to operating the vehicle, drivers act as visible authority figures who supervise passenger behaviour and provide help when needed.

However, the increasing development of autonomous public transport challenges this model. In fully autonomous buses, the driver may no longer be present, which removes an important source of supervision and reassurance.



Figure 14: Check-in machine at the entrance of a bus. (Redacció TheNBP, 2022)

CLEANLINESS AND MAINTENANCE

Operators also emphasise cleanliness and maintenance as important contributors to passenger comfort and safety perception. According to Pandey and Pathak (2021), the Broken window theory shows that neglected environments emphasize anti-social behaviour. Clean environments signal that a space is monitored and cared for, which can reduce fear and increase trust in the system.

This aligns with findings from environmental psychology, where well-maintained spaces are perceived as safer and more controlled environments.



Figure 15: Abandoned busstop

LIGHTING AND VISIBILITY

Another commonly mentioned factor is adequate lighting inside vehicles and stations. Bright, evenly distributed lighting improves visibility and reduces hidden areas where passengers may feel vulnerable (TU Delft (z.d.)).

Visibility is also related to the ability of passengers to observe their surroundings and other passengers, which can contribute to feelings of social safety (Harris, 2023). Ceccato et al. (2025) shows that anonymous, desolate spaces (without visible staff or other passengers) make passengers feel vulnerable and increase actual safety risks.

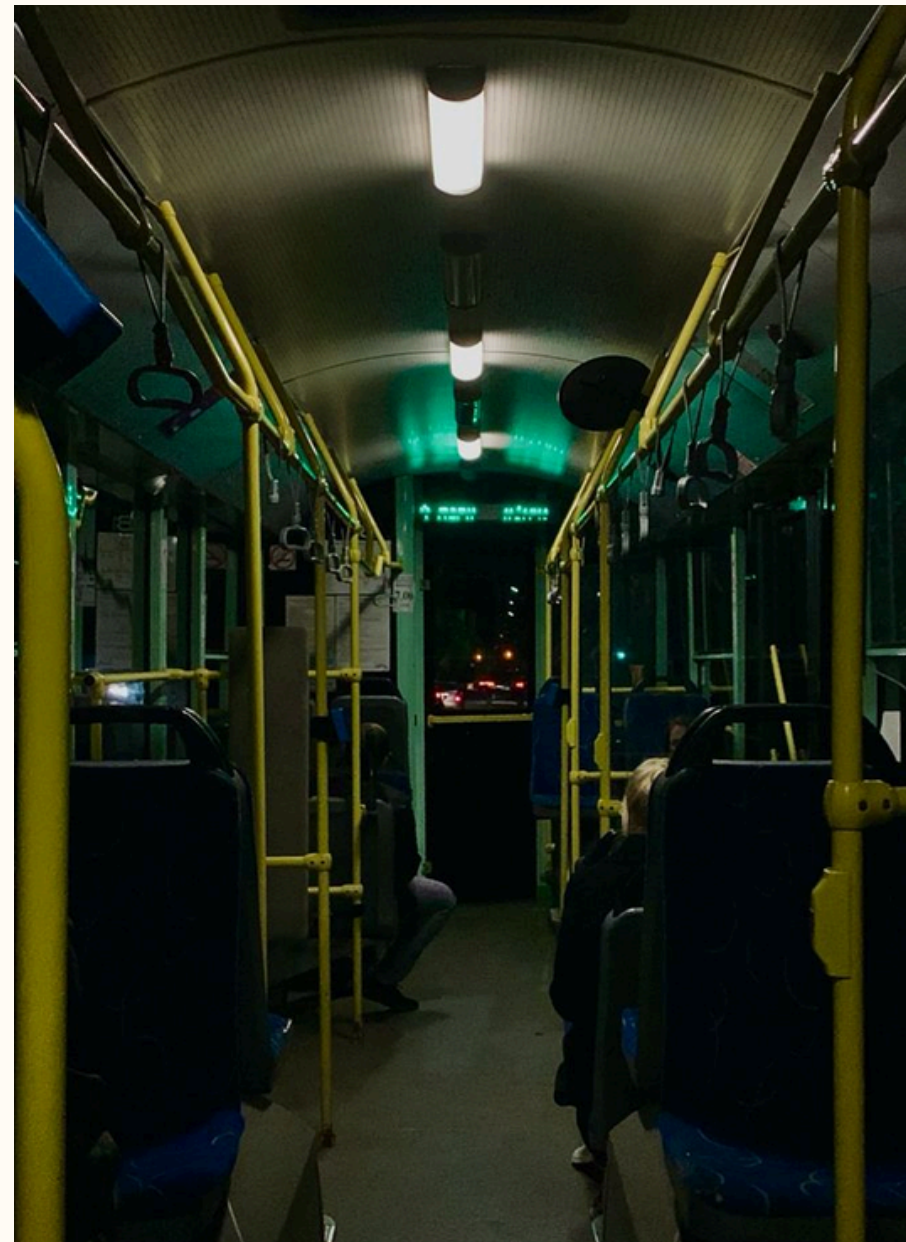


Figure 16: Dark bad lit bus interior. (Кінцева Зупинка-тролейбусний Парк, z.d.)

ACCESSIBILITY

EBS (n.d.) ensures that all its buses are wheelchair accessible by means of a low-floor design and an electric ramp operated by the driver. Passengers with limited mobility can board almost level with the platform, and if there still is a height difference, the driver can make the bus "kneel" (tilt to one side) for easier boarding. Also the Department of Transport and Main Roads (2025) states that "every message needs to be available in a range of ways (visual, auditory, tactile, plain English, multilingual) so people have options on how to access it. Information needs to be simplified for everyone, particularly those with lower literacy."

According to cognitive load theory (Sweller, 1988, working memory is limited and can only process 2-4 pieces of information at a time. When a system is not intuitive, it creates unnecessary mental effort.



Figure 17: Wheelchair ramp of a bus. (Masats S.A., 2025)

RELEVANCE FOR THE DESIGN PROJECT

Overall, the industry and internet research reveals that current safety strategies in public transport mainly focus on technological surveillance and operational control rather than interior spatial design.

Most existing measures aim to:

- monitor behaviour
- respond to incidents
- enforce rules
- provide emergency assistance

These strategies are effective when they are visible and

noticeable to passengers. A camera that is clearly visible deters anti-social behaviour. An emergency button that is easy to find provides reassurance.

A driver who greets passengers creates a sense of human connection. The key is that passengers must be aware of these measures for them to contribute to perceived safety.

The research also highlights the important role that human presence, particularly drivers and staff, plays in providing reassurance and supervision. The potential removal of drivers in autonomous buses therefore introduces a new challenge

for maintaining perceived safety.

At the same time, relatively little attention is given to how the design of the interior environment itself can contribute to passengers' sense of safety. Elements such as spatial layout, seating organisation, visibility, and environmental atmosphere could help increase perceived safety.

Therefore, this project investigates how interior design interventions could complement existing safety measures by creating environments that feel clear, understandable, socially comfortable, and reassuring for passengers.

Figure 18: Beveiliger in een NS trein. (Van de Ven, 2023)



USER RESEARCH

To understand how people really feel about safety in buses specifically, a survey was conducted. While the literature review provided theories and the industry research looked at current measures in general public transport, the survey was designed to hear directly from potential passengers. The goal was simple: find out what makes people feel safe or unsafe in a normal bus, and how those feelings change when the driver is gone. This direct feedback is crucial for a design project that aims to meet real user needs.

ABOUT THE SURVEY

The survey was shared online and completed by 98 people (see Appendix A for all the results. It asked about their experiences in regular buses and their expectations for driverless ones. The group was mixed in age and gender, giving a broad range of perspectives. The largest age groups were 18-24 year olds and 45-64 year olds, with a fairly even split between men and women.

How safe do you usually feel in a normal bus with a driver? *

Not safe at all 1 2 3 4 5 Very safe

What makes you feel safest inside a normal bus? (Select 3 answers) *

- ☐ Visibility - I can clearly see around me
- ☐ Lighting - The bus is bright with no dark corners
- ☐ Driver presence - The driver is visible and present
- ☐ Cleanliness - The bus looks clean and well cared for
- ☐ Social awareness - I can see and notice other passengers
- ☐ Information clarity - Screens or announcements show where we are
- ☐ Seat layout - The seats feel comfortable and logical
- ☐ Personal space - place for yourself
- ☐ None - Nothing makes me feel safer
- Others: _____

Figure 19: One page of the form that is used for this survey

SAFETY IN A NORMAL BUS (WITH A DRIVER)

First, respondents rated how safe they usually feel in a normal bus. The average score was 4.2 out of 5. This shows that, in general, people feel quite safe when a driver is present.

When asked what makes them feel safest, three answers were chosen far more than others (Figure 20):

- 1.Visibility – I can clearly see around me
- 2.Social awareness – I can see and notice other passengers
- 3.Driver presence – The driver is visible and present

This tells us that feeling safe is strongly linked to being able to see your surroundings, being aware of other people, and knowing there is a driver there.

On the other hand, the things that made people feel most unsafe were (Figure 21):

- Passenger behaviour – Other passengers behave unpredictably
- Crowding – The bus is too full, little personal space
- Feeling trapped – I cannot leave quickly if needed

Even in a bus with a driver, the biggest worries are about other people and the feeling of not having control over the space you are in.

SAFETY IN A DRIVERLESS BUS (WITHOUT A DRIVER)

When asked to imagine a bus with no driver, the average safety score dropped dramatically to 2.8 out of 5. This big difference shows just how important the driver is for people's sense of security. As one person put it, the driver has "some sort of authority... when something happens he can act upon it. I think I'll miss that."

The main worries in a driverless bus were clear (Figure 22):

- 1.No contact - No person to talk to if something happens
- 2.Technical failure - Fear the system could stop working
- 3.No control - feeling I can't influence or stop anything
- 4.Uncertainty - Not knowing what the bus will do next

The biggest fear is being alone with no one to turn to. This is followed by a lack of trust in the technology itself. Worries about other passengers are still there, and are even worse without a driver to manage them.

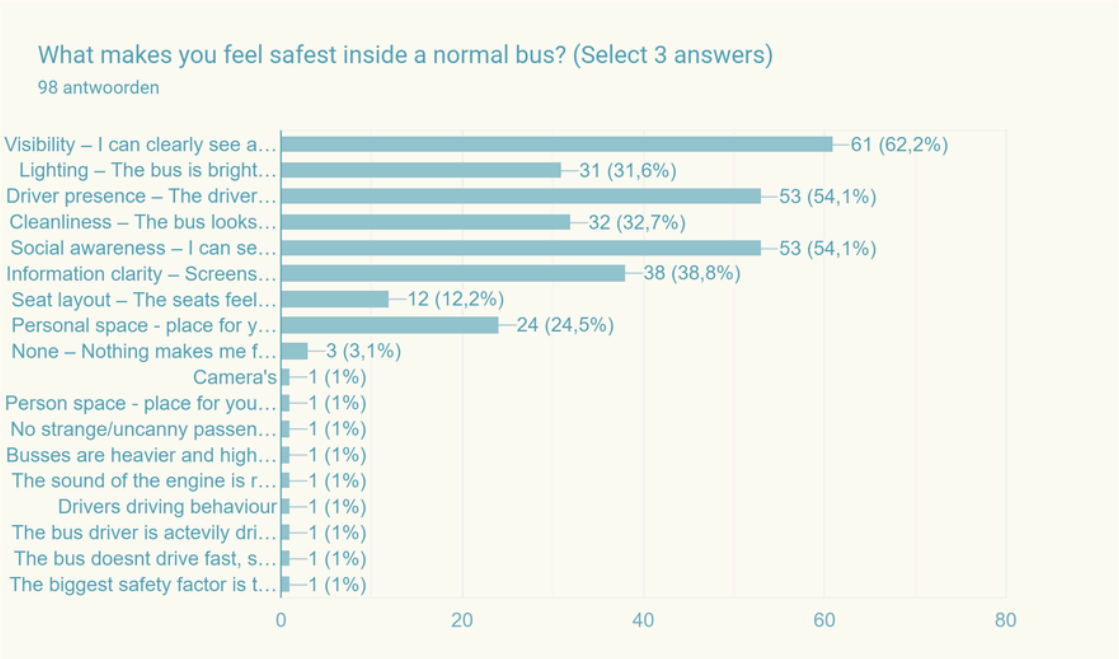


Figure 20: Answers of the question “What makes you feel safest inside a normal bus?”

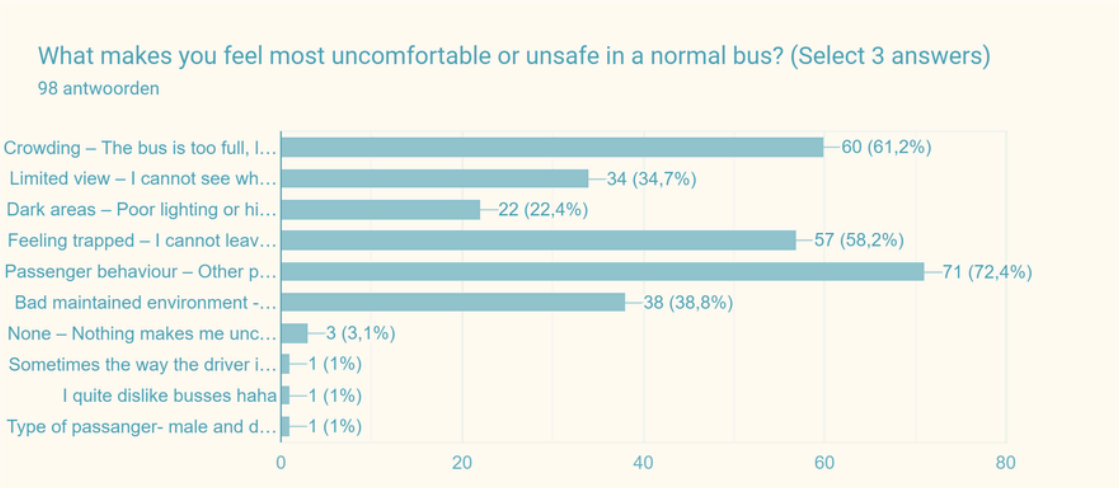


Figure 21: Answers of the question “What makes you feel most uncomfortable or unsafe in a normal bus?”

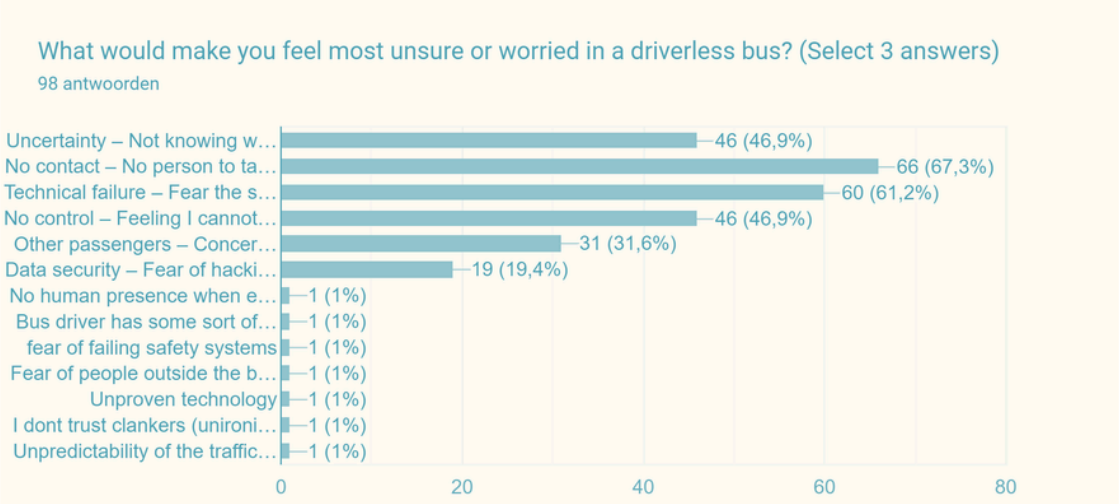


Figure 22: Answers of the question “What would make you feel most unsure or worried in a driverless bus?”

WHAT WOULD INCREASE TRUST?

To find solutions, respondents were asked what would make them trust a driverless bus more (Figure 23). The top answers point directly to design opportunities:

- 1. Help access – Easy and visible way to ask for help
- 2. Action explanation – The bus clearly explains what it is doing
- 3. System status – Clear confirmation that the system works
- 4. Calm design – A quiet, well-designed interior that feels cared for

People don't just want the bus to be safe; they want to feel safe. They want to see that help is available, understand what the bus is doing, and be in a space that feels calm and well-cared for.

PRIORITY

If passengers must make a decision what should be most important designing a driverless bus, both Transparency and Assistance would be the top priorities (Figure 24).

WHAT PEOPLE TOLD US IN THEIR OWN WORDS

The open-ended question at the end of the survey gave even deeper insight. Several strong ideas came up again and again:

- A need for a human presence: Many people suggested having a security guard or someone on board to replace the driver. One person summed it up as "een soort vervanger voor buschauffeur, dus dat het nog steeds een beetje persoonlijk voelt" (a kind of replacement for the bus driver, so that it still feels a bit personal).
- Being seen and monitored: Some people mentioned cameras, but not just for recording. One idea was to have a screen showing live camera footage inside the bus, so that everyone can see they are being watched. This suggests that making monitoring visible could make people behave better and feel safer.
- Having some control: Suggestions like a "stop button," an emergency button at every seat, or being able to see how crowded the bus is beforehand all point to a desire for passengers to have some control in an automated environment.
- Doubts about the idea itself: A few people questioned the whole idea of a driverless bus, with one simply saying, "Feels impersonal." This is a reminder that good design is essential to win people over.

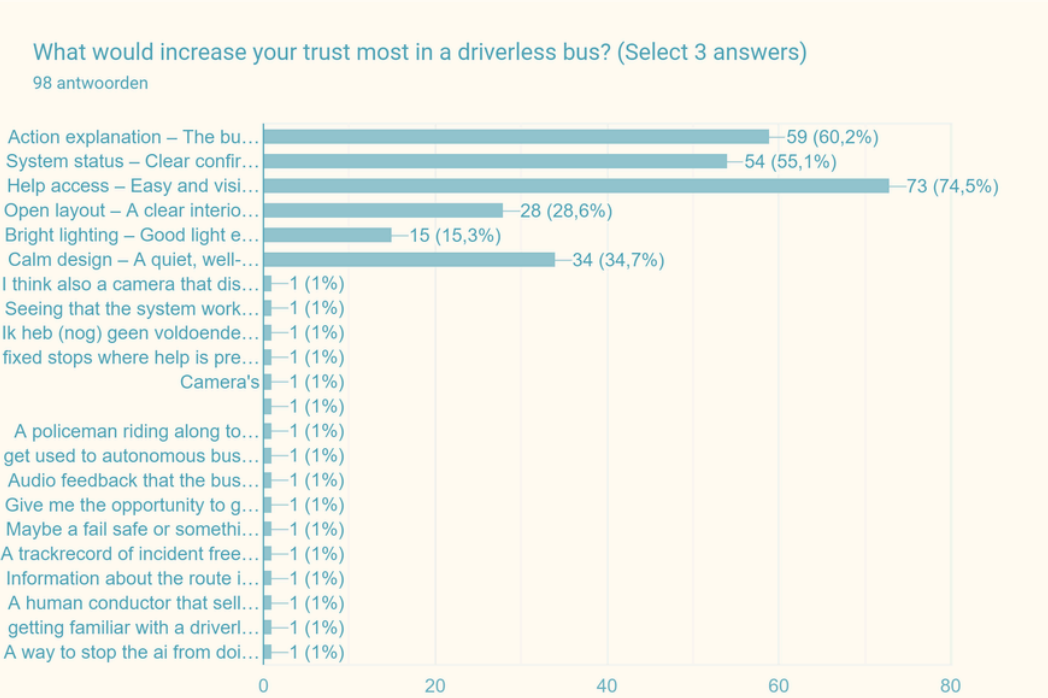


Figure 23: Answers of the question “What would increase your trust most in a driverless bus?”

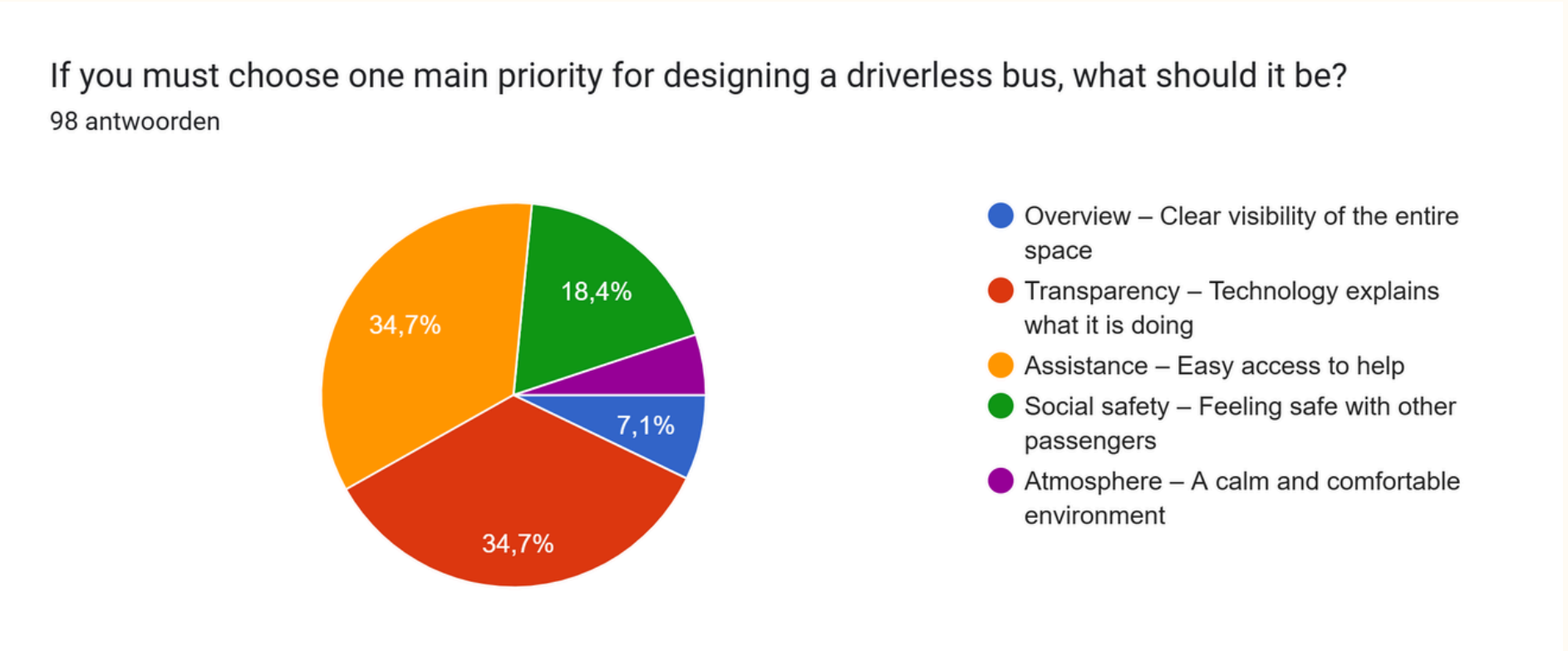


Figure 24: Main priority for designing a driverless bus

RELEVANCE FOR THE DESIGN PROJECT

The survey reveals a clear pattern: passengers feel significantly less safe when the driver is removed. The average safety score drops from 4.2 in normal buses to 2.8 in driverless buses. The main reasons are the loss of human contact, uncertainty about what the bus will do, and one thing that is already a problem is the fear of other passengers but now with no authority figure present.

Current autonomous vehicles often communicate their status but not their intention, leaving passengers guessing what will happen next (Brunel University London, z.d.), even though people like predictability.

In the end, what passengers want most is visible help and clear explanations of the vehicle and its behaviour. These insights provide a direct foundation for design.

EXPERT INTERVIEWS WITH BUS OPERATORS

To better understand how perceived safety is handled in practice, interviews were conducted with three public transport operators in the Netherlands: HTM (The Hague) (Appendix B), EBS (Schiphol region) (Appendix C), and RET (Rotterdam) (Appendix D). The goal was to learn how operators think about perceived safety, what measures they already use, and how they view autonomous buses.

HOW PERCEIVED SAFETY IS CONSIDERED

In the Netherlands, public transport is organised through concessions. A transport authority (such as a province or the MRDH) grants a concession to a bus operator and sets the basic requirements. The operator runs the service and is responsible for the vehicles. How much influence an operator has on interior design depends on the tender. In some cases, the authority decides most requirements; in others, the operator has more freedom.

This means that not all operators have the same level of control. Some, like HTM, work closely with the authority and can give many points to interior quality, forcing suppliers to invest in atmosphere and passenger flow rather than only price. Other operators, like EBS and RET, have less influence on bus interiors, but still pay attention to sightlines and seating where possible. However, the general rule is that social safety cannot be a separate competition criterion in Dutch tenders. It can only be included indirectly, through comfort, atmosphere, or passenger experience.

All three operators agreed that comfort and cleanliness strongly influence safety perception. When comfort or cleanliness is poor, the feeling of unsafety increases.

SPECIFIC DESIGN CHOICES

All three operators show camera images on screens inside the vehicle. Passengers see themselves on screen, which deters bad behaviour. RET is also experimenting with AI to recognise aggressive behaviour on platforms.

HTM has clear requirements for sightlines: from every seat, passengers must see at least two metres forward and look through a window.





Figure 25: HTM newest eCitaro bus. (eCitaro Elektrische Bus | HTM Zero-Emissie Vervoer, z.d.)

Lighting is carefully controlled with minimum and maximum levels to avoid a "hospital feel". Emergency buttons in trams are at every door, but in buses there is none or in some cases only at the wheelchair space because passengers can walk to the driver.

EBS noted that high backrests are comfortable but hurt social safety because passengers become hidden. Two-seat configurations are preferred over four-seat configurations for comfort, but this makes the bus less transparent. Low dividing walls near doors improve transparency, and vandalism-proof materials (fewer tables, footrests) help indirectly.

RET uses special upholstery and smooth floors that are easier to clean after graffiti. Seats in coach configuration prevent people from lying with feet on opposite seats. Atmosphere lighting is brighter at darker moments.

PASSENGER COMPLAINTS AND CONCERNS

All three operators agreed that the behaviour of other passengers is the biggest concern. HTM specifically mentioned groups of schoolchildren running and shouting. RET added concerns about being alone in the vehicle, night travellers with alcohol or drugs, aggressive fare-dodgers, gender-unfriendly behaviour, too many bicycles or pushchairs, and overcrowding.

HTM also noted that driving style (hard braking and accelerating) is directly linked to feeling unsafe, and that passengers currently cope by sitting near the driver, a strategy that will disappear in autonomous buses.

THOUGHTS ON AUTONOMOUS BUSES

HTM does not run autonomous pilots but follows developments through DAM Shuttles. An autonomous shuttle already runs in Rotterdam. HTM noted that the threshold for passengers is high, where many people feel unsafe without a driver, and that driving behaviour can be unexpected. The driver has multiple roles (social control, human contact, a point of help) that must be built into the interior of an autonomous bus.

EBS has not really thought about autonomous buses yet. The first step, they said, will be autonomous transport with a staff member still on board. Only when no staff is present will social safety become truly different.

RET has limited thoughts on this topic, focusing mainly on physical safety (collision risk, fire risk). For an unmanned bus, the situation is different from a metro because the current driver also provides information, welcome, and ticket sales.

WHAT OPERATORS SAID COULD BE IMPROVED

HTM emphasised calm colours, matching visual lines, and avoiding chaotic patterns. A pleasant, calm environment makes passengers feel safer.

EBS said staff presence, whether the driver or frequent inspections, is essential for perceived safety.

RET said atmosphere and communication towards passengers are important. Nicer things are less likely to be destroyed. Stronger enforcement and faster intervention through camera surveillance are also needed.

RELEVANCE FOR THE DESIGN PROJECT

From these interviews, several key insights guide my design.

First, visibility works. All three operators show camera images on screens, and HTM has formal sightline requirements. The new design must prioritise clear sightlines and make passengers feel seen.

Second, passenger behaviour is the biggest concern. People feel unsafe because of others, not because of the bus itself. The new design must reduce anonymous zones and create natural social control through layout and visibility.

Third, the driver does many things. Social control, human contact, a point of help, and even a simple greeting. In an autonomous bus, these functions must be replaced by interior design.

Fourth, there are trade-offs. Comfort (high backrests, two-seat layouts) can hurt social safety. The new design must balance both.

Fifth, operators have different levels of control. HTM actively designs for perceived safety, while EBS and RET are more limited by tenders and manufacturer designs. This means the new concept should be presented as a flexible package that operators can choose from, not a fixed mandatory design.

Finally, autonomous buses are still a future vision. This gives room for speculative design, but the design must be grounded in what we know today. The insights from HTM, EBS and RET about lighting, sightlines, cameras, and passenger behaviour provide that grounding.

REFINED PROBLEM DEFINITION

After the research the problem definition can be refined. The literature review explained psychological, social and spatial factors that shape perceived safety. The industry research looked at what public transport operators currently do. It found that measures like cameras, emergency buttons and staff presence work best when they are visible. The user survey showed that passengers feel much less safe without a driver, mainly because they lose a point of contact, help, and authority, but also the uncertainty about what the bus will do is a major concern. The interviews with HTM, EBS and RET added practical insights: visible cameras, clear sightlines and calm interiors help, while the behaviour of other passengers is the biggest concern even with a driver present.

Across all methods, several findings stand out. First, passengers need to understand what the bus is doing. Uncertainty about braking, turning, and route information is a big concern. Second, passengers need to feel safe around other people. The behaviour of fellow passengers is the biggest concern in practice. Third, passengers need a sense of human presence. The driver is currently a point of contact, a source of authority, and a reassuring presence. When the driver is removed, these functions disappear.

This means that the core problem for autonomous buses is broader than just replacing the driver. An autonomous bus must:

- **Be predictable** – passengers need to understand what the bus is going to do.
- **Provide social safety** – the interior must reduce the threat of other passengers.
- **Offer support** – passengers need to know they can get help when something happens.

The driver currently fulfils part of these needs, especially the last one. But even with a driver, passengers already worry about uncertainty and other passengers. Removing the driver makes these existing problems worse and adds the new problem of having no one to turn to.

Cameras, emergency buttons and monitoring systems can help address these issues, but they need to be visible, accessible and reassuring, not hidden or hard to find. Interior design can support this by integrating these elements into a coherent whole, where lighting, seating

layout, materials, sightlines, and feedback systems work together to create an environment that feels safe, predictable, and socially comfortable.

It is important to acknowledge that design cannot solve everything. In cases of serious incidents or conflicts, human intervention may still be necessary. This project does not assume that all staff can or should be removed. Instead, it explores to what extent the interior environment can support perceived safety in everyday situations. The goal is to find a balance where the interior takes on as much of the driver's psychological and social role as possible, while also improving predictability and social safety.

This leads to the following design question:

To what extent can interior design support perceived safety in fully autonomous buses?

This question will guide the next phase of the project, where design themes, principles, and criteria will be developed to translate research insights into concrete design solutions.

Figure 26: Driver greeting passenger entering the bus. (Keolis met en Place La Prédicibilité D'affluence À Bord, z.d.)



Design framework

DESIGN THEMES

The previous chapters explored perceived safety from different angles. This chapter brings these insights together into a coherent framework for design. It translates research findings into concrete design themes, principles, and criteria that will guide the next phase of the project.

The following four themes emerged from synthesising all research (Figure 27). Each theme addresses a specific aspect of what improves perceived safety and what passengers need.



Figure 27: The design themes that emerged from research about perceived safety

THEME 1: OVERVIEW & COMPREHENSIBILITY

The bus must make its behavior and environment understandable and predictable.

Passengers need to know what the bus is going to do. Uncertainty creates stress, even when there is no real danger (Brosschot et al., 2016). Predictability reduces cognitive load and increases trust (Rubagotti et al., 2022).

The survey showed that passengers want this: 55 respondents selected "action explanation" and 52 selected "system status" as trust-factors. Uncertainty was a primary worry for 40 respondents.

The interviews added practical examples. HTM requires clear sightlines in their buses: from every seat, passengers must see two metres forward and look through a window. EBS noted that high backrests and two-seat layouts, while comfortable, reduce overview. This shows a trade-off between comfort and transparency.

THEME 2: CONTROL & SUPPORT

Passengers must feel supported and not alone, especially in unexpected situations.

When people know help is available, they feel safer (Desmet & Fokkinga, 2020). The driver normally provides most of support (Goldbach et al., 2022). Without a driver, passengers feel vulnerable. Control comes from the psychological need for autonomy, which is the feeling that you can influence what happens to you (Desmet & Fokkinga, 2020). In a conventional bus, passengers can ask the driver questions or the driver can wait for someone who is running. In an autonomous bus, these small moments of control disappear.

The survey confirmed this: 68 respondents selected "help access" as the most important trust-factor. 61 worried most about "no contact". 41 mentioned "no control".

The interviews showed how help is currently organised. HTM places emergency buttons with intercoms at every tram door, but in buses no buttons are present and if they are it will only be at the wheelchair space because passengers can walk to the driver. For autonomous buses, this is a problem. HTM stated clearly that staff presence is essential for perceived safety.

THEME 3: SOCIAL SAFETY

The interior must reduce perceived social threat.

Passenger behaviour is the biggest safety concern in practice. The survey ranked it highest: 67 respondents felt unsafe because of other passengers. Crowding (54) and feeling trapped (49) followed.

The interviews confirmed this. Both HTM and EBS said that passenger behaviour is the most frequent source of complaints. HTM added that passengers currently cope by sitting near the driver. In an autonomous bus, that option disappears.

Ceccato et al. (2022) show that both crowded and empty vehicles reduce perceived safety. Gekoski et al. (2015) found that staff presence is the most effective safety measure. Trindade (2024) also links cleanliness and visibility to social safety.

THEME 4: ACCESSIBILITY & INCLUSIVITY

The bus must be comprehensible and accessible for everyone, regardless of age, ability, or experience.

A driverless bus cannot assume that all passengers are young, tech-savvy or familiar with autonomous systems. Literature shows that inclusive design features improve safety and comfort for passengers with disabilities (Jaydarifar et al., 2025), and Aasvik et al. (2025) says that older adults and women often feel less comfortable with autonomous technology.

The interviews confirmed that legal requirements exist for physical accessibility like low-floor designs and ramps, but not for perceived safety. This gives designers room to propose new solutions. HTM added that calm, consistent interiors with good lighting help all passengers, not just those with disabilities.

RELATIONSHIP BETWEEN THE DESIGN THEMES

The four design themes presented above do not exist in isolation. In practice, they overlap and reinforce each other. This is not a weakness of the framework, but rather a reflection of how passengers experience a space. A person inside a bus does not think in separate categories. They feel safe or unsafe based on the whole environment, not individual features.

OVERLAP IS LOGICAL

When a single design intervention addresses multiple themes, it means the design is efficient and coherent. This is not a problem. It shows that the themes are connected, which they should be. In a well-designed interior, psychological and social needs are not met by separate elements but by an integrated whole.

A SPECIAL ROLE FOR ACCESSIBILITY & INCLUSIVITY

Among the four themes, Accessibility & Inclusivity functions slightly differently than the others. While Overview, Control, and Social Safety each describe a specific passenger need, Accessibility is a quality that should be present in all design decisions. It is not an extra feature. It is a lens through which the other three themes must be viewed. Every design choice should be tested against the question: does this work for everyone?

HOW TO READ THE THEMES

The themes can best be understood as four questions that the design must answer positively:

1. Overview & Comprehensibility: Does the passenger understand what is happening?
2. Control & Calm: Does the passenger feel supported and in control?
3. Social Safety: Does the passenger feel safe around others?
4. Accessibility & Inclusivity: Does this work for all passengers, regardless of ability?

These questions overlap because passenger experience is layered. A design that succeeds on all four fronts will feel intuitive, reassuring, and safe for everyone.

DESIGN CRITERIA

To move from research insights to concrete design decisions, a set of evaluation criteria was developed. Two types of criteria were defined: **requirements (must-haves)** and **wishes (nice-to-haves)**.

The requirements ensure that a concept meets the basic needs that emerged from the literature review, survey, and interviews. A concept that does not meet all requirements cannot be considered a valid direction for further development. There are sixteen requirements, divided over five categories: overview & comprehensibility, control & support, social safety, accessibility & inclusivity, and feasibility. Each requirement can be answered with yes or no.

The wishes are used to compare concepts that already meet all requirements. They help to identify which concept performs best on aspects such as rich communication, learnability, social choice, and visual appeal. There are eleven wishes, each scored on a scale from -2 to +2.

The requirements and wishes are listed in the tables below in Table 2 and Table 3.



Figure 28: Building blocks with checked marks representing criteria. (Ai, z.d.)

	Requirements	Question	Justification	Source
Overview & Comprehensibility	1.1 Communication of intention	Is it made visible or audible before the bus brakes, turns or accelerates that it is going to do this?	Passengers want to know what the bus will do. Uncertainty is a major concern (40 respondents). Action explanation was selected by 55 respondents as trust-increasing.	User survey; Brosschot et al. (2016); Rubagotti et al. (2022)
	1.2 Predictability of movement (during action)	Can the passenger feel or see braking, accelerating and turning through an external signal at the moment it happens?	Passengers need to understand bus movement while it happens. This reduces surprise and increases feelings of control.	User survey; Rubagotti et al. (2022)
	1.3 Route and position insight	Does the passenger know at all times what and when the next stop is and how many stops are left?	Passengers want to know where they are and how long the journey will take. This reduces uncertainty and gives control over the trip.	User survey (Uncertainty)
Control & Support	2.1 Visible help access	Is there a way to ask for help from every seat without standing up? The button or help point should be within arm's reach of a seated passenger which is 81 centimetres (arm reach mean international)	"No contact" is the biggest concern (61 respondents). "Help access" was selected by 68 respondents as the most important trust factor. Help must be visible and nearby. Based on global anthropometric data, the average forward reach is 81 cm.	User survey; Goldbach et al. (2022), Bolzmacher et al.(2026), DINED (z.d.)
	2.2 Low-threshold help request	Can a passenger from a seated position locate and press a help button within 3 seconds ?	"No control" was mentioned by 41 respondents as a concern. Passengers need to take direct action without barriers. This is based on reaching movement research: at a distance of 0.8 metres, the average movement duration is 1.6 seconds. Adding 0.3 seconds reaction time and a margin for older adults or people with reduced mobility gives a total of approximately 3 seconds."	Mirnig et al. (2020), MeasureHuman (z.d.), Oguz et al. (2018)
	2.3 Avoid overstimulation	Does the idea avoid excessive, bright, flashing or loud stimuli that could cause stress?	A calm environment reduces stress. HTM emphasised that a pleasant, calm atmosphere contributes to safety perception. Bright or flashing lights can actually cause stress.	HTM interview; Desmet & Fokkinga (2020)
Social safety	3.1 Prevent anonymous zones	Are there no places where passengers can sit completely out of sight of other passengers?	Passenger behaviour is the biggest concern (67 respondents). Anonymous zones increase the chance of antisocial behaviour and make passengers feel vulnerable.	User survey; EBS interview; Ceccato et al. (2022); Ceccato et al. (2025); Broken Window Theory (Pandey & Pathak, 2021)
	3.2 Support 360° social visibility	Can seated passengers easily see passengers in the seats directly in front of them, next to them, and behind them?	"Feeling trapped" (49) and "Limited view" (30) are major concerns. HTM has sightline requirements (minimum 2 metres forward, window from every seat).	User survey; HTM interview; Trindade (2024); Ceccato et al. (2025)

	Requirements	Question	Justification	Source
Accessibility & Inclusivity	4.1 Help for everyone	Is the help function usable for deaf, blind, people with physical disabilities and wheelchair users ?	A driverless bus must be accessible to everyone. Literature shows that inclusive design improves safety and comfort for people with disabilities.	Jaydarifar et al. (2025); Aasvik et al. (2025)
	4.2 Works without language	Can essential information (help request, stop info, bus behaviour) be understood without reading text ?	Passengers with language barriers (tourists, low literacy) must also be able to use the bus. Universal cues like light and colour work better than text.	Department of Transport and Main Roads (2025)
	4.3 Works for first-time use	Is the concept understandable for a first-time user (elderly, tourist, child) with the help of clear, intuitive cues such as pictograms, light signals, or short animations? Long texts or complex menus should not be needed.	No one reads a manual before boarding. The design must be intuitive for all ages and experience levels.	Sweller (1988)
	4.4 Capacity	Does the concept allow at least the minimum of 70 passengers (including 30 seats)?	Bus operators need sufficient capacity to remain economically viable. Standard 12-metre city buses typically carry 70-100 passengers, with at least 30-45 seats . A minimum of 60 passengers (30 seats) is a realistic lower bound. If a design reduces capacity below this number, operators are unlikely to accept it.	Broek en Broek (2025)
Feasibility	5.1 Visualisable	Can this concept be sketched, modelled in 3D, or tested with a prototype within the time of this graduation project?	The project has a limited timeframe. Concepts must be visualisable to be tested and evaluated.	Project scope
	5.2 Technically feasible	Does the technology exist or is it realistic within 15 years ?	Both HTM and EBS see autonomous buses as a future vision. Designs must be based on realistic technology within 15 years.	HTM interview; EBS interview
	5.3 Fits inside interior	Is it an interior element (no app, no external infrastructure)?	The project focuses on interior design. Solutions that depend on apps, phones or external infrastructure are outside the project scope.	Project scope
	5.4 Operationability	Can the concept be cleaned, maintained, and operated by the bus operator using standard equipment and routines? It should be resistant to normal wear and tear and incidental vandalism, without requiring extra staff or specialised tools .	Bus operators cannot accept interiors that are hard to clean, easily damaged, or require additional personnel (HTM and EBS interviews). The Broken Window Theory also shows that worn or dirty interiors reduce perceived safety.	Broken Window Theory (Pandey & Pathak, 2021)

Table 2: Requirements

	Wishes	Question	Justification	Source
Overview & Comprehensibility	Rich communication	Does the concept use multiple senses (sight, sound, touch)?	Multiple senses make information accessible to more people and reinforce understanding.	Department of Transport and Main Roads (2025)
	Familiarisation speed	Do passengers understand the concept better on their next ride compared to their first use? The faster this improvement happens, the better.	A concept that becomes familiar quickly builds trust faster and reduces cognitive load over time. This wish rewards designs that passengers can master after only a few rides.	Goldbach et al. (2022); Lee en Pitts (2025)
Control & Support	Feeling of being supported	Do passengers feel not alone , even without direct help?	Besides functional help, emotional reassurance is important. A feeling of security and relatedness strengthens the overall safety feeling.	Desmet & Fokkinga (2020); Goldbach et al. (2022); Bolzmacher et al.(2026)
Social safety	Discourages antisocial behaviour	Is antisocial behaviour made less attractive by the concept?	Visible surveillance and open layouts can discourage antisocial behaviour without physical intervention.	Industry research (visible cameras); HTM interview
	Social choice freedom	Can passengers choose between social or private spaces ?	Passengers differ in how social they want to be. Freedom of choice gives control and increases comfort.	Haferl (2025); Deng et al. (2025)
	Social overview (whole bus)	From your seat, can you see most other seats in the bus (e.g., 80%) without standing up?	"Feeling trapped" (49) and "Limited view" (30) are major concerns. HTM has sightline requirements (minimum 2 metres forward, window from every seat). User survey; HTM interview; Trindade (2024); Ceccato et al. (2025)	User survey; HTM interview; Trindade (2024); Ceccato et al. (2025)
	Social norm visible	Is it visible what normal behaviour is in the bus?	Clear behaviour expectations (e.g. quiet zone, social zone) help passengers adapt their behaviour.	Ryan-Christensen (2026)
	Material durability and maintenance	Are the materials easy to clean, scratch-resistant, and durable enough to stay looking well-maintained over time ?	The Broken Window Theory states that a neglected environment invites antisocial behaviour. A clean, well-maintained bus signals that the space is monitored.	Broken Window Theory (Pandey & Pathak, 2021)
Accessibility & Inclusivity	Works for blind people	Can blind people use all functions of the concept?	Besides the basic help function (requirement), it is desirable that blind people can also understand route information and bus behaviour.	Department of Transport and Main Roads (2025)
	Works for deaf people	Can deaf people use all functions of the concept?	Besides the basic help function (requirement), it is desirable that deaf people can also receive audio information through visual or tactile signals.	Department of Transport and Main Roads (2025)
	Works for people with physical disability? (e.g. Wheelchair)	Can people with physical disabilities use all functions of the concept?	Besides the basic help function (requirement), it is desirable that people with physical disabilities can reach every element.	Department of Transport and Main Roads (2025)
Feasibility	Small space usage	Does the design take up little floor space ?	Efficient use of space leaves more room for passengers and wheelchairs.	Jabrams (2026)
	Visually attractive	Does the concept contribute to a calm, inviting interior ?	An attractive interior invites use and contributes to a positive first impression.	HTM interview (calm atmosphere, no "hospital feel")
	Future-proof	Is the concept easy to adapt or modular ?	Technology and insights change over time. Modular designs can be adapted more easily	Hemmerling & Huber (2025)

Table 3: Wishes

CORE CHALLENGE

The question for this project remains: **To what extent can interior design support perceived safety in fully autonomous buses?** In everyday situations, where no serious incidents occur, the interior should make passengers feel safe without a driver and with the already known issues around perceived safety. It should provide reassurance, clarity, and a sense of social safety for everyone.

The design framework presented in this chapter provides the answer to that question. By focusing on the design themes, the interior can address the needs to improve perceived safety issues in buses. The next phase will explore how these principles can be translated into concrete design concepts.

CURRENT BUS INTERIOR

To design a new interior for an autonomous bus, it is important to first understand what a current bus interior looks like. This section describes the typical layout, dimensions, and materials of a standard city bus, and explains why this project focuses on a 12-metre bus.

TYPICAL LAYOUT AND DIMENSIONS

A standard city bus for public transport in the Netherlands is usually between 12 and 18 metres long. The most common type is the **12-metre bus**, which is used on most city lines because it offers enough space for about 70 to 100 passengers, including approximately 25 to 45 seats. An 18-metre articulated bus (with a bend in the middle) is used on busier lines and can carry about 120 to 150 passengers, but it is less common (OV in Nederland Wiki, 2023).

The interior of a standard 12-metre bus typically has the following layout (Figure 29):

- **Front section:** The driver's cabin on the left side (in the Netherlands). The front door is for boarding. A ticket validator and information screen are usually placed near the driver and the doors.
- **Middle section:** A mix of forward-facing and sometimes rear-facing seats. Most buses have priority seats for elderly or disabled passengers. Handrails and standing space are in the aisle.
- **Rear section:** The floor is often higher because of the wheel axles. Seats are placed on a raised platform. In electric buses the batteries are located in different places, where on the roof is most common but can make the bus less stable (Lambert & Lambert, 2018). Under the chassis is also possible making the bus steadier (Editorial staff, 2020).

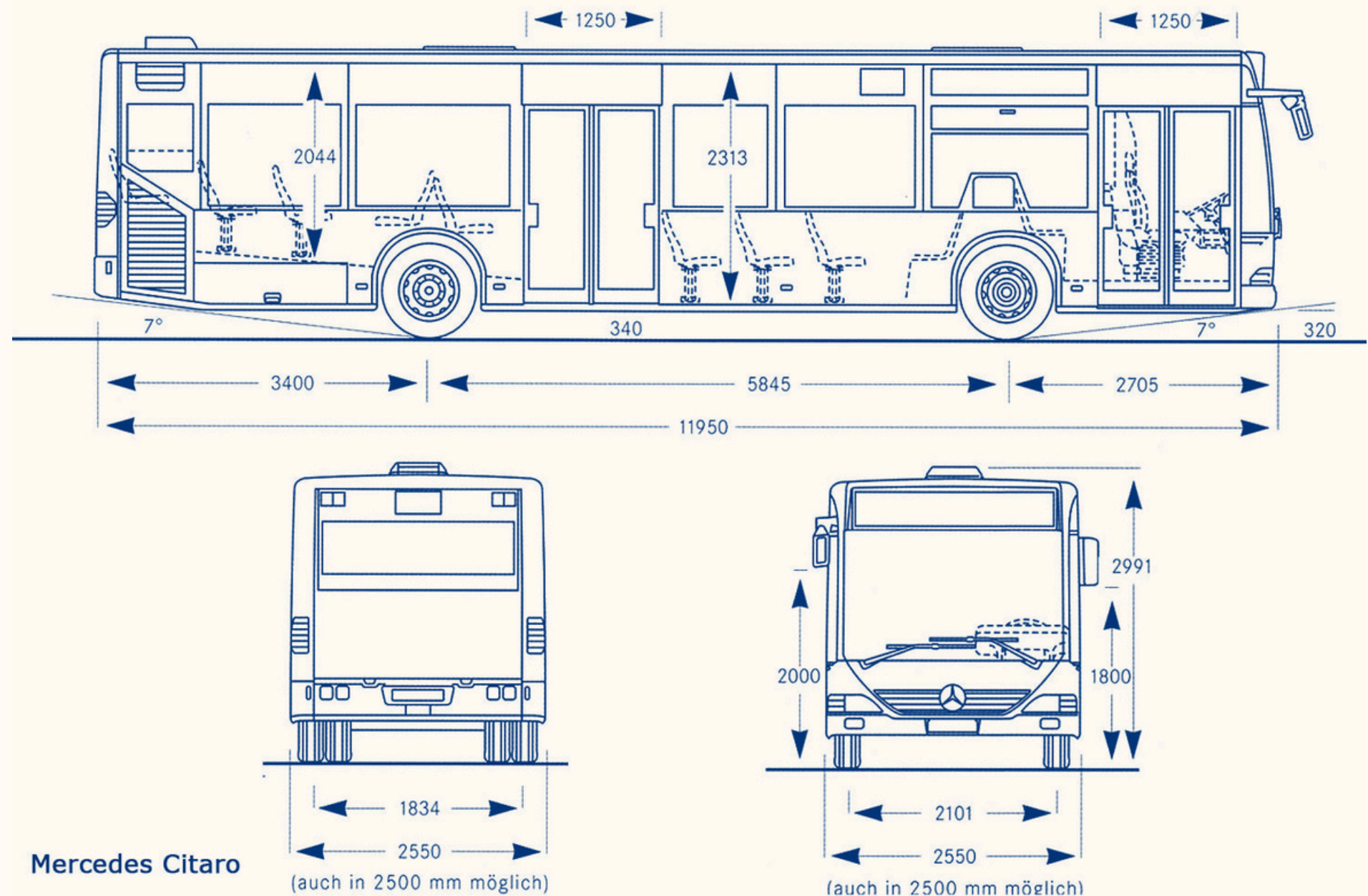


Figure 29: Bus measurements of a citaro bus. (Blueprints, z.d.)

FLOOR AND ACCESSIBILITY

Modern buses in the Netherlands, including those operated by HTM, have a fully low-floor design (Appendix B). This means the floor is at the same low level from the front to the back, which makes boarding easier for wheelchair users, people with pushchairs, and elderly passengers. The aisle remains level throughout the bus, improving accessibility (Figure 30).

However, even with a fully low-floor design, the seats are still slightly higher than the aisle floor. This is because the wheel axles are placed under or behind the seats.

MATERIALS AND SEATING

Bus seats are designed to be durable, easy to clean, and resistant to vandalism. Common seat materials include hard plastic, coated fabric, or synthetic leather (Vehicle Assemble, n.d.). Seat designs vary from high-back seats (more comfort, less visibility) to low-back seats (less comfort, more overview) (Appendix C). Bus seat configurations show different layouts, including 2+2 seating, forward-facing and aisle facing seats for faster boarding and more standing space if folded (Swenson, 2014).

The floor is usually made of slip-resistant vinyl or rubber. Gerflor Transport produces floor coverings specifically for buses that are easy to clean, durable, and have good slip resistance (Gerflor Transport, n.d.). These materials are chosen to withstand heavy daily use, frequent cleaning, and vandalism.

Most bus structures (Figure 31) are made of carbon steel. However a study on stainless steel bus structures shows that stainless steel is corrosion resistant and reduces maintenance and has a weight reduction which is important for electric buses, as it helps to increase the driving range (Editorial Staff, 2023).

WHY FOCUS ON A 12-METRE BUS?

This project focuses on the 12-metre bus for several reasons. First, the 12-metre bus is the most common type in public transport. Most city lines use this length. Designing for this bus means the concept can be applied widely.

Second, an 18-metre articulated bus is essentially a 12-metre bus with an extra segment (a bend in the middle). If the concept works on a 12-metre bus, it can be adapted to an 18-metre bus by repeating the same design elements in the extra segment. The core ideas do not change; they are just duplicated or extended in the longer vehicle.



Figure 30: HTM bus interior with a fully low floor design. (HTM Presenteert Nieuwe Elektrische Bussen, 2024)



Figure 31: Skelet construction of a bus. (Île-de-France Mobilités, 2023)

Third, a 12-metre bus is easier and less expensive to prototype and test.

Therefore, the design in this project is made for a 12-metre bus, with the understanding that it can be scaled up to an 18-metre bus if needed. Also a low floor will be used to ensure greater accessibility for everyone.

Ideation

APPROACH

This chapter describes the process of generating and selecting ideas for the interior design of an autonomous bus. The goal of this phase was to move from research insights to concrete design directions. The ideation process was structured in several steps described below.

HOW TO'S: GENERATING IDEAS

The first step was to generate a broad range of ideas. The goal was quantity over quality, exploring as many directions as possible without judging them. To do this, the How To's method was used. Ideas that came up were put on sticky notes, focusing on one theme at a time: Overview & Comprehensibility, Control & Support, Social Safety, and Accessibility & Inclusivity.

To bring in a fresh perspective, a person was invited who is not a designer to join one of the sessions. This person was in their 70s and had no background in public transport or design. The reason for involving a non-designer was to challenge my own assumptions and to gain insights from someone who represents the perspective of an everyday passenger. Older adults are often less familiar with new technologies, and their perspective is valuable when designing for accessibility and inclusivity. The session resulted in some new ideas, such as physical buttons over touchscreens, the need for clear visual cues for stops, and the value of familiar, home-like elements were emphasized. These ideas were later included in the selection process.

The How To's session resulted in a large collection of ideas (Figure 32). Some were practical, others more speculative. At this stage, all ideas were considered valuable.

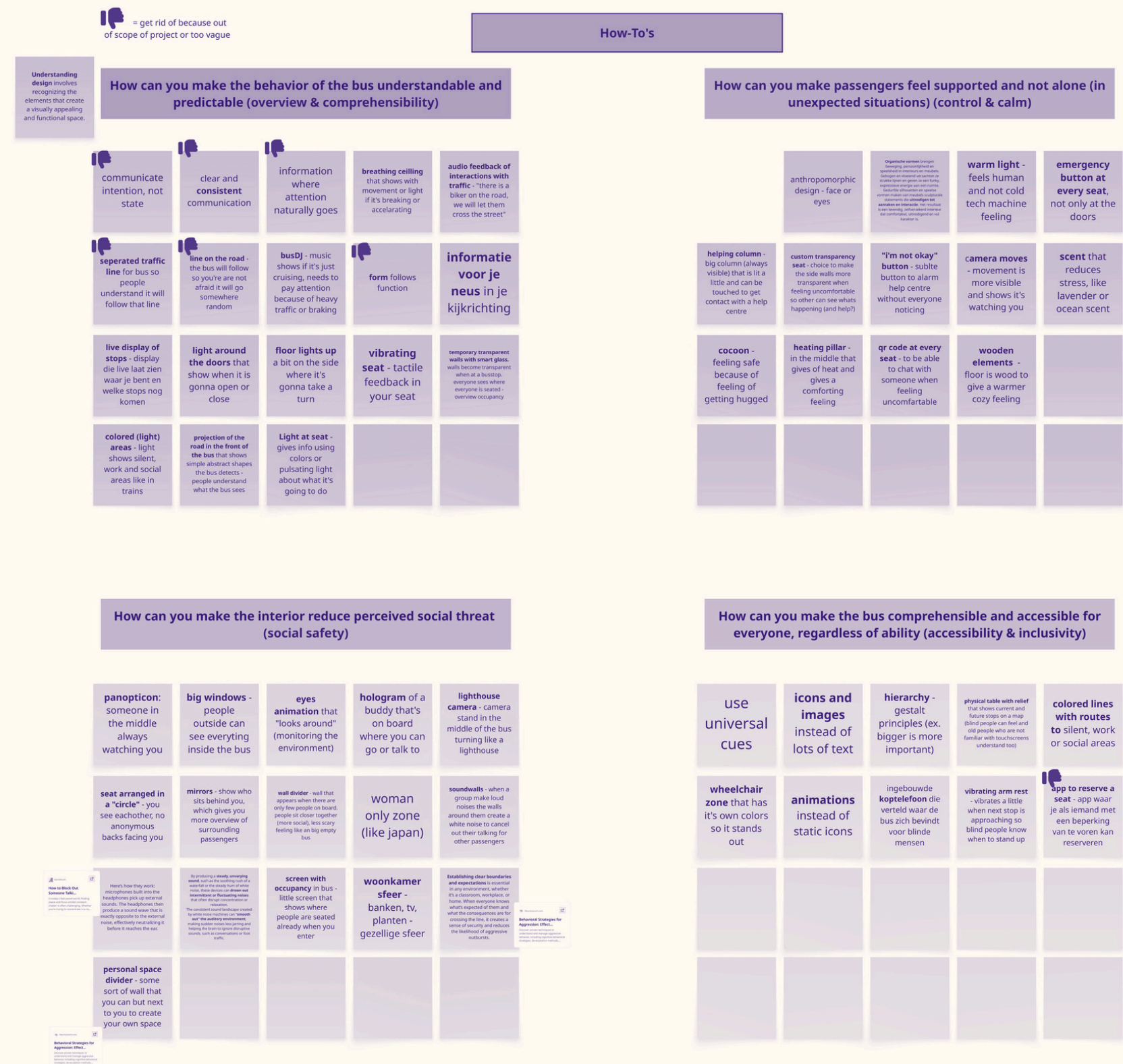


Figure 32: Brainstorm of ideas using How To's for each design theme made in Miro.

After generating ideas, the next step was to categorise them to identify which ones were most promising. For this a C-box was used, a visual method that places ideas on two axes (Figure 33). The axes were chosen based on the research findings and the goals of the project.

The horizontal axis represented **impact on perceived safety**. This refers to how much an idea contributes to the passenger's feeling of safety. To make this measurable, the top concerns from the survey were used. An idea was considered to have high impact if it directly addressed one or more of these concerns.

- Top right (Q1): Easy to implement, high impact → priority ideas
- Bottom right (Q2): Difficult to implement, high impact → promising but complex ideas
- Top left (Q3): Easy to implement, low impact → nice extras
- Bottom left (Q4): Difficult to implement, low impact → drop

[illegible]

Extra's (can later be implemented)	Priority (basis of concepts)
Q3	Q1
Q4	Q2
Let go	Promising (Distinctive core of the concepts)

SELECTING IDEAS WITH CRITERIA

The C-box resulted in two groups of high-impact ideas: those from the top-right quadrant (easy to implement) and those from the bottom-right quadrant (complex but promising). However, not all high-impact ideas were equally suitable for further development. To make a more refined selection, three additional criteria were applied. Each idea was evaluated on the following questions seen in Table 4.

Only ideas that scored positively on all three criteria were selected for further development.

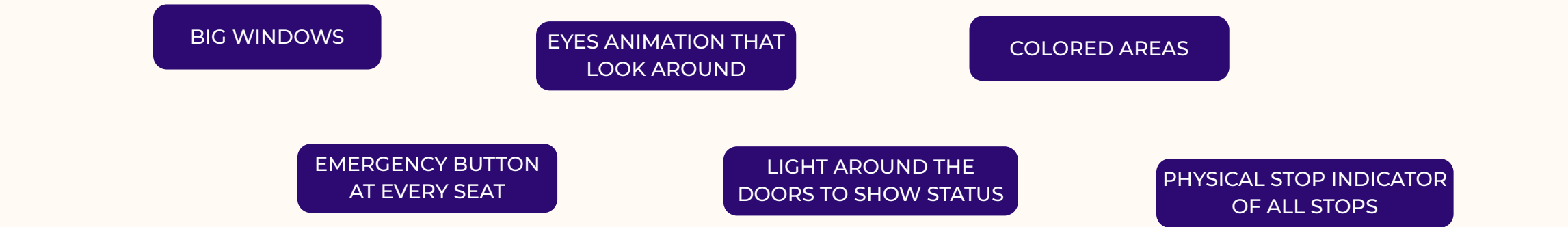
This selection process ensured that the remaining ideas were not only impactful but also inclusive and immediately noticeable to passengers.

The selected ideas from Q1 and Q2 are shown below. These 17 ideas formed the foundation for the next phase of ideation.

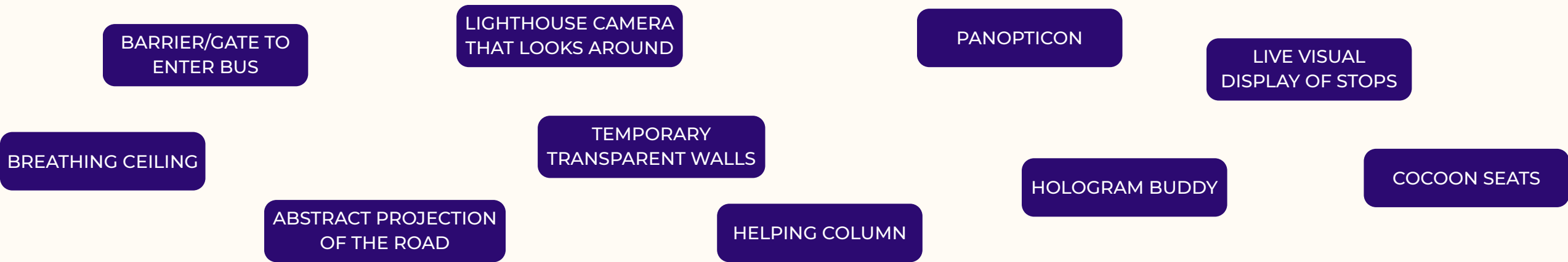
CRITERIA	QUESTION	SCORE
Link with topconcern from survey	Does this adress one of the five most chose concerns? (No contact, technical failure, no control, passenger behaviour, uncertainty)	+1 if yes
Universal use	Does this work for everyone (all ages, without language)?	+1 if yes
Speed of effect	Does the passenger feel it directly when entering or during the journey? (perceived safety is influenced by first sight/impression)	+1 if yes

Table 4: Evaluation criteria for the chosen ideas from the c-box

Q1: Easy to implement and high impact



Q2: Difficult to implement and high impact



CLUSTERING IDEAS INTO CONCEPT THEMES

With a selection of 17 ideas, the next step was to find structure. To have a different perspective and create a unbiased structure to move on, another design student was asked to group the ideas together based on what they do or what function they serve. This clustering was done iteratively, first grouping ideas with similar functions, then grouping those clusters into broader themes.

The first level of clustering resulted in functional groups that can be seen in Figure 36 on the right under the darkest sticky notes.

After reviewing and refining these groups, they were combined into four overarching themes (Figure 36). These themes represent different strategies for enhancing perceived safety in an autonomous bus:

- **Passenger feels supported:** Ideas that provide help, comfort, and a sense of being cared for. This includes the helping column, emergency buttons, and the hologram buddy.
- **Bus behaviour:** Ideas that explain what the bus is doing or will do. This includes the breathing ceiling, abstract projection, and light around doors.
- **External supervision/control:** Ideas that create a sense of oversight and control over who enters the bus. This includes the panopticon, lighthouse camera, and barrier/gate.
- **Overview bus interior:** Ideas that improve visibility and spatial awareness inside the bus. This includes mirrors, big windows, and colored areas.

These four themes are not random. They emerged from the ideas themselves and represent the directions that the selected ideas point toward. Each theme offers a different approach to making passengers feel safe, and together they should cover the different aspects of perceived safety identified in the research.

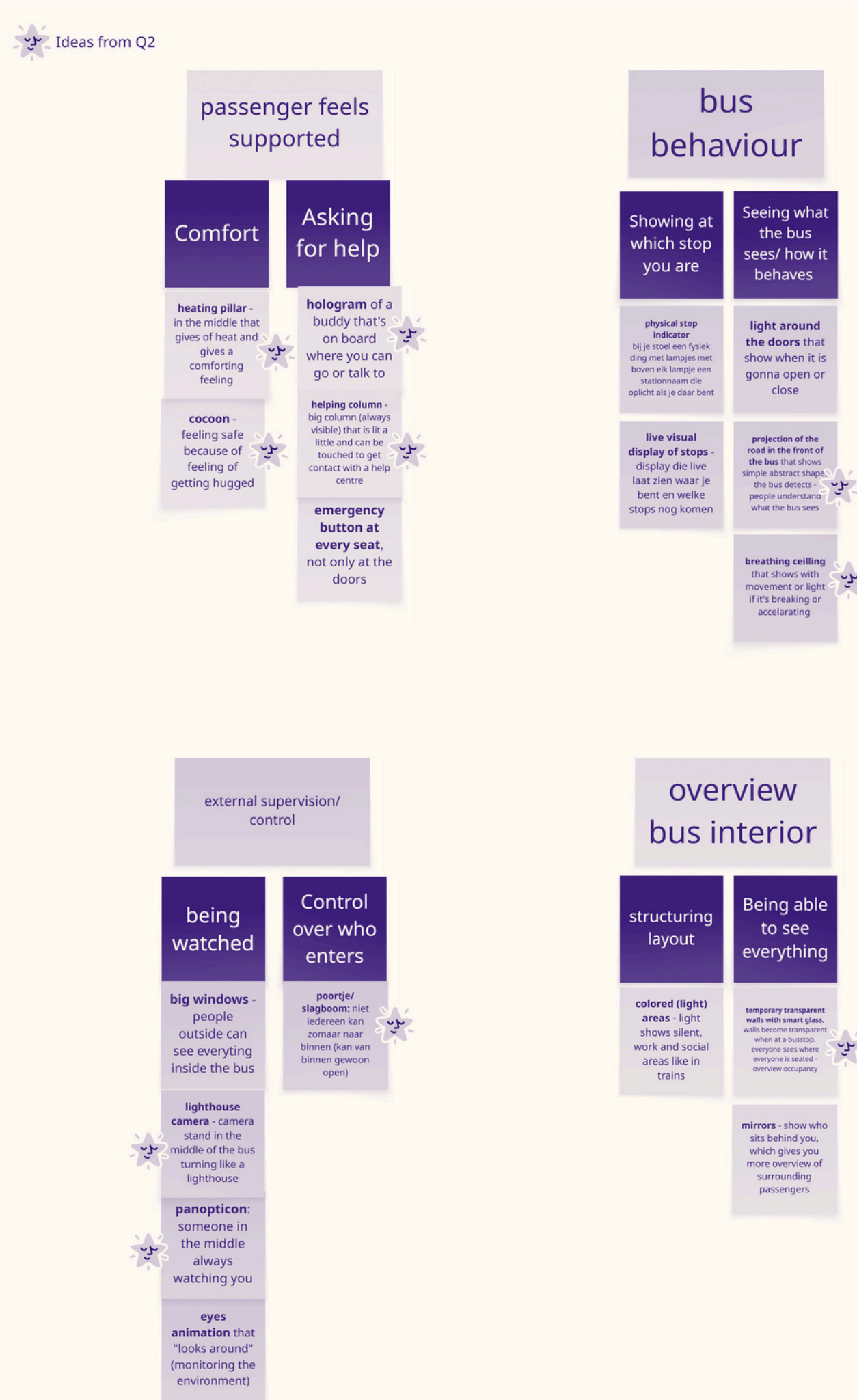


Figure 36: First level of clustering are refined into four overarching themes.

CREATING CONCEPT DIRECTIONS

The four themes described above are strategies, not yet complete concepts. A concept direction combines ideas from different themes into a coherent whole. The goal was to create concepts that are distinctive but still address all important aspects of perceived safety.

Each concept direction was built around one main idea from the complex quadrant (bottom-right Q2) as its core focus. This core gives the concept its distinctive character. Around this core, simpler ideas from the easy quadrant (top-right Q1) were added to make the concept complete. These simpler ideas address the other concept themes that the core idea does not cover.

This process, which is visually displayed in Figure 37, resulted in six concept directions, described in the next section.

When combining ideas into a concept, two things were checked. First, the concept was tested against a set of requirements (must-haves) based on the research. If a requirement was missing, an idea was added to fix it. If a requirement could not be met without changing the core of the concept, the concept was discontinued.

Second, the concept was checked for coherence. A good concept is not a random collection of features. All elements should work toward the same goal and feel like they belong together. For each concept, a clear "samenhanglogica" (logic of coherence) was formulated that explains what the concept is about and how the elements support each other.

OVERVIEW CONCEPT DIRECTIONS

This section describes the six concept directions that were developed. Each description includes the core idea, the supporting ideas, and the coherence logic that ties everything together.

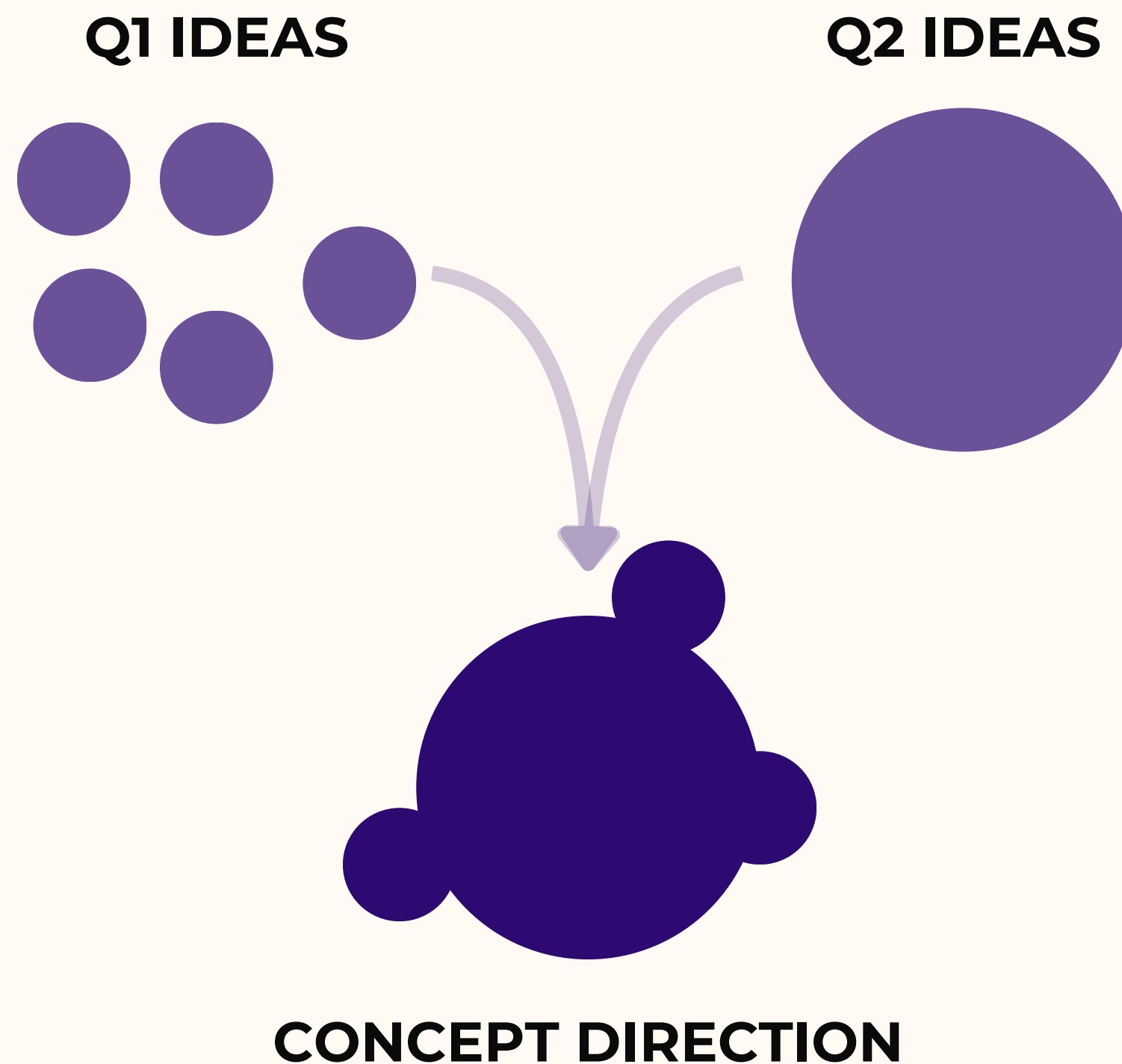


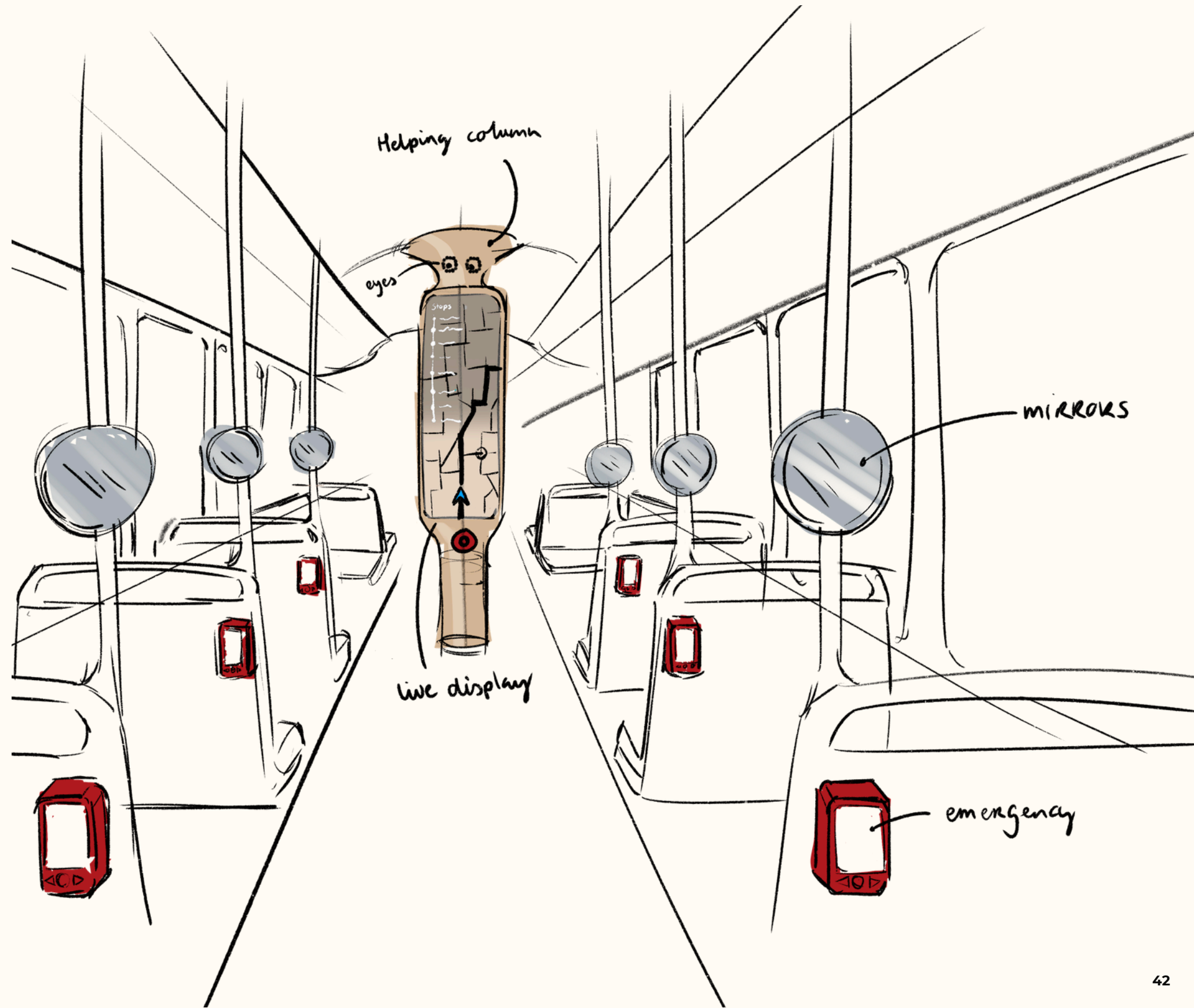
Figure 37: Abstract visual of how the concept directions are formed.

COMPANIAN CORE

Core idea (Q2): Helping column

Supporting ideas (Q1): Emergency button at every seat, mirrors, live visual display of stops, eyes animation

Coherence logic: Everything revolves around "you are not alone". The column is always there and also has the live display. The eyes on the column look around. The emergency button is your direct line to help. The mirrors show that other people are also there around you. Every element strengthens the feeling of presence and support.

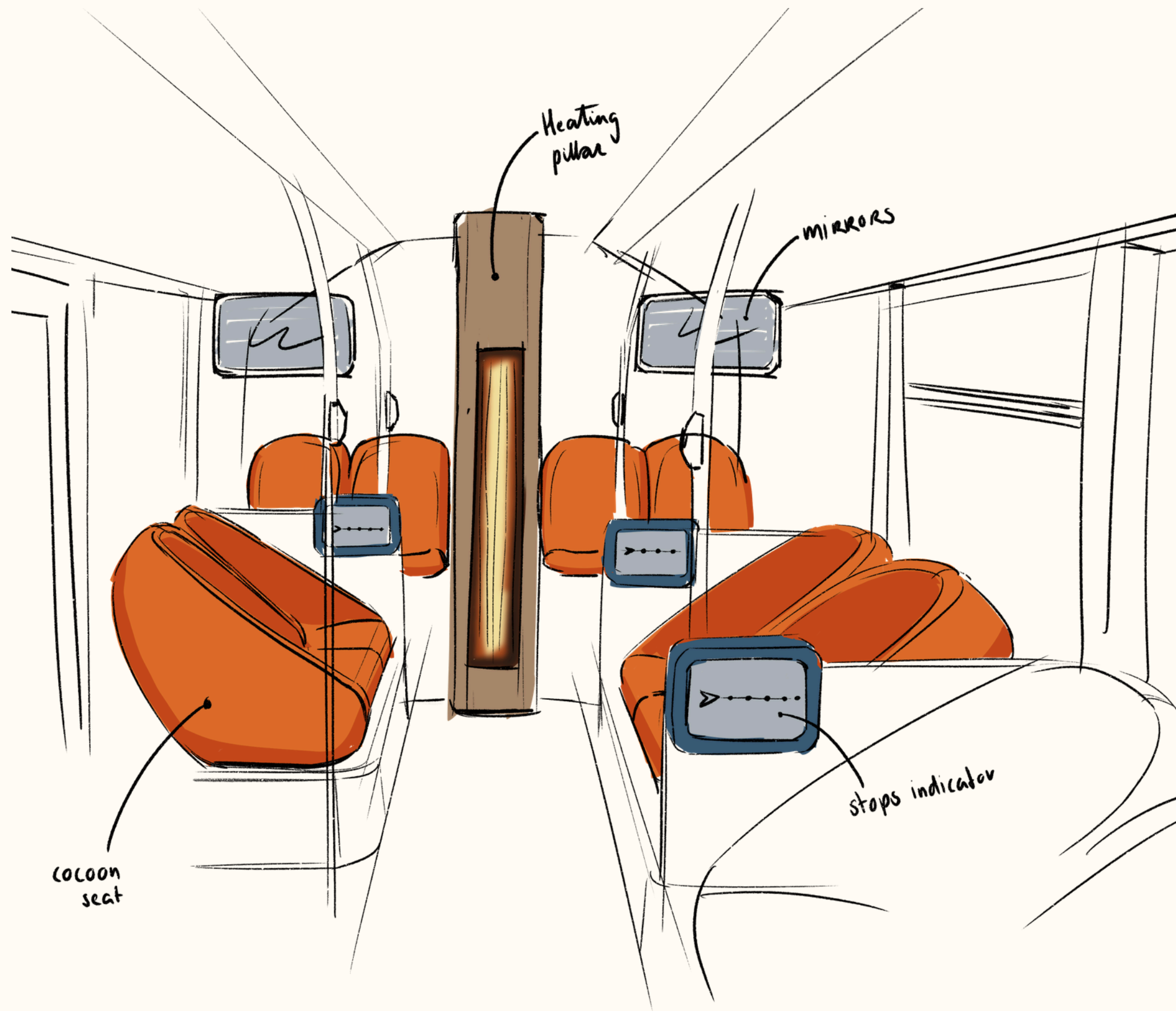


COCOON COACH

Core idea (Q2): Cocoon

Supporting ideas (Q1): Emergency button at every seat, heating pillar, physical stop indicator, mirrors, barrier/gate

Coherence logic: Everything revolves around "sheltered comfort". The cocoon seat wraps around you. The heating pillar gives warmth. The stop indicator at your seat lets you stay in your cocoon. The barrier keeps unwanted people out. You feel safe and protected in your own bubble.

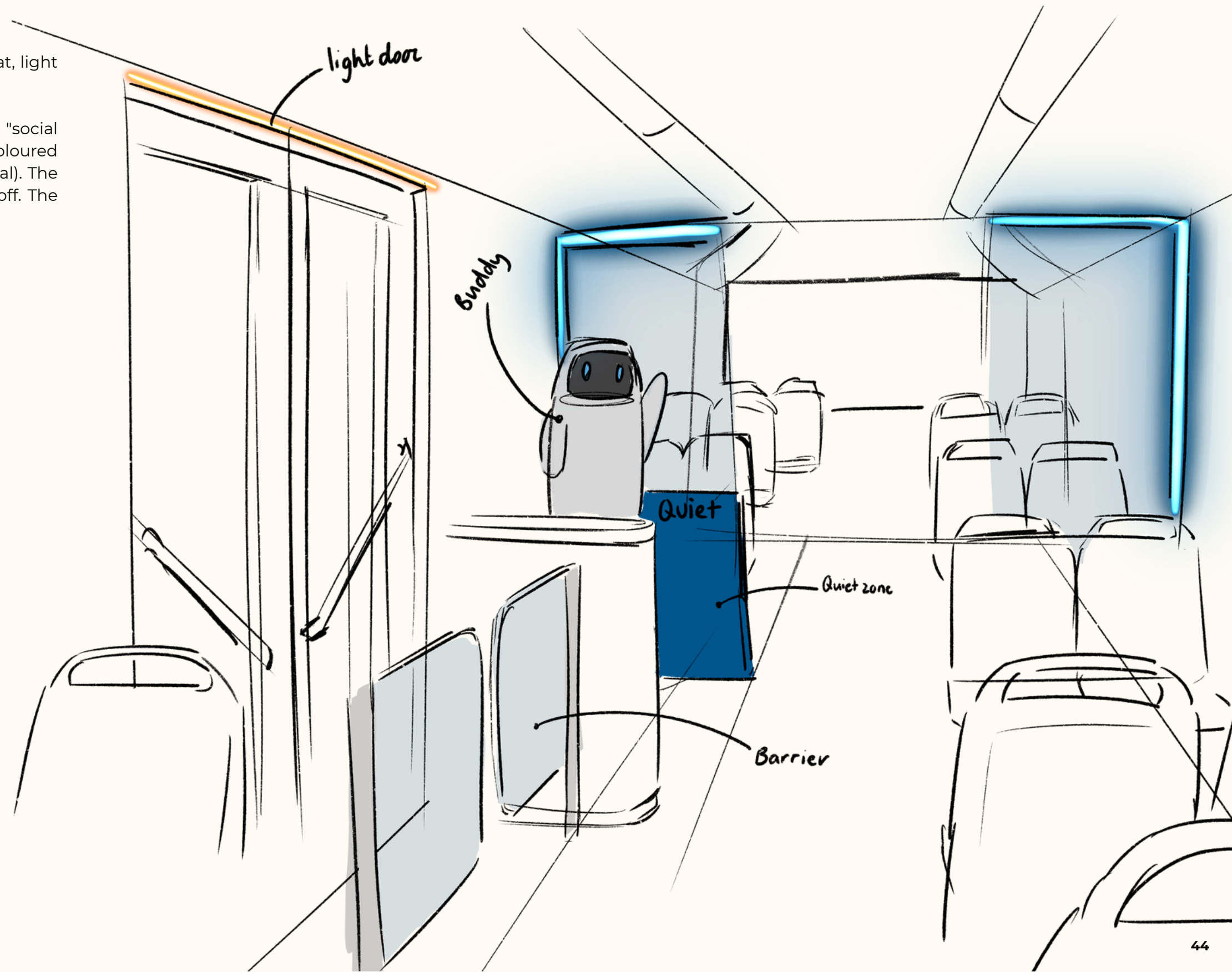


BUDDY BUS

Core idea (Q2): Hologram buddy

Supporting ideas (Q1): Emergency button at every seat, light around doors, colored areas, barrier/gate

Coherence logic: Everything revolves around "social guidance". The buddy is your guide on board. The coloured zones help you choose where you fit (quiet, work, social). The light around doors guides you when getting on and off. The barrier makes sure only proper passengers enter.

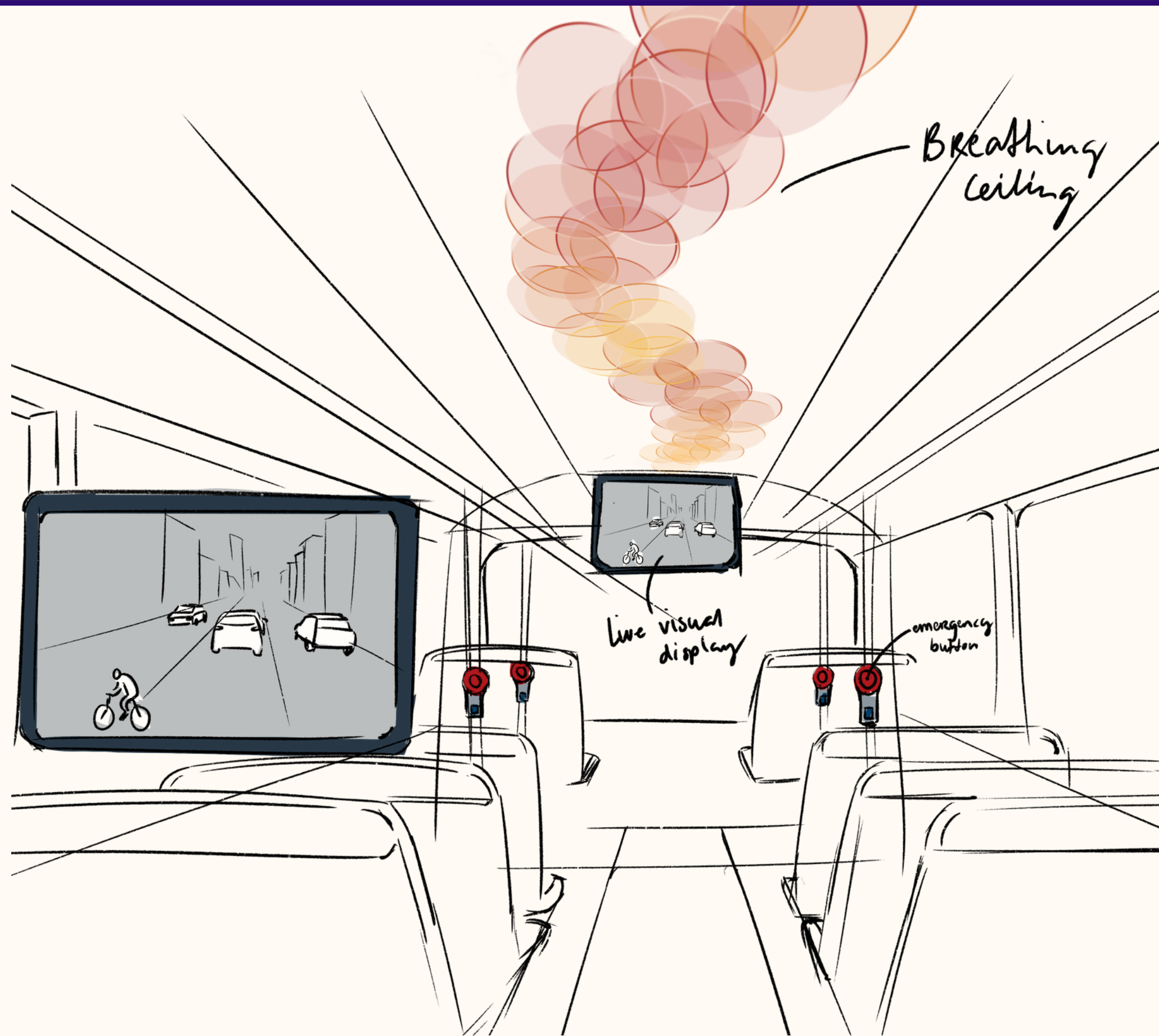


PULSE ROAD

Core idea (Q2): Abstract projection of the road + breathing ceiling

Supporting ideas (Q1): Emergency button at every seat, mirrors, big windows

Coherence logic: Everything revolves around "transparency". The projection makes the road transparent (you see what the bus sees). The breathing ceiling makes movement transparent (you feel when the bus brakes or accelerates). The big windows make the bus transparent to the outside. The mirrors make the bus transparent to the inside.

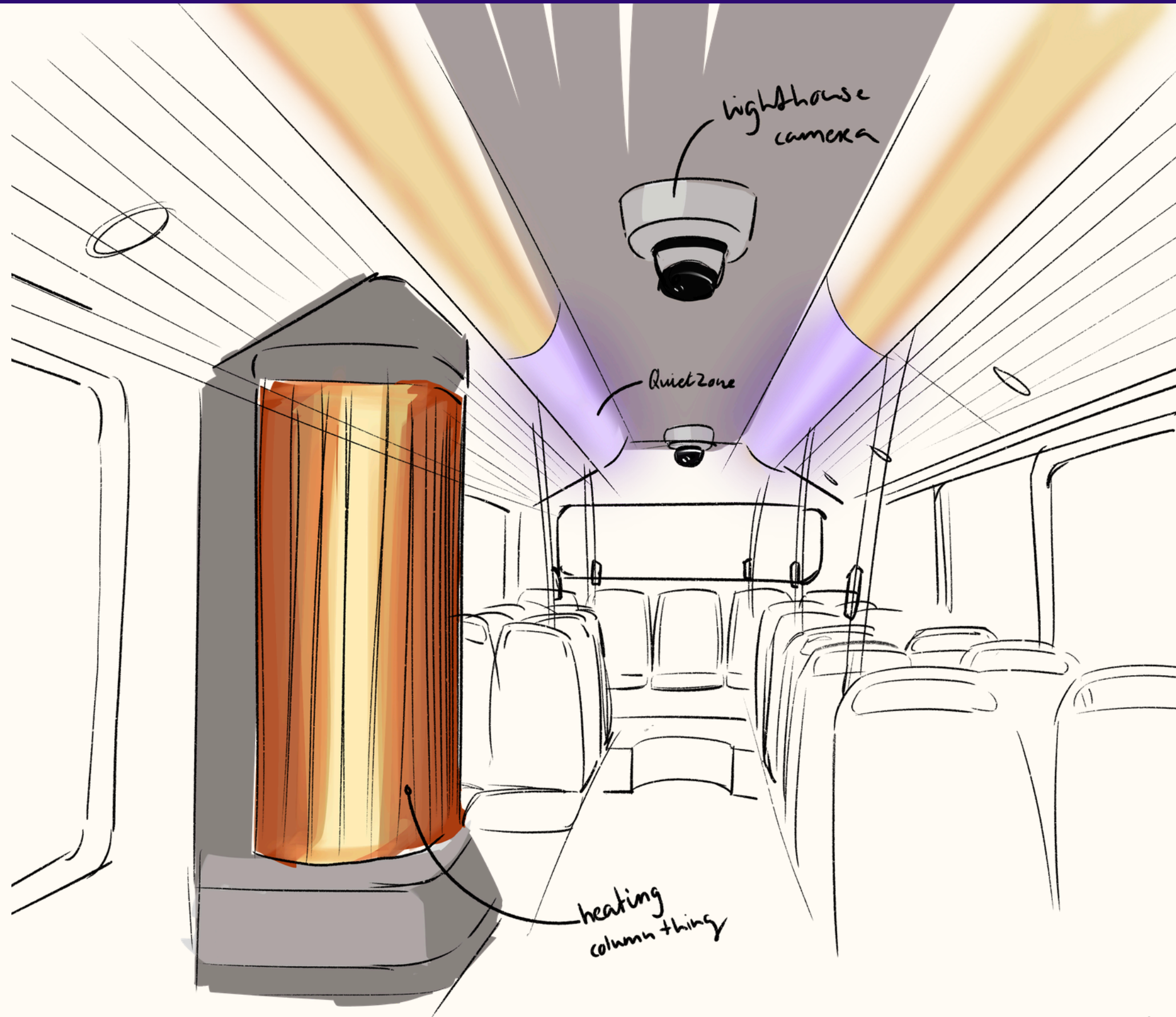


LIGHTHOUSE LOUNGE

Core idea (Q2): Lighthouse camera + panopticon

Supporting ideas (Q1): Emergency button at every seat, heating pillar, colored areas, physical stop indicator

Coherence logic: Everything revolves around "visible supervision". The lighthouse camera and panopticon are always watching, but the heating pillar softens this hard surveillance. The coloured zones give structure. The stop indicator gives route information. You know you are being seen, but it does not feel threatening.

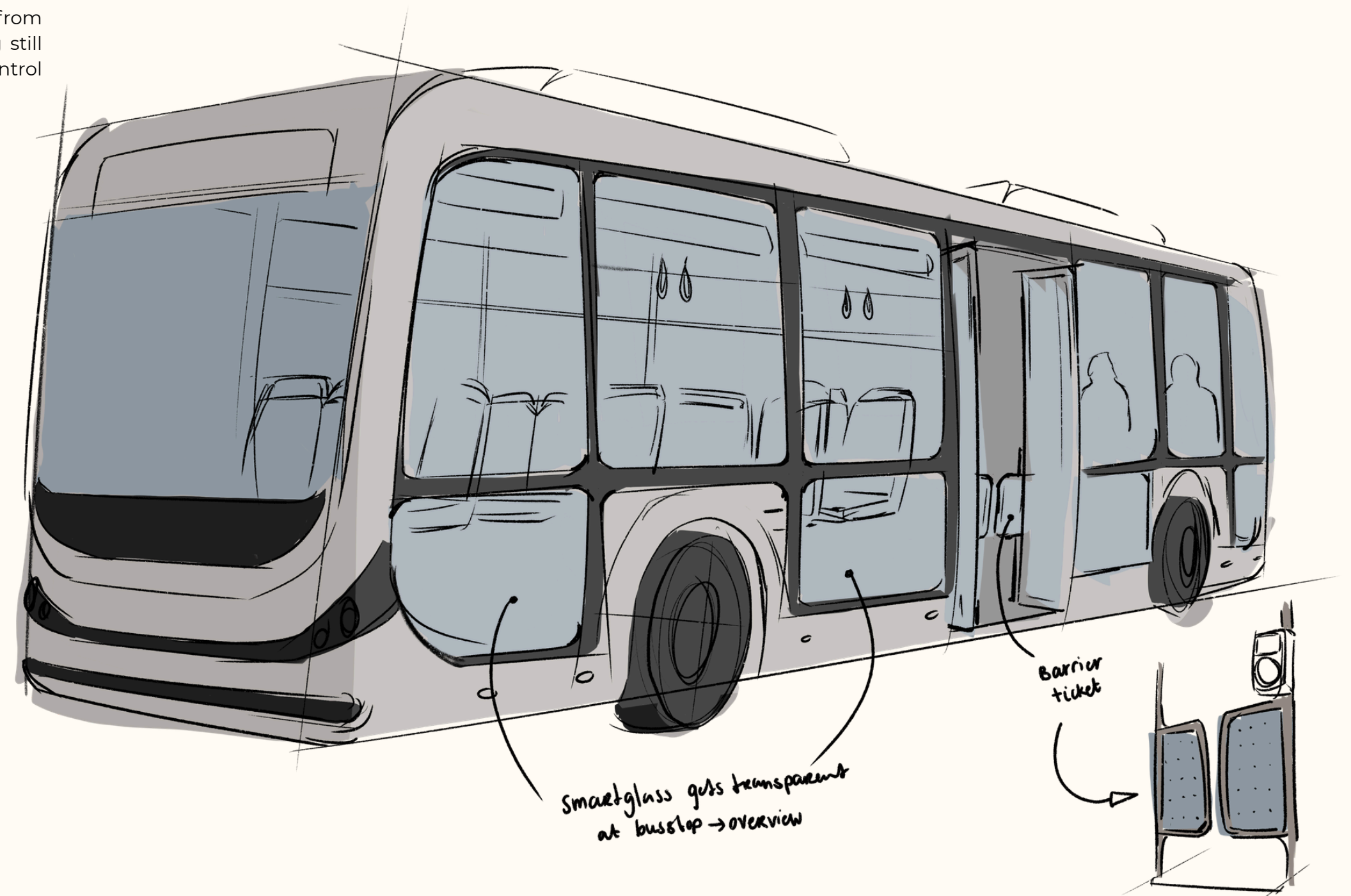


OPEN STOP

Core idea (Q2): Temporary transparent walls (smart glass)

Supporting ideas (Q1): Emergency button at every seat, live visual display of stops, barrier/gate

Coherence logic: Everything revolves around "control over who is around you". The barrier filters who enters. The transparent walls show who is inside (social control from outside). The emergency button is for when something still goes wrong. The live display shows where you are (control over your own journey).



SELECTION OF CONCEPTS FOR FURTHER DEVELOPMENT

After creating the six concept directions, each was tested against the sixteen requirements that were developed from the research (Figure 38). These requirements cover overview, control, social safety, accessibility, and feasibility. A concept that did not meet all requirements could not be considered a valid direction. Some concepts could be fixed by adding missing elements. Others had fundamental problems that could not be solved without changing the core of the concept.

Core Companion met all requirements. The concept is coherent and technically feasible. It was selected for further development.

Pulse Ride also met all requirements. The concept has a strong coherence logic (transparency) and all elements work well together. It was selected for further development.

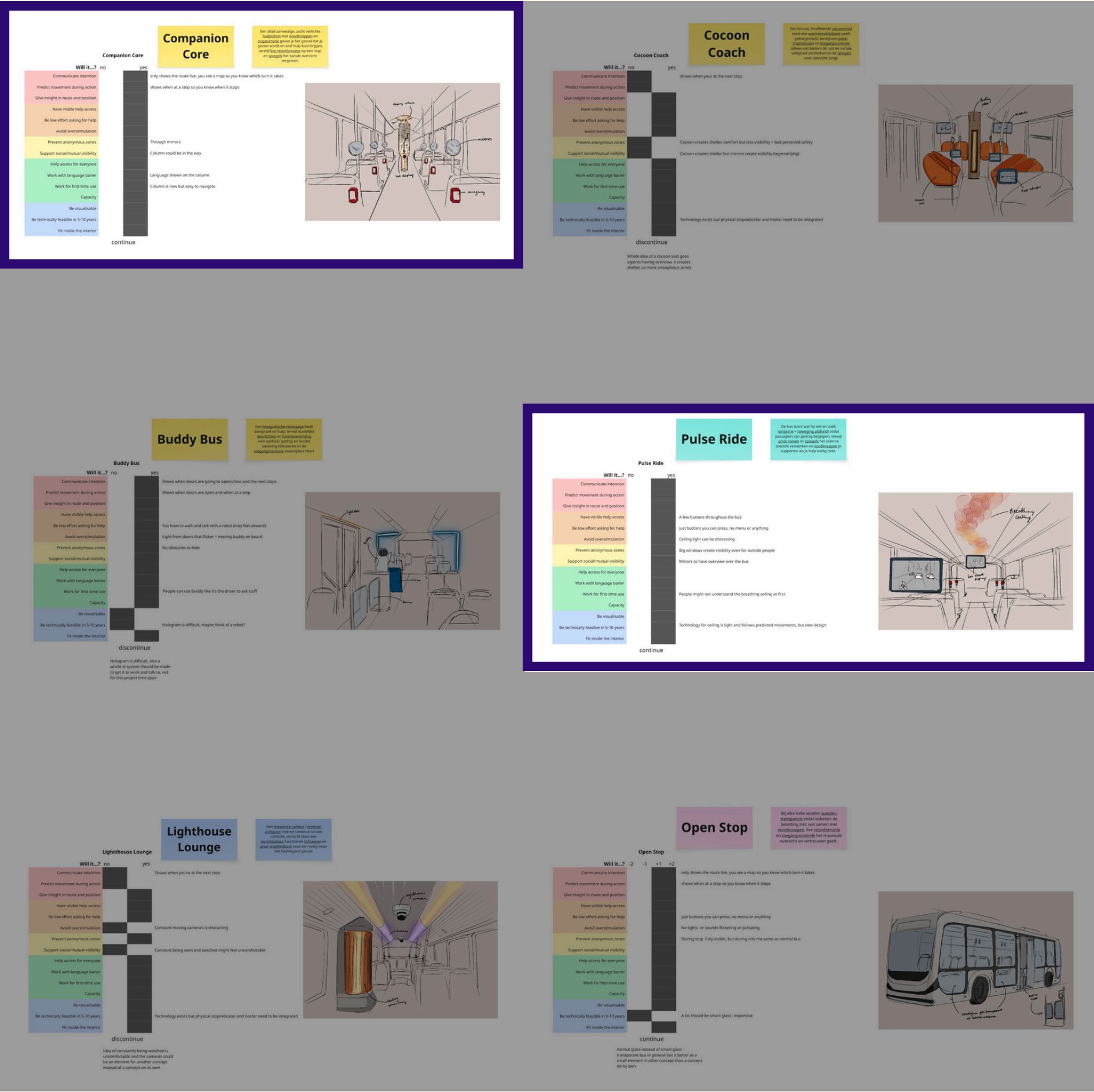
Open Stop did not meet all requirements. The smart glass walls only work at bus stops, not during the ride. This makes the concept incomplete. Also, smart glass over the entire bus wall is expensive and complex. If transparency is wanted during the whole ride, large windows are a simpler solution. This reduces the concept to elements that already exist in other concepts. Open Stop was therefore discontinued as a standalone concept, but its ideas (transparency, social control) are present in Pulse Ride.

Buddy Bus did not meet the feasibility requirements. Hologram technology is not yet mature and not realistic within 5-10 years. The concept also has accessibility problems: a speaking buddy does not work for deaf people or people with a language barrier. Also a whole AI algorithm should be developed to get this to work. The idea of a human or buddy on board could be implemented in later concepts as a feeling of safety so could be held in mind. The coherence logic is strong, but the execution is not yet possible. The concept was discontinued, but elements such as coloured zones and door lights may be added to other concepts later.

Will it...?	no	yes
Communicate intention		
Predict movement during action		
Give insight in route and position		
Have visible help access		
Be low effort asking for help		
Avoid overstimulation		
Prevent anonymous zones		
Support social/mutual visibility		
Help access for everyone		
Work with language barrier		
Work for first-time use		
Capacity		
Be visualisable		
Be technically feasible in 5-10 years		
Fit inside the interior		

dicontinue or **continue**

Figure 38: Sixteen requirements testing table



Cocoon Coach did not meet the social safety requirements. The cocoon blocks visibility, creating anonymous zones where passengers cannot see others and others cannot see them. This works against perceived safety. The coherence logic is strong (sheltered comfort), but the strategy is fundamentally unsuitable for a public transport environment. The concept was discontinued.

Lighthouse Lounge did not meet the control requirements. The concept offers only supervision, no help or explanation. Passengers need more than just being watched, they also need to know they can get help and understand what is happening. A bus that only watches feels like a prison, not a safe place. The concept was discontinued, but elements such as the panopticon may be added to other concepts later.

After this evaluation, two concepts remained: **Core Companion** and **Pulse Ride** (Figure 39). Both meet all requirements, have strong coherence, and address different aspects of perceived safety. Core Companion focuses on help and presence (Control & Support). Pulse Ride focuses on understanding and predictability (Overview & Comprehensibility). Together, they represent two complementary strategies.

The other concepts were not completely thrown away. Ideas that worked well in those concepts, such as coloured zones, door lights, and the panopticon were kept in mind for the next iteration phase. If Core Companion or Pulse Ride still have weak points, these elements may be added later.

The next chapter describes how the two selected concept directions were further developed.

Figure 39: The two concept directions that were most promising are highlighted

COMBINATION OF TWO CONCEPT IDEAS

After selecting the two most promising concept directions (Core Companion and Pulse Ride), both met all requirements. However, each concept had a different emphasis. Core Companion focused strongly on providing a point of contact and a sense of human presence. It directly addressed the "no contact" concern. Pulse Ride focused strongly on making bus behaviour transparent and predictable. It directly addressed the "uncertainty" concern. Both concepts already addressed both problems to some extent. Core Companion also gave route information, and Pulse Ride also had emergency buttons. However, each concept clearly prioritised one problem over the other. Core Companion was much stronger on help and presence. Pulse Ride was much stronger on transparency and predictability.

The survey showed that passengers worry about both problems. They want to understand what the bus is doing, and they want to know they can get help if something happens. Neither problem is more important than the other. Therefore, it would be a compromise to choose only one concept. Instead of choosing one, the two concepts were combined.

The result is a new concept that keeps the core of both directions:

- From Core Companion, the concept keeps the idea of a central, visible help point and the sense of human presence.
- From Pulse Ride, the concept keeps the breathing ceiling and the front screen that shows what the bus sees.

The other elements (windows, mirrors, emergency buttons) were already present in both concepts or are standard features that support the core ideas and other problems. They do not change the character of the concept.

The combined concept is called The Heartbeat Bus. Iterating sketches made to refine the design (See Figure 40 on the right). The name reflects the combination: a beating heart (presence, help) and a breathing rhythm (transparency, predictability).

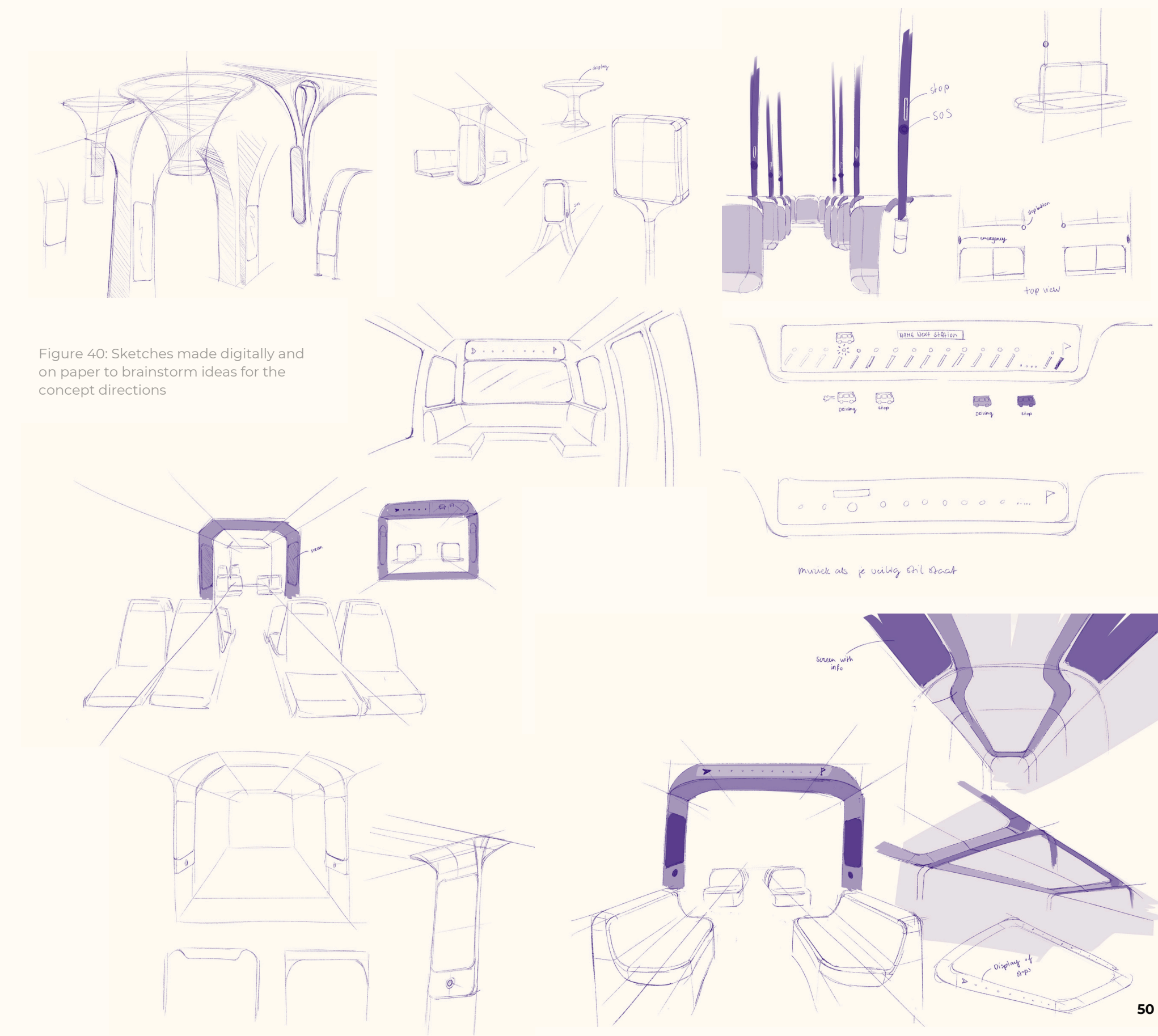
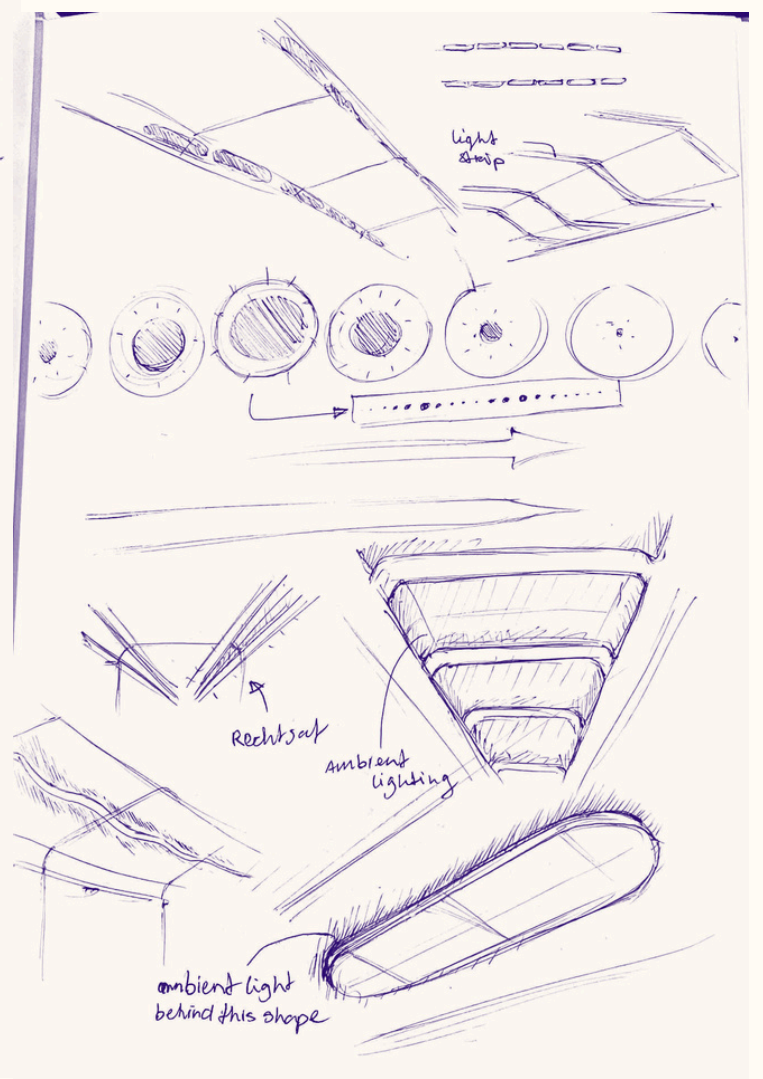
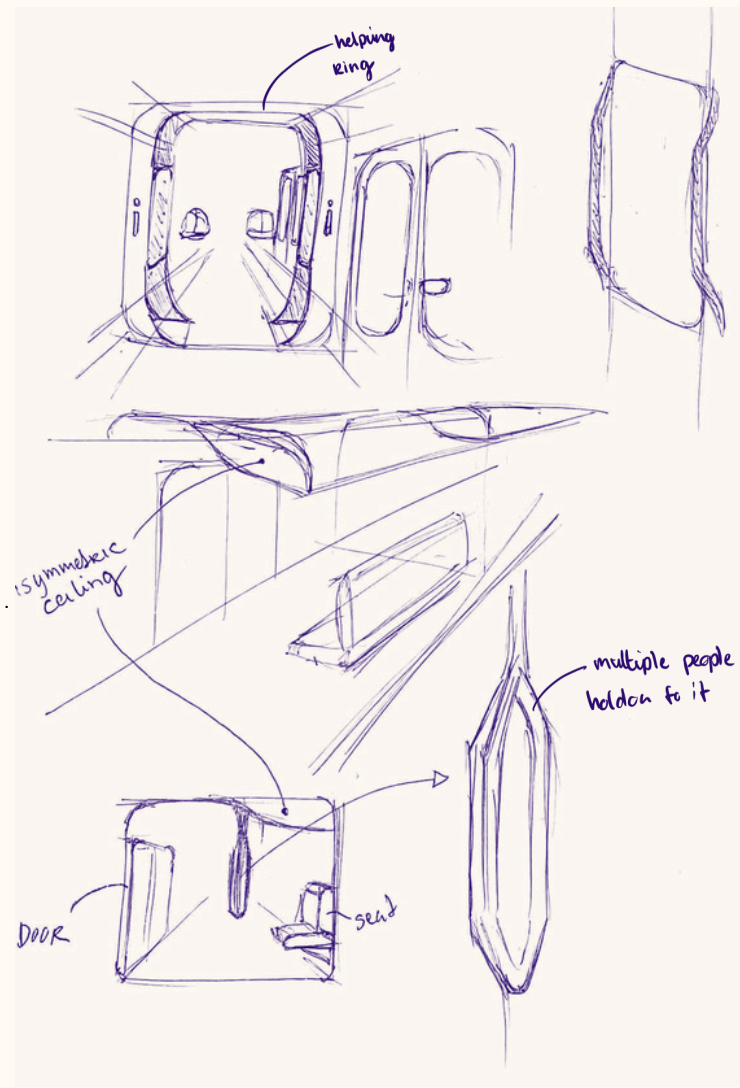
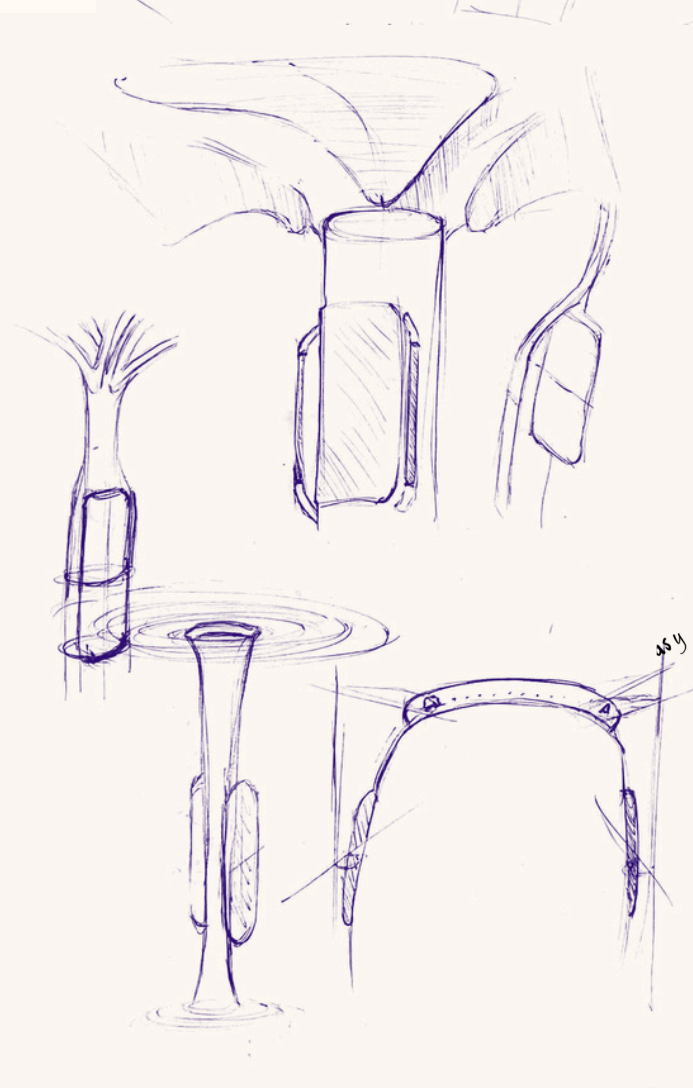
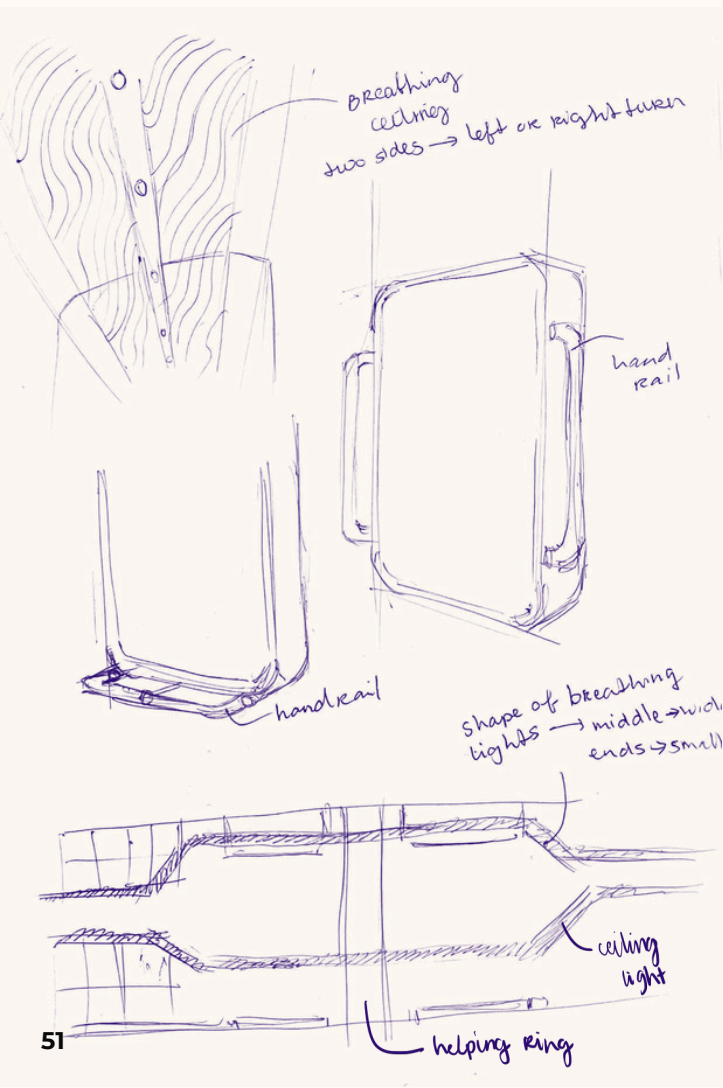
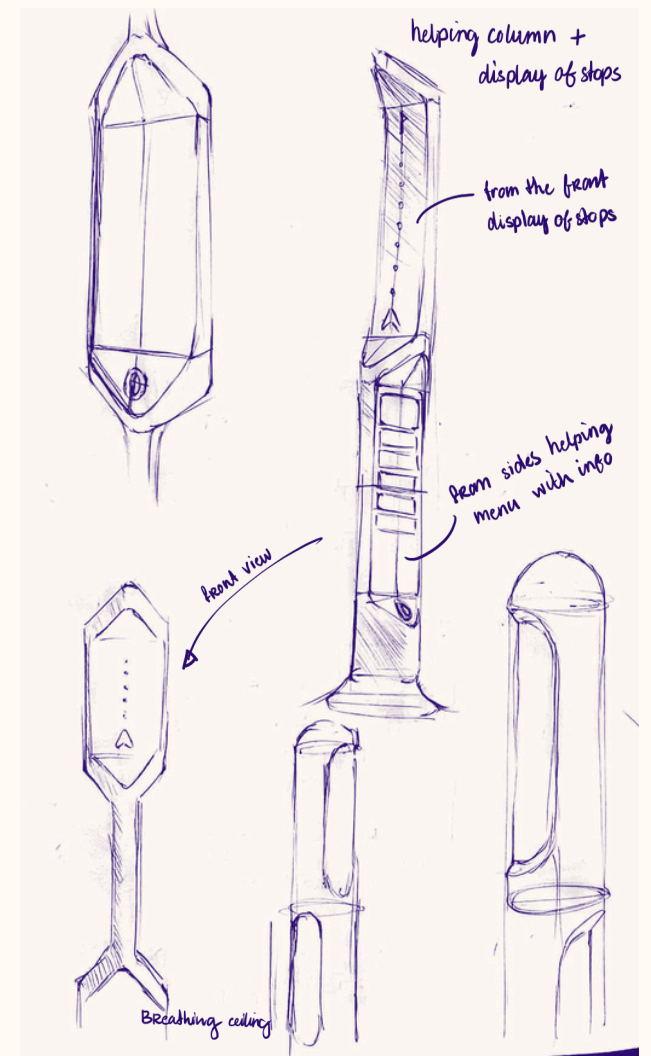
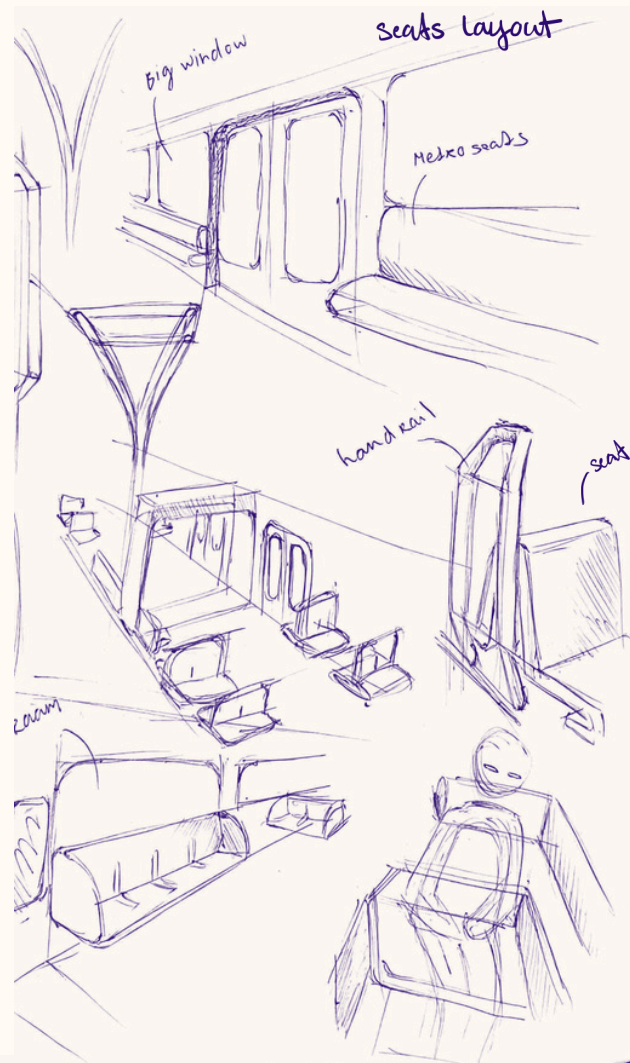
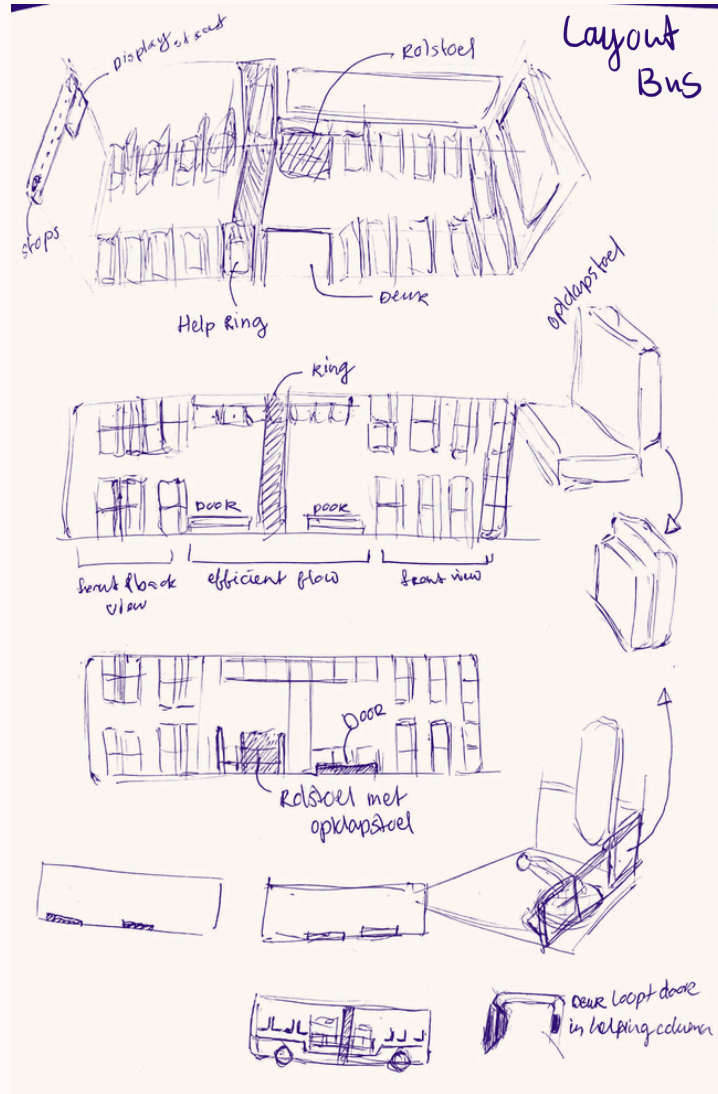


Figure 40: Sketches made digitally and on paper to brainstorm ideas for the concept directions



Validating the idea

FEEDBACK FORM OF THE IDEA

Before investing time in building a full prototype, a short survey was conducted to test whether the Heartbeat Bus concept would work in principle (see Appendix E for all answers). The goal was to validate the two main new elements (the help ring and the breathing ceiling) and to catch major misunderstandings or concerns early. The helping column changed to a ring to ensure visibility instead of a column blocking the view. For this survey a blender model was created with the necessary elements inspired by previous sketches from above.

METHOD

The survey was shared online and completed by 51 respondents. The group was mixed in age and gender, with the largest age groups being 18-24 and 45-64, and a fairly even split between men and women. Participants were shown images of the redesigned bus interior and a short explanation of all elements. They were then asked to rate several statements about the two new elements that need validation, which are the help ring and breathing ceiling, and to provide open feedback.

MODEL

For this model a Mercedes-Benz Citaro Blueprint (Figure 41) is used to get the exact measures of a standard 12 meter bus and to inspire the seat placements throughout the bus, however the Heartbeat bus has some alterations to increase overview and visibility inside the bus.

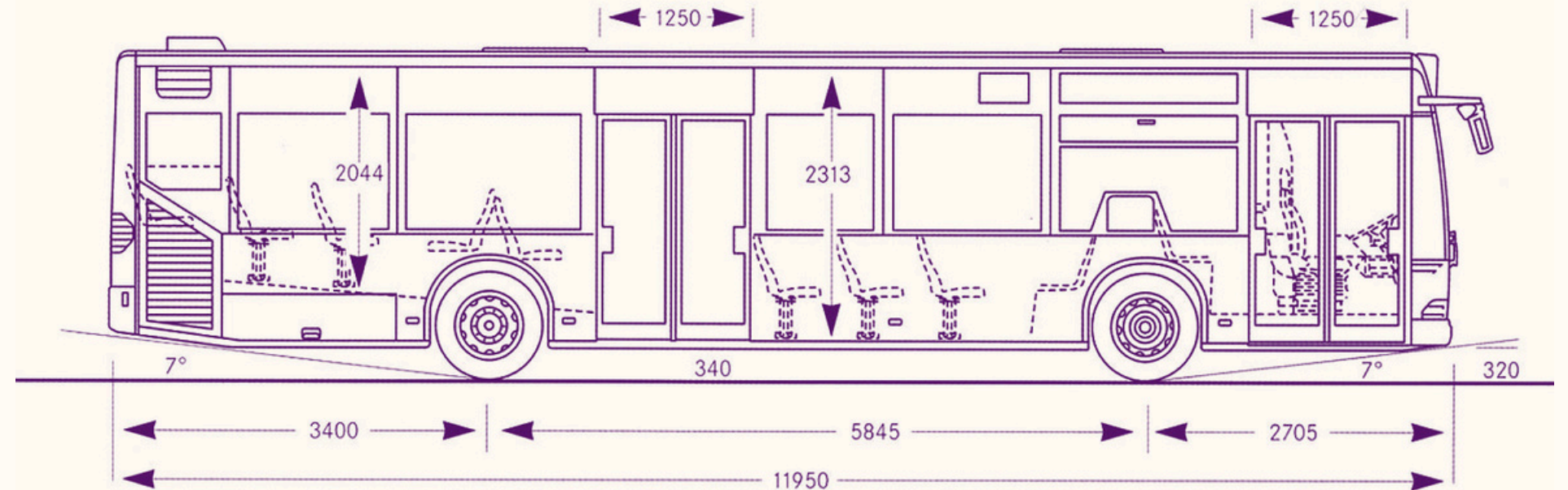
FIRST IMPRESSION

When asked "Compared to a normal autonomous bus (Figure 42), how safe does this redesigned bus feel to you?", the results were positive. **36 out of 51 respondents (71%)** felt the redesigned bus was better or much better than a normal autonomous bus. Only two respondents found it worse. This is a strong first indication that the concept works.

Respondents said things like:

"I feel like this bus would be much safer and nicer."

"I am quite excited for these things so I don't really feel insecure about its quality."



A. NORMAL BUS INTERIOR



B. REDESIGNED BUS INTERIOR

Figure 42: Figure made to use in the survey to compare the interior of a normal bus and the redesigned bus.

QUESTIONS ABOUT THE HELP RING



The help ring scored well on most questions (Figure x). However, several concerns were raised in the open feedback about different things described below.

6. Questions about the Help Ring (1 = strongly disagree, 5 = strongly agree)

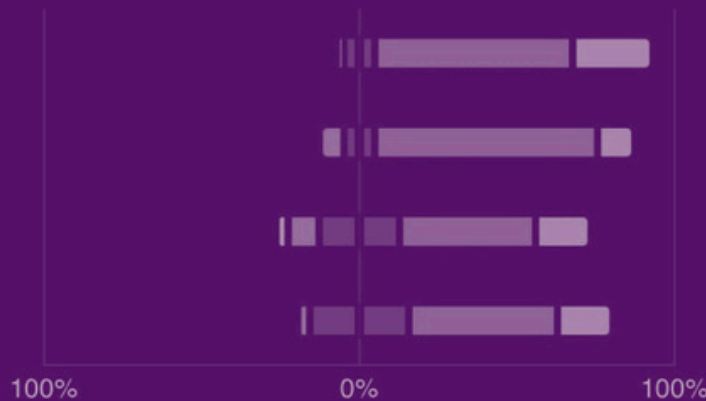
● Strongly disagree ● Disagree ● Neither agree nor disagree ● Agree ● Strongly agree

The ring helps me know where to find help if I need it.

The ring feels reassuring; I know I can get help

I like being able to ask questions via the screen (e.g. "Do I get off here?").

This element makes me feel safer in an autonomous bus than without it.



ACCESS IN A CROWDED BUS

"If the bus is very full, how can I ask for help?"

"I'm afraid it'll be very busy, so I would prefer a screen with the necessary information so I don't have questions."

"I would say perhaps not just one screen (maybe on opposite to it as well). When I want to ask questions promptly and the screen is occupied or the bus is really busy it might prevent me from using it."

TRUST IN TECHNOLOGY

"I just hope it can really help. I feel like often technology like this breaks or doesn't work properly."

"I think it's a good element that you thought of with the 'where do I get off?', because that would be something I would like to know. Like if I put in where I need to get out, it puts a timer for example with how long I still have to wait, and a reminder to start getting up."

PRIVACY CONCERNS

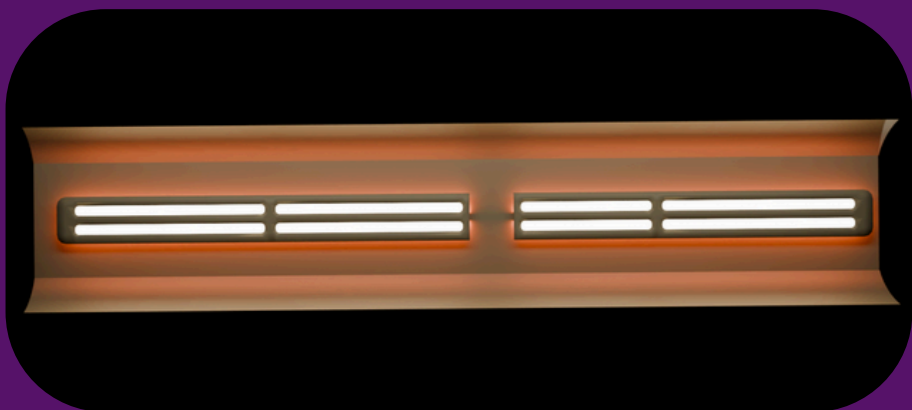
"I can imagine if you're a woman at night in a bus, you don't want everyone to know that you don't know where you are (if you ask for directions for example) or where you get off."

"The problem is with asking out loud, if you do not feel safe, you do not want your environment to know that you are insecure about where you are going and this way make yourself a possible target."

TARGET AUDIENCE FOR THE SCREEN

"I feel like the helpscreen should mainly be for people that are handicapped, children that don't have a smartphone yet or are very unsure about how to use the bus and elderly people. It should be designed with those groups in mind, as I think that the majority of normally abled people nowadays will just use their smartphones for information."

QUESTIONS ABOUT THE BREATHING CEILING



The breathing ceiling scored lower than the help ring, but still on the positive side with some comments you can see below.

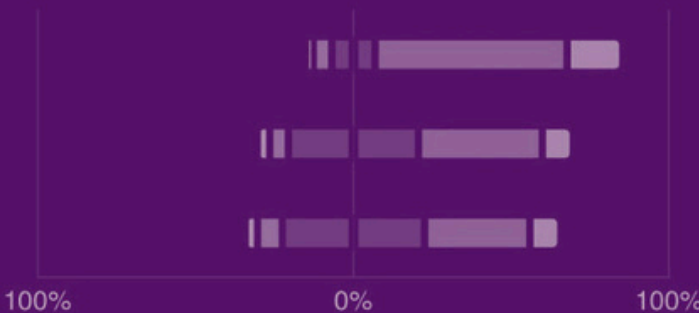
8. Questions about the Breathing ceiling (1 = strongly disagree, 5 = strongly agree)

● Strongly disagree ● Disagree ● Neither agree nor disagree ● Agree ● Strongly agree

The pulsing ceiling helps me understand what the bus will do (brake, drive).

The ceiling makes me feel calmer because I know what is coming.

This element makes me feel safer in an autonomous bus than without it.



MOTION SICKNESS AND OVERSTIMULATION

"Lijkt mij redelijk misselijk makend?"

"I am curious how this would work in my body. Like what if this makes me more distracted or overwhelmed or even nauseous?"

"If all the ceiling light is changing constantly and the light level with it it can be annoying (some flicking the light switch). Maybe less intrusive light / extra light / different coloring light?"

"The change in lighting in the bus would annoy me I think"

POSITIVE ABOUT MOTION SICKNESS

"I know the challenge of motion sickness is greatly related to the passenger's connection to the movement of a vehicle, so I really think that implementing a kind of visual stimulus like this is a must-have in an autonomous bus like yours!"

COGNITIVE LOAD

"This is too much cognitive states for me. A maximum of 3 states is easier to understand and makes it more intuitive."

LEARNABILITY OF THE LIGHT PATTERNS

"Is this going to be the same for every bus? Will it become common knowledge? How will I know what each type of light means?"

"Passengers might not know what the different lights means."

"I think I would need a video showing the exact effect or I need to experience it before being able to agree to this."

WHAT PEOPLE STILL NEED TO FEEL SAFE



The open question "What would still be needed for you to feel safe in this bus without any staff on board?" revealed several important themes.

SOCIAL CONTROL AND INTERVENTION

"Who is going to help when there are annoying passengers? For example if someone is smoking? Fare-dodgers? Harassment?"

"What if a crazy person loses it? Is there a way this person gets removed from the bus? Can there be 'bus safety guards' hopping on and off on buses to guard social safety?"

"With a chauffeur, it feels like people behave more polite/normal. What if someone misbehaves, is there an employee who can help?"

EMERGENCY RESPONSE

"Who can stop the bus? Can it be stopped remotely?"

"Emergency button if something bad happens on the bus like someone wants to steal or a person it will signal the police."

"Noodrem, hulp knoppen." ("Emergency brake, Help buttons")

PROOF AND TRACK RECORD

"Proof that the concept has been thoroughly tested and deemed safe by an authority."

"The positive statistics after a period of driving without a driver."

"I need to know the system has been tested quite a while."

HUMAN PRESENCE OR VOICE

"Perhaps the bus announcing itself with a friendly voice? So it still has something 'human' in it."

"In a way it should feel like that there is a person still supervising what's happening inside the bus. Maybe like in the metro with the screens that show what the cameras are filming. Maybe a real person speaking through the speakers every now and then if something is not right?"

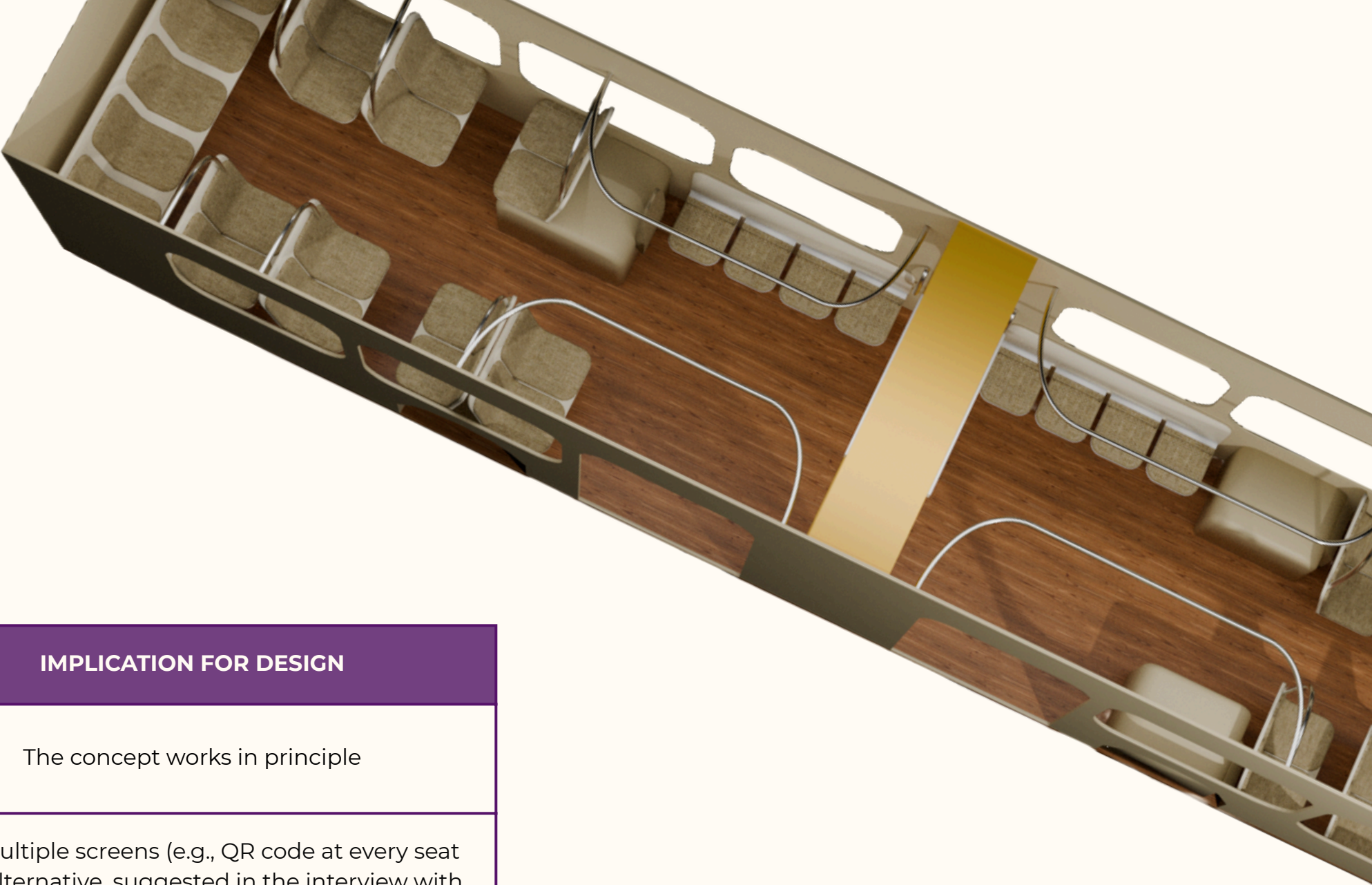
OTHER CONCERNS ABOUT THE INTERIOR

"In the render right now there's a big open space, which people would fall at if they walk there and the bus is driving. Normally a bus driver waits for someone to sit if it's an older person for example. Maybe this one won't do that."

"The seats look like they have very hard edges. When I am standing in the bus and it's moving, bumping into them seems not to be fun."

"Handles on the ceiling and sides of the chairs to grab onto seem crucial to me as well. To avoid strangers grabbing onto my chair/backrest when I'm seated."

"Maybe some rearview mirrors would be nice, to check what sketchy men behind me are up to."



KEY FINDING	IMPLICATION FOR DESIGN
71% of respondents felt the redesigned bus was better or much better	The concept works in principle
Concerns about reaching the ring in a crowded bus	Add multiple screens (e.g., QR code at every seat as an alternative, suggested in the interview with BYD on the next page)
Privacy concerns about asking questions out loud	Offer a quiet, text-based option (typing instead of speaking)
Mixed reactions to the breathing ceiling	Simplify the light patterns (maximum 3 states) and test before finalising
Need for social control and intervention	Clarify how misbehaviour is handled (e.g., connection to help centre, remote intervention)
Need for proof and track record	The design itself cannot provide this, but the bus operator can (e.g., test certificates, public reports)
Enough handrails and grab bars were missing	Add handrails for standing passengers so that people in middle of the bus won't fall

WHAT THIS MEANS FOR THE NEXT PHASE

The survey confirmed that the Heartbeat Bus concept is promising. However, the feedback also showed areas for improvement before building the next prototype:

- 1.Add multiple help access points (QR code at every seat or more screens) for crowded situations.
- 2.Add a quiet, text-based option for the help ring (typing instead of speaking) to address privacy concerns.
- 3.Simplify the breathing ceiling to a maximum of three clear states (brake, drive, turn) with gentle transitions.
- 4.Clarify emergency procedures (who can stop the bus, how police are alerted) in the concept description.
- 5.Add more handrails and grab bars in the renders for the next iteration, especially in the middle of the bus.

Feasibility

INTERVIEW WITH BYD

To assess whether the Heartbeat Bus concept is realistic to manufacture, an interview was conducted with an expert from BYD, a major electric bus manufacturer. The goal was to understand the technical feasibility of the help ring, the breathing ceiling, the front screen, and the overall concept within a 15-year timeframe. The questions asked can be found in the Appendix F.

HELP RING: REALISTIC, WITH MATERIAL CONSIDERATIONS

The expert confirmed that the help ring is realistic to build. However, he raised several practical points.

First, the floor part of the ring should be made of PVC flooring, not a separate plastic or fibreglass part (Figure 43 and Figure 44). PVC is durable and can be produced in different colours. A separate plastic part on the floor would wear out quickly. The ring can be created by using a different colour of the same PVC flooring material.

Second, the wall and ceiling parts of the ring can be made from aluminium extrusion, fibreglass, or recycled plastics. The expert recommended using sustainable materials because the help ring is the most attractive point of the bus. Recycled materials are becoming more common and would make the concept more appealing to operators.

Third, the sharp edges of the ring in the current renders need to be rounded. Bus interiors have strict safety requirements for radii to prevent passengers from injuring their heads. The ring should follow these requirements.

Fourth, the screen is mounted on the wall at a certain height that should be accessible for wheelchair users too. You could think of a mechanism behind the screen with adjustable heights. However, this will increase maintenance and production costs.

Finally, the expert noted that the ring can only serve a few people at a time (two to three). He suggested thinking about scenarios where more people need help simultaneously. One solution is adding QR codes at every seat, allowing passengers to access bus information on their own phones.



Figure 43: Wood vinyl floor inside a bus. (August Flooring, n.d.)

This is already used in China and reduces the need for multiple screens. The help ring then serves passengers who do not have a smartphone or prefer not to use one.

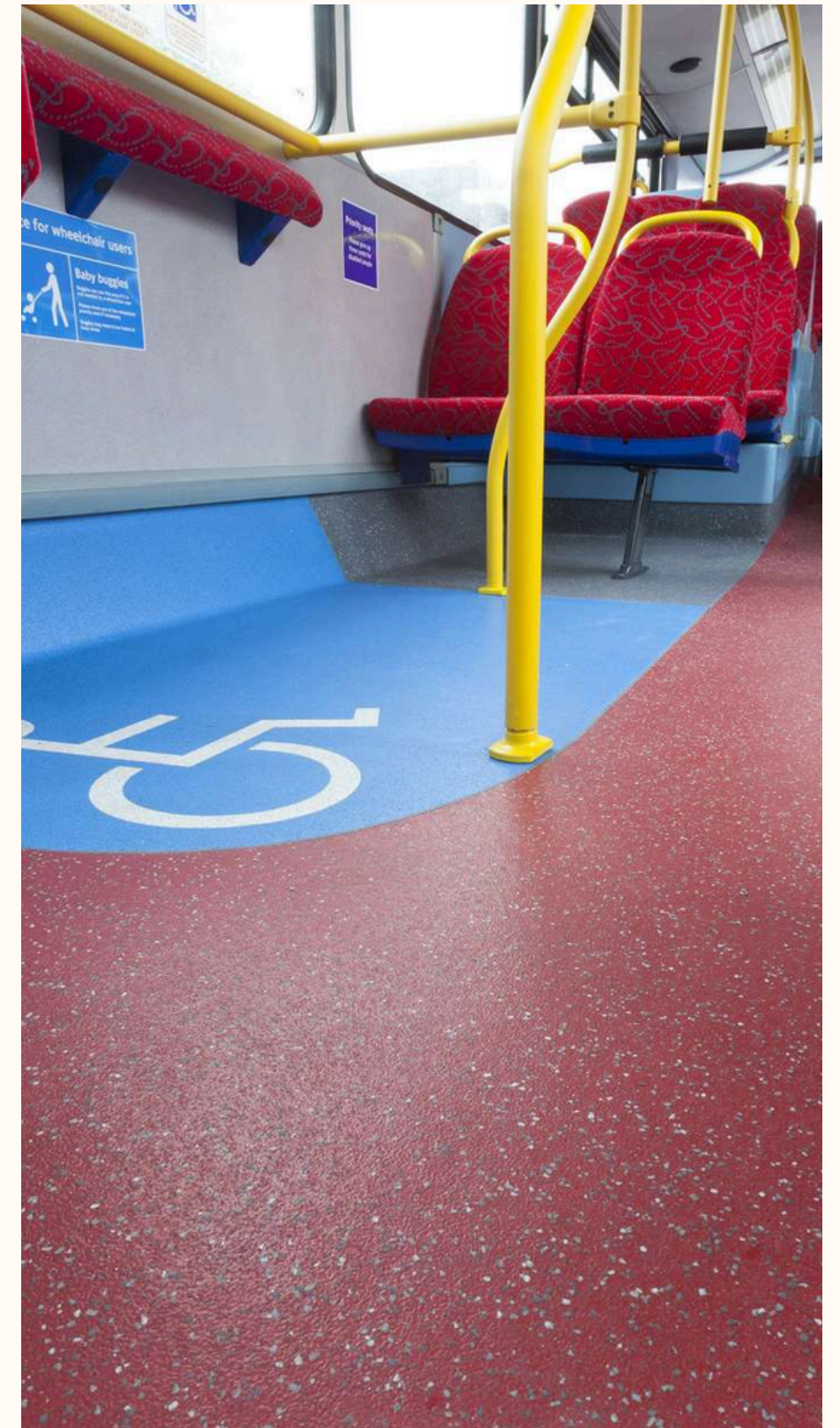


Figure 44: Vinyl floor inside a bus. (Altro, 2026)

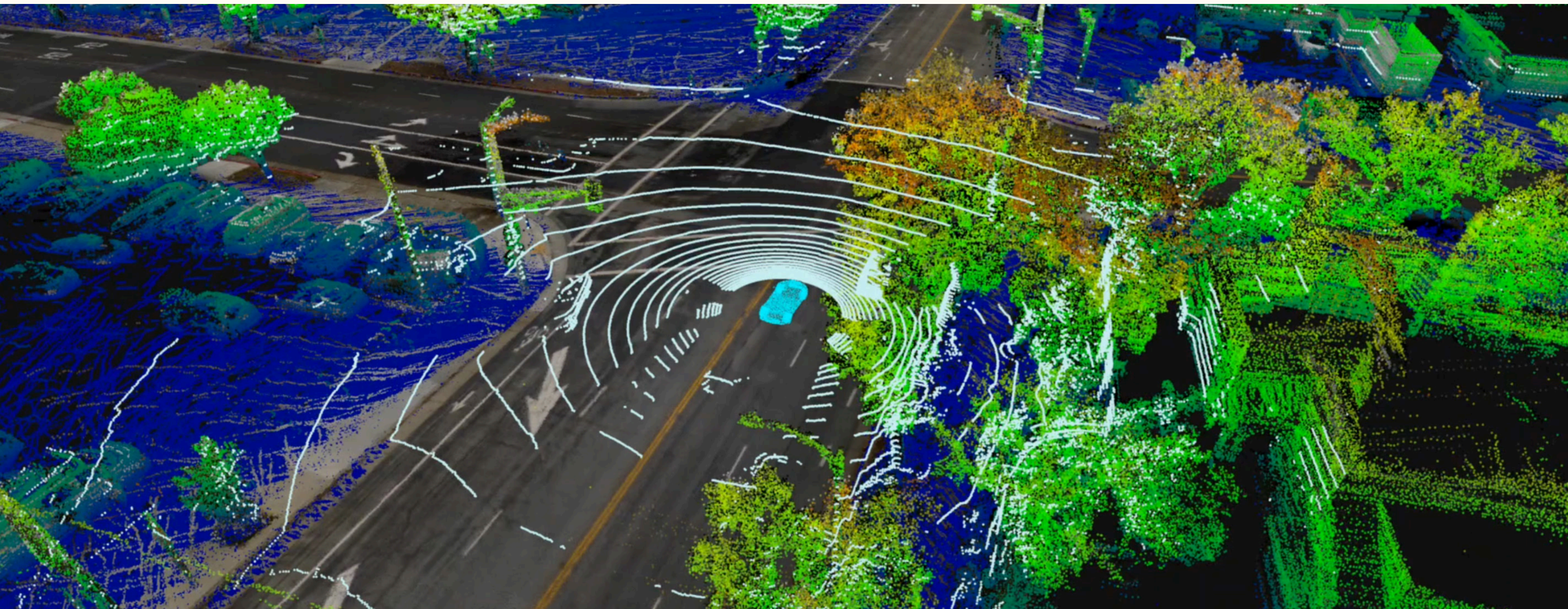


Figure 45: HD map visual mapping out the surroundings. (Geospatial World, 2019)

BREATHING CEILING: FEASIBLE BUT MUST BE SUBTLE

The breathing ceiling is technically feasible. The expert explained that autonomous driving systems already have signals about what the bus is doing (e.g., turning, braking, accelerating). These signals can be used to control the LED lighting.

However, he warned that the ceiling lights could become annoying if they are too frequent or too bright. Buses turn, brake, and accelerate often. Constant lighting changes could distract passengers. He advised making the pulses subtle and smooth, not flashing or abrupt. The lighting should be noticeable but not demanding attention.

The expert also clarified that showing a signal before the bus actually turns or brakes is possible using GPS and HD map data (Geospatial World, 2017) (Figure 45). The bus knows its route in advance, so it can trigger the light a few metres before a turn. However, showing a signal before an emergency brake is not possible because emergency stops happen unpredictably.

FRONT SCREEN: REALISTIC, BUT CONSIDER VISIBILITY FOR ALL PASSENGERS

The screen at the front showing what the bus sees is realistic. However, the expert noted that only passengers at the front can see it clearly. Passengers in the middle or back of a 12-metre bus would not see the screen well.

He suggested adding additional screens at different locations, or providing the same information via QR codes on passengers' own phones. Operators typically want all passengers to have access to at least one screen. The current design with only one front screen may not be sufficient for a full-length bus.

MOST EXPENSIVE OR DIFFICULT TO MAINTAIN

The expert identified two main cost drivers: scaling up for a fleet and spare parts inventory.

First, any extra part becomes expensive when multiplied across a fleet of 100 or more buses. Operators are sensitive to additional costs. The help ring, screens, and ceiling lighting all add cost compared to a standard bus interior.

Second, the help ring would require operators to keep spare parts in stock. If a ring is damaged, it must be replaced. The expert noted that if the design is modular and the parts are small, maintenance becomes cheaper. Large, integrated parts are more expensive to replace.

The expert also mentioned that vandalism is a problem. Passengers sometimes scratch or draw on interior parts. There is no perfect solution, but durable, easy-to-clean materials help.

OVERALL FEASIBILITY FOR A BUS IN 15 YEARS

The expert concluded that the concept is realistic for a bus in 15 years. He noted that all the discussed devices will be much more affordable by then, as long as they are made from recyclable materials.

The expert particularly liked the door layout with two doors in the middle, similar to a metro or train. He said many operators want to achieve this because it improves passenger flow. To have the best flow in the vehicle an opening with one sliding door is better than an opening that is opened using two doors. The only drawback is that it is physically more expensive to have large door than two small ones.

To create a more coherent overall design, design elements should be integrated and the form language should match throughout the whole bus. Just like the curves in the windows which repeat in the seats and screens as well.

WHAT THIS MEANS FOR THE NEXT PHASE

The interview confirmed that the Heartbeat Bus concept is technically feasible. The expert's suggestions will be incorporated into the next design iteration:

- Add **QR codes at every seat** to complement the help ring.
- **Round the edges** of the ring and other interior elements.
- Specify **PVC flooring** for the floor part of the ring.
- Use **subtle, smooth pulses** for the breathing ceiling (avoid flashing).
- Consider **screen height** for wheelchair users.
- **Integrate design elements** more (e.g., combine the stop display with the ring shape).

These changes will make the concept more realistic for manufacturers and more attractive to operators, while keeping the core ideas (help ring, breathing ceiling, front screen) intact. How the elements are produced and what choices are made in case of modularity are kept in mind but are not the focus of this project. The design choices are therefore mostly based on accomplishing the goal of this project: to support perceived safety in buses.

Colour selection

FORM ABOUT COLOURS AND MATERIALS

The colours and materials used in a bus interior can influence how passengers feel. Research shows that colour has a direct impact on human emotions, behaviour, and cognition, and that different colours can trigger different emotional responses (Zhang et al., 2022). Warm colours can create a sense of comfort, while cool colours can feel clean but sometimes clinical. To determine which colour palette would make passengers feel safest, a short survey was conducted.

Survey method

Three versions of the same bus interior were created. The layout, the help ring, and all design elements were exactly the same. Only the colours and the floor texture were different. The three options were:

All floors were vinyl, which is standard for buses because it is durable, anti-slip, and easy to clean. Only the colour and texture were changed. The survey was completed by 79 respondents. They were asked three questions:

1. Which bus would make you feel safest?
2. Why does that bus feel safest to you?
3. Which specific colours or textures from any of the buses should be included in the final design?

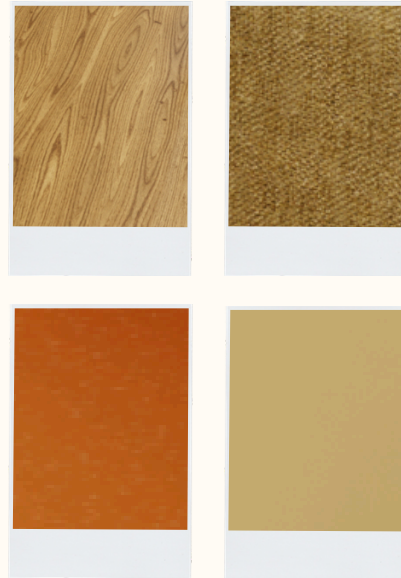
All answers can be found in Appendix G.

RATIONALE FOR THE THREE COLOUR OPTIONS

The three colour options were developed based on existing research on colour psychology in transport and public interiors.

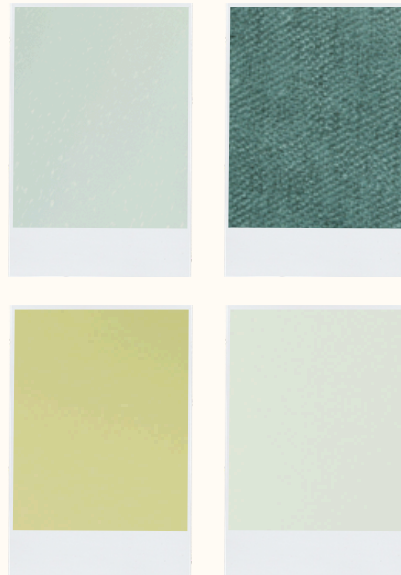


Figure 46: The three colorschemes made for the Heartbeat bus.



Bus A – Warm, home-like (orange/yellow, brown, wood-look)

Warm colours like orange and yellow are known to attract attention and signal caution without urgency (Science Insights Team, 2026). Research on visual comfort found that orange and yellow hues produce energetic but approachable visual perception and is tied to communication (Science Insights Team, 2026). The wood-look floor was included because research confirms that interiors with exposed wood can positively affect sensory perception and reduce anxiety (Ojala et al., 2023).



Bus B – Cool, clean (light blue, light yellow, blue-grey)

Cool colours like blue are often associated with calmness and relaxation (Desk, 2026). Research on aircraft interiors by Boeing has shown that blue and green tones tend to lower visual stress and are widely linked to peace across many cultures (Desk, 2026). However, studies on healthcare, which are associated with sterile and clinical environments, have also found that cool colours can cause calmness and trust, reducing anxiety in patients (Ryan, 2026).



Bus C – Natural, balanced (cream, dark green, light brown)

Green is associated with nature, calmness, and grounding. Studies have shown that green lighting can evoke positive psychological responses (Desk, 2026). Research on visual comfort found that green hues produce comfortable visual perception (Desk, 2026).

Figure x: All three colorschemes with color and material swatches..



Figure 47: Answers to the question "In which bus would you feel safest?"

Bus A was the clear winner. Almost half of the respondents (46%) chose the warm, home-like bus as the safest. Bus C came second with 33%. Bus B was the least popular, with only 11% of respondents choosing it (Figure 47).

WHAT RESPONDENTS SAID

The open answers explained why people chose a specific bus.

Respondents who chose **Bus A** said:

- "Warm colours feel like an embrace."
- "It feels like a living room, like home."
- "The wooden floor feels warm and safe."
- "The blue one feels like a hospital or dentist."

Respondents who chose **Bus C** said:

- "Green is calming, like nature."
- "It is a good mix between warm and clean."
- "The earthy tones feel safe, like being in a forest."

Respondents who chose **Bus B** said:

- "It looks clean and bright."
- "The light colours make the bus feel more spacious."
- "It has a clinical atmosphere"

WHAT WILL BE TAKEN INTO THE FINAL DESIGN

Based on the survey results and the supporting research, the final design will combine the strongest elements from the most popular buses.

The following elements from Bus A will be kept:

- Warm colour palette (beige, cream, warm orange/yellow)
- Wood-look vinyl floor
- Warm lighting

The following elements from Bus C will be used as accent colours:

- Green accents (for a calming effect, but not as the main colour)
- The balance between "cosy" and "clean"

What will not be used:

- Bus B's blue tones (these were seen as too clinical)
- Cold, hospital-like environments
- Overly dark or old-fashioned looks

The final colour palette will therefore be:

- Warm base: cream/beige walls, warm lighting
- Wood floor: wood-look vinyl for a home-like feeling
- Warm accents: orange/yellow for the help ring to attract
- Small green accents: for a calming, natural touch

This combination responds to the two strongest desires from the survey: a home-like, warm feeling (Bus A) and a calm, modern feel (Bus C). The clean, clinical feel of Bus B will be avoided. The result should be a bus that feels welcoming, safe, and not like a hospital or a cold, high-tech space.



Final colour palette

Full concept test

FORM ABOUT FINAL DESIGN

To validate whether the Heartbeat Bus concept actually works, a final test was conducted. All answers can be found in Appendix H. The goal was to measure how passengers experience the complete concept together with every individual element. The test examined whether participants understood the different design elements and whether these elements contributed to their feeling of safety.

The test used a 360° photo and different render of the redesigned bus interior. Participants could view the bus on their phone by moving the device around, giving them a realistic sense of the space. A photo of a normal bus (without the redesign) was shown as a baseline for comparison. After viewing both buses, participants answered a questionnaire about their understanding and perceived safety.

TEST DESIGN

The questionnaire measured several aspects. First, it asked about the overall safety perception of both the normal bus and the redesigned bus. Then, it asked about each individual element: the help ring, the breathing ceiling, the front screen (what the bus sees), the QR code, the emergency buttons, the silent alarm, the mirrors and cameras, and the door light.

Each element was evaluated on two levels: understanding (does the participant know what it does?) and contribution to safety (does it make them feel safer?). Finally, participants answered open-ended questions about which element they found most convincing, which they understood the least, and what they would change.

The test was completed by 24 participants. The group was mixed in age and gender, with a slight majority of participants aged 45 and older. This is a relevant demographic for autonomous buses, as older passengers are often less familiar with new technologies and therefore a critical test group.



OVERALL IMPRESSION

When asked how safe they would feel in a normal autonomous bus without any design changes, the average score was 2.9 out of 5 (Figure 48). This confirms the earlier survey finding that passengers do not feel very safe in a driverless bus without additional measures.

When asked to compare the redesigned Heartbeat Bus to the normal bus, participants rated it significantly higher. The average score was 3.9 out of 5 (Figure 49). The majority of participants felt the redesigned bus was "much safer" or "safer" than the normal autonomous bus.

Several participants commented on the open, inviting atmosphere of the new design. One participant noted: "The open characteristics of the design is very comforting." Another said: "It has a much more 'inviting' feel, which really influences the atmosphere of the bus!"

UNDERSTANDING AND CONTRIBUTION OF EACH ELEMENT

All elements scored well on both understanding and contribution to safety. Scores were generally around 4 out of 5, indicating that participants understood the elements and felt they contributed to a safer experience. Some participants had specific comments about certain elements, which are discussed in more detail below.

NORMAL BUS INTERIOR

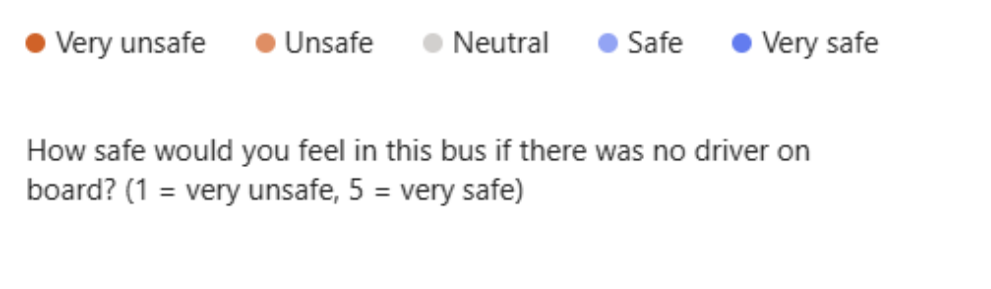


Figure 48: Answers to the question "How safe would you feel in this bus if there was no driver on board?"

NEW REDESIGNED BUS INTERIOR

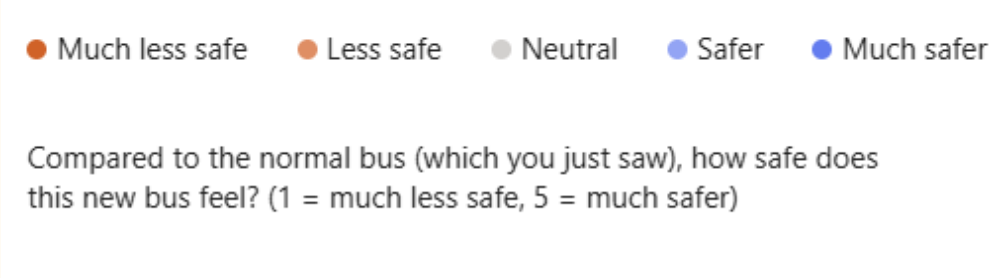


Figure 49: Answers to the question "Compared to the normal bus, how safe does this new bus feel?"



HELP RING

The help ring scored highly on both understanding and safety. Participants appreciated its central location: "It's nice it's in the centre of the bus, easy to find."

One participant asked: "Is it also accessible for people with disabilities?" This is a valid concern. The help ring is designed to be accessible for wheelchair users. The screen is large and positioned at a height that is reachable from both standing and seated positions. Also, blind people could use the ring by pressing the button to speak to a help centre and get their questions answered. Additionally, a wheelchair icon will be added on the screen that allows users to move all menu items to the lower half of the screen, making them easily accessible. This ensures that the ring works for everyone, regardless of disability.



BREATHING CEILING

The breathing ceiling scored well, with some participants calling it the most convincing element: "The breathing ceiling gives a direct sense of what the bus will do. It makes you feel like you can trust the bus more, also you can predict the motion of the bus more, and thus might reduce motion sickness."

Some participants raised concerns about having to look up to see the ceiling. However, the light is visible without actively looking up. The subtle glow is designed to be noticed subtly, so passengers can be aware of it without straining their neck or constantly staring at the ceiling. It is also not overstimulating or distracting, as the pulses are slow and gentle. Passengers who do not wish to pay attention to it can simply ignore it, as the light is subtle enough not to demand attention.



FRONT SCREEN (WHAT THE BUS SEES)

The front screen scored well on understanding and safety. Participants felt it improved trust: "Knowing what the bus is processing (e.g., whether it recognizes cars or pedestrians) improves trust that it can react in time and properly."

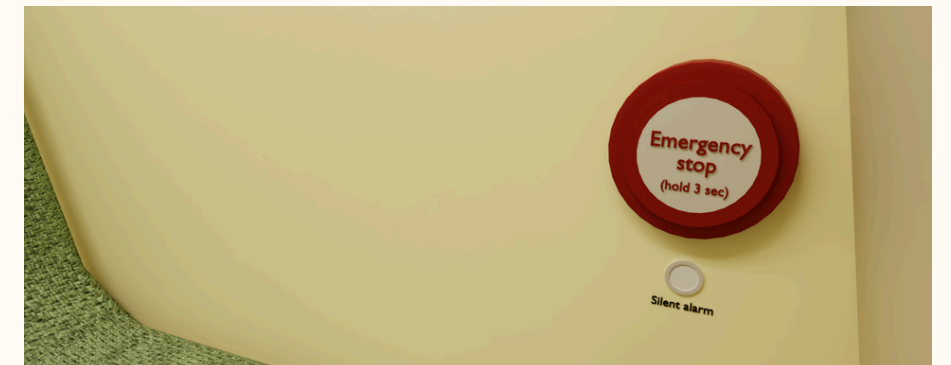
Some participants found the object detection confusing: "I can imagine it can be distracting and confusing for other people. What do these squares around objects mean?" A short explanation near the screen or an introductory sign can clarify that the squares indicate what the bus has detected and is responding to. This is a simple addition that can be made without changing the design itself. On top of that, it is normal that new things need some time to adapt to. This means that people might need time to understand what the screen shows.



QR CODE

The QR code was appreciated as a backup option: "Daardoor voel je je zelfverzekerd waar je moet uitstappen en hoeveel haltes/hoe lang het nog duurt" ("This makes you feel confident about where to get off and how many stops/how long it will take").

Some participants expressed privacy concerns or said they would not use it: "I never scan public QR codes (cybersecurity risk for spoofing and rerouting to malicious websites)." This is a legitimate concern. Even though the QR code is part of the bus and is made sure of its safety, the QR code is an optional feature, intended as an alternative when the bus is crowded or when passengers prefer to use their own phone. It is not a mandatory element. The bus already has multiple other ways to get information and help, so passengers who do not trust QR codes can simply use the ring screens or the help button.



EMERGENCY BUTTON

The emergency button scored highest on safety contribution. Participants recognised the value of having help available from every seat: "It feels safe when there is an emergency button next to me."

One participant noted: "I think there being an emergency button at every seat would be nice, but I also think that 1 press is enough to trigger it might end up causing either bad actors abusing the button or people pressing it by accident." To prevent misuse, the emergency button will be equipped with a seal, similar to emergency buttons in trains. Breaking the seal is required before the button can be activated, making it clear that pressing it is a serious action. This discourages accidental or malicious use while still allowing quick access in real emergencies.



SILENT ALARM

The silent alarm was appreciated for offering a discreet way to call for help: "It's great to have a silent button option."

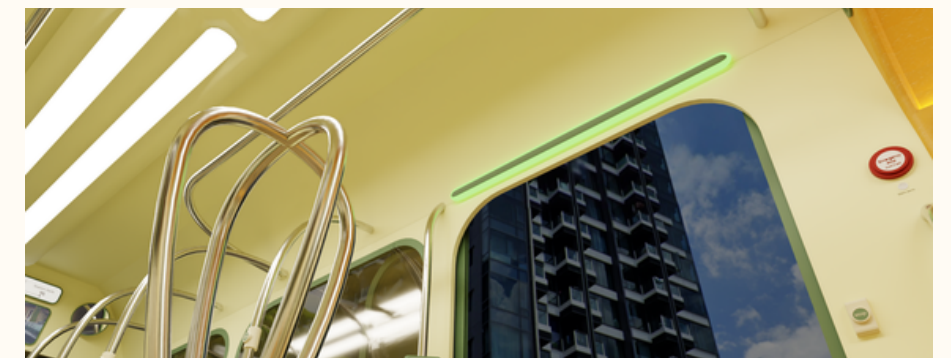
Some participants raised concerns about how to use it: "It's not clear for me however whether I have to press that one for 3 seconds too to activate its functionality." A clearer label can be added, such as: "Press if you feel unsafe, help will be on their way" One participant suggested: "You'd have a circle LED around the button that lights up as you press it to show the progress of the 3 seconds." Something that show feedback when pressing is a good suggestion. The silent alarm will therefore provide tactile feedback upon pressing, so the user knows it has been activated without anyone else noticing.



MIRRORS AND CAMERAS

The mirrors and cameras were seen as useful for overview: "It is good to see the other passengers." However, some participants expressed concerns about feeling watched: "Why also cameras? That gives me the feeling that we are followed everywhere, but not a safer feeling."

While this feedback is noted, the cameras are kept because research has shown that visible cameras deter antisocial behaviour. When passengers know they are being recorded, they are less likely to misbehave. The cameras, combined with the mirrors, provide both social control and personal overview.



DOOR LIGHT

The door light was appreciated for its clarity. One participant asked: "How about the blind person? How can they recognize when the door opens or closes?" To address this, an audio signal will be added to the door. A soft beep will indicate that the door is opening and a repeating beep will show the door is closing and you shouldn't board anymore just like traindoors do, so visually impaired passengers can also understand the door's status.

FINAL QUESTIONS

When asked whether they would feel comfortable using this bus without a driver, **20 out of 24 participants (83%) answered "Yes"** (Figure 50). This is a strong indication that the concept works.

The most convincing element according to participants was the breathing ceiling, followed by the help ring and the front screen. One participant said: "De schermen die laten zien wat een denkbeeldige chauffeur zou zien. De wand in het midden met informatie, maar vooral ook de overzichtelijkheid in de bus" ("The screens showing what an imaginary driver would see. The wall in the middle with information, but especially the overview in the bus").

When asked which element they understood the least, the front screen and breathing ceiling were mentioned often. This suggests that the breathing ceiling may need clearer introductory information for first-time users, and that the front screen could benefit from a simple explanation.

When asked what they would change to feel even safer, participants suggested: providing clearer information about the silent alarm, adding music or calming sounds, and ensuring multilingual support.

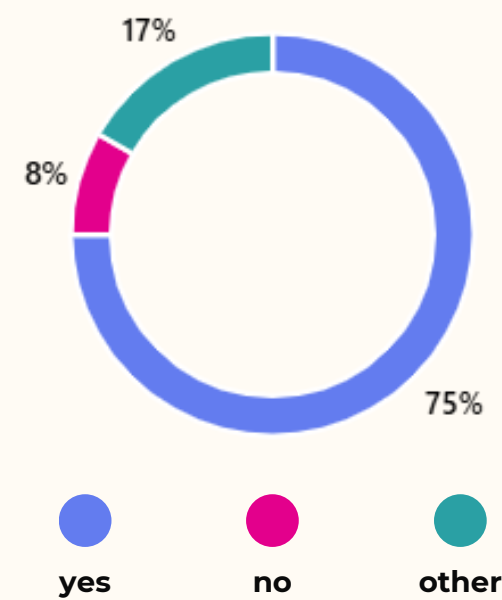


Figure 50: Answers to if people would feel comfortable using this bus?

WHAT THIS MEANS FOR THE DESIGN

The test confirmed that the Heartbeat Bus concept works. Participants understood most elements and felt significantly safer in the redesigned bus compared to a normal autonomous bus.

The changes on the right will be implemented based on the feedback.

The test results confirm that the Heartbeat Bus successfully addresses the three core problems: support (help ring, emergency button, silent alarm), social safety (open layout, mirrors, cameras), and uncertainty (breathing ceiling, front screen, door light). The high acceptance rate (83%) shows that passengers are willing to use this bus, even without a driver.

Element	Change	Reason
Silent alarm	Add clearer label and feedback when pressing	To make the usage clear and provide visual feedback
Emergency button	Add a seal that must be broken before activation, similar to train emergency buttons	To prevent misuse or accidental pressing
Door light	Add a soft audio signal for blind passengers	To make the door status accessible to visually impaired passengers
Help ring	Ensure wheelchair accessibility (menu items can be moved to lower half of screen) and multilingual options	To make the ring usable for everyone
Breathing ceiling	Keep as designed; the light is noticable without looking up and is not overstimulating and already has simple signals	The design is already subtle and does not require active attention
Cameras	Keep as designed; research shows visible cameras deter antisocial behaviour	The safety benefit outweighs concerns about being watched

The Heartbeat bus

CONCEPT EXPLANATION

The Heartbeat Bus is not a random collection of separate gadgets. It is one integrated system built around two core elements: the help ring and the breathing ceiling. All other elements (windows, mirrors, camera screens, emergency buttons, QR codes) are either existing bus features or simple additions that support the two core ideas. They do not add complexity; they complete the experience.

Think of the bus as a living body. The help ring is the heart; warm, central, always present. The breathing ceiling is the breath; showing that the bus is alive and predictable. The front screen is the eyes; showing what the bus sees. The windows and mirrors are the skin; making the bus transparent and open. The emergency buttons are the reflex; immediate action when needed.

Just like a body, all parts work together. You cannot point to one part and say "this is the body". The body is the whole. The same is true for the Heartbeat Bus. The ring and ceiling give the bus its character. The other elements support them without taking over. The result is a calm, predictable, and safe environment, not because of many features, but because everything works as one.

Next the different elements will be explained in more detail.





THE HELP RING

The help ring is a warm-coloured band that wraps around the entire cross-section of the bus in the middle, exactly between the two centrally placed doors. This central position is chosen intentionally: passengers stepping in through either door can see the ring immediately. The ring serves as the visual and functional heart of the bus. The ring has several functions, combining proactive information, simple touch controls, personal help, and smartphone integration.

1. Route information

The narrow screen at the top of the ring on both sides shows the following stops on the route, with the current stop made bigger and has a bus icon (Figure 55). The passengers can always see the final destination of the bus. A similar display at the front and back of the bus provides the same information for passengers not near the ring. Just like current busses, every stop will be announced through speaker, so deaf people also know where they are.

2. Quick questions via simple menu

The two vertical screens offer a simple menu with three standard categories where questions can be answered with two taps. The categories show information about three topics about frequently asked questions; “Destinations + times”, “Transfers”, “Emergency/ help guide”. At the top of this screen, the final destination and next stop is always displayed for extra confirmation. See Figures 51-54 for the possible screen interfaces.

3. Personal help (physical button)

A large physical button on the ring connects directly to a human-staffed help centre for emergencies or for passengers who have other questions or prefer to talk to someone. No typing, no menus, just press and speak.

4. Smartphone option (QR code at every seat)

For passengers who prefer to use their own phone, a QR code at every seat opens a webpage with live bus information and also the option to ask questions just like the help ring. This option works for people comfortable with smartphones, while the ring works for those who are not. It is also an option in case the bus is crowded.

5. Accessibility

The screens on the help ring are designed to be accessible for everyone. For wheelchair users, a wheelchair icon on the screen allows all menu items to move to the lower half of the screen, making them easy to reach from a seated position. No physical adjustment of the screen is needed. The reach distance for wheelchair users should be between 900mm and 1200mm from the ground (Haug & Bouw Advies Toegankelijkheid, z.d.). For passengers who speak a different language, the screens offer a simple language selection at the top, allowing users to switch the interface to their preferred language with one tap.



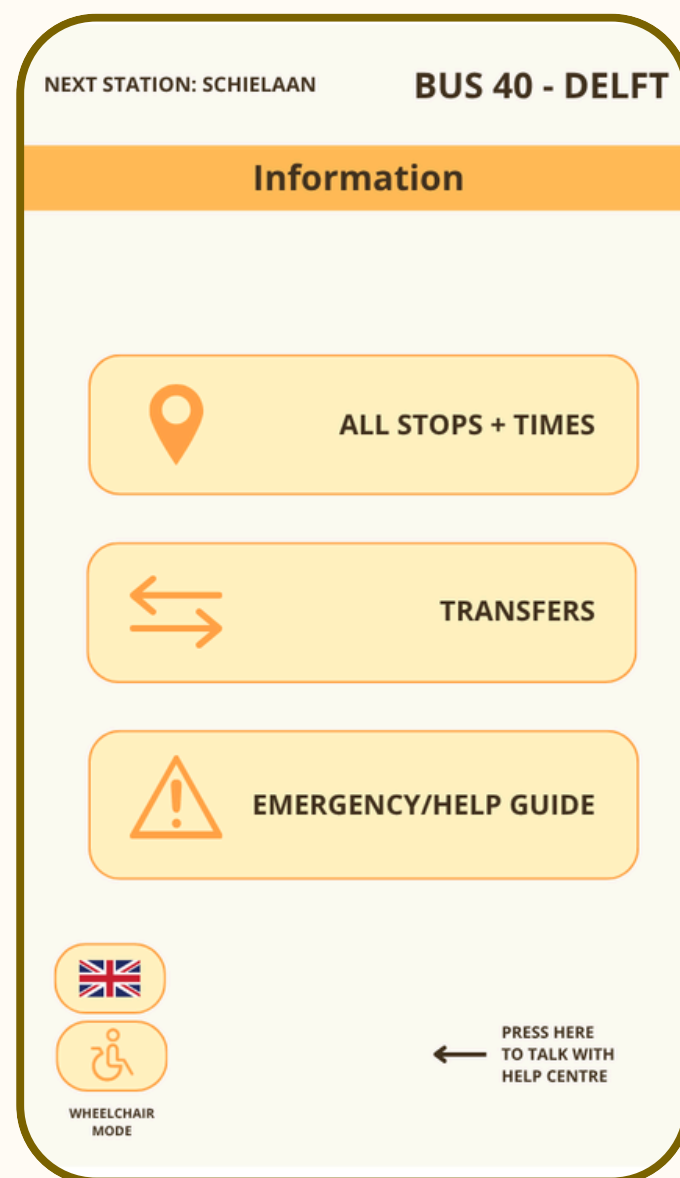


Figure 51: Homescreen with the three categories to find all information people usually need. If you still want to ask a real person you could use the talk button.

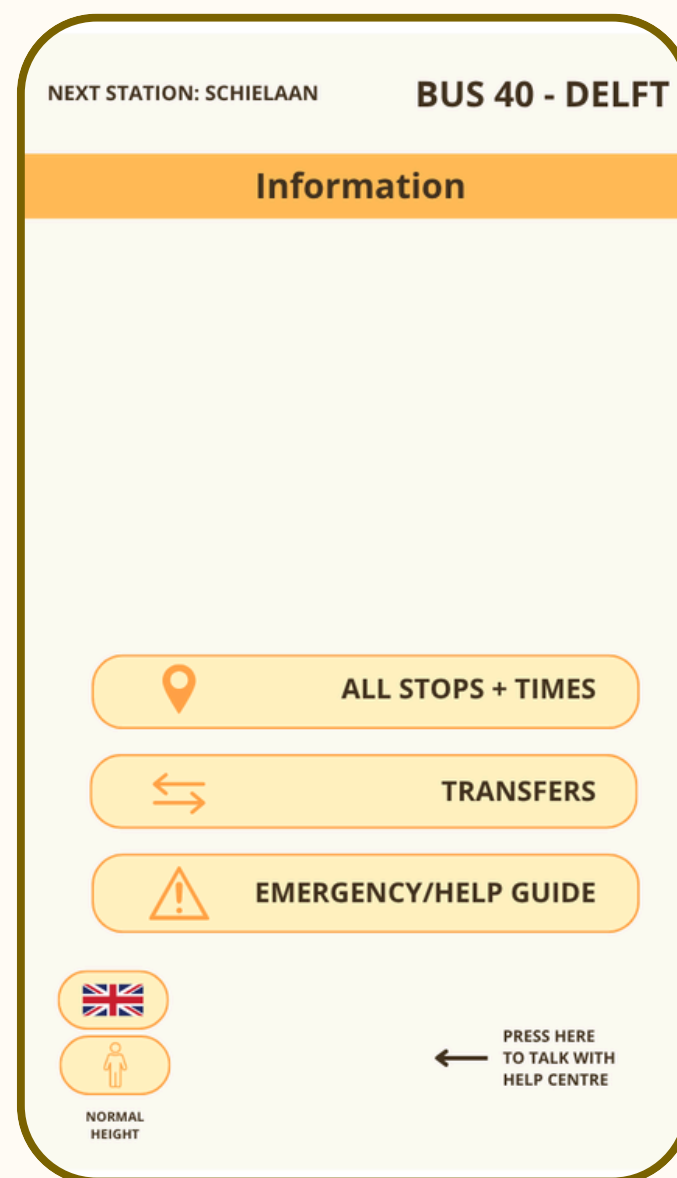


Figure 52: Homescreen for wheelchair users where every button is placed on the lower half so wheelchair users can reach it. You can access this mode through the button on the bottom left.

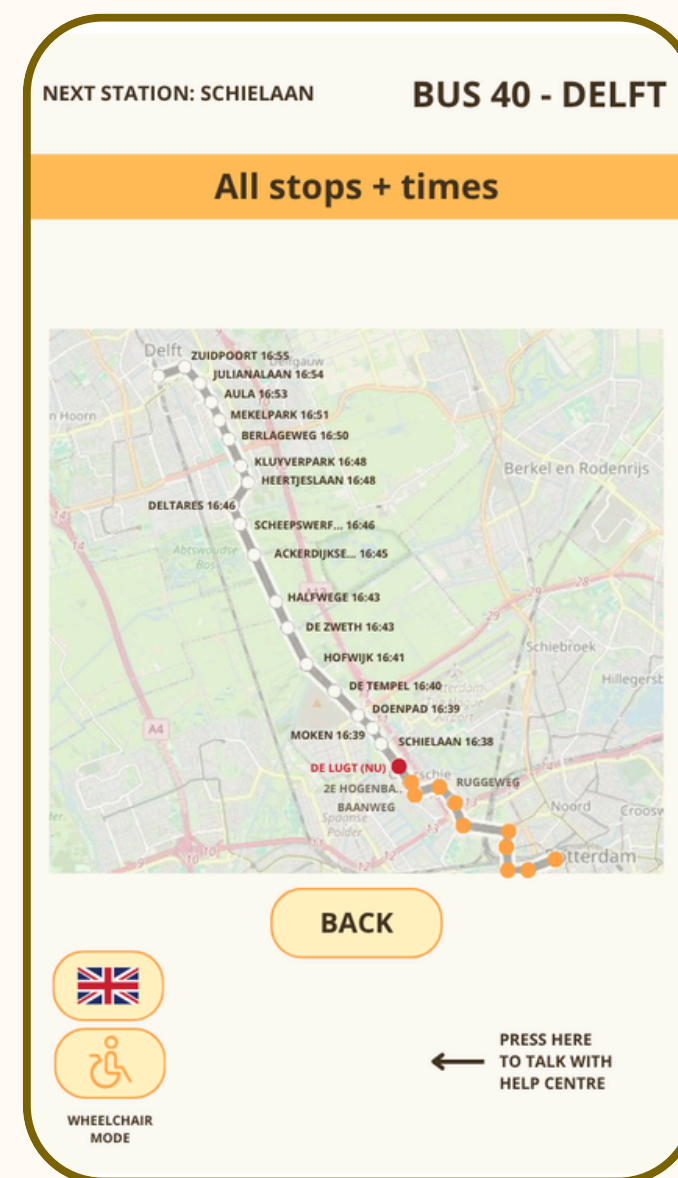


Figure 53: Possible interface to show all stops. Yellow stops are the stops that already have been passed.

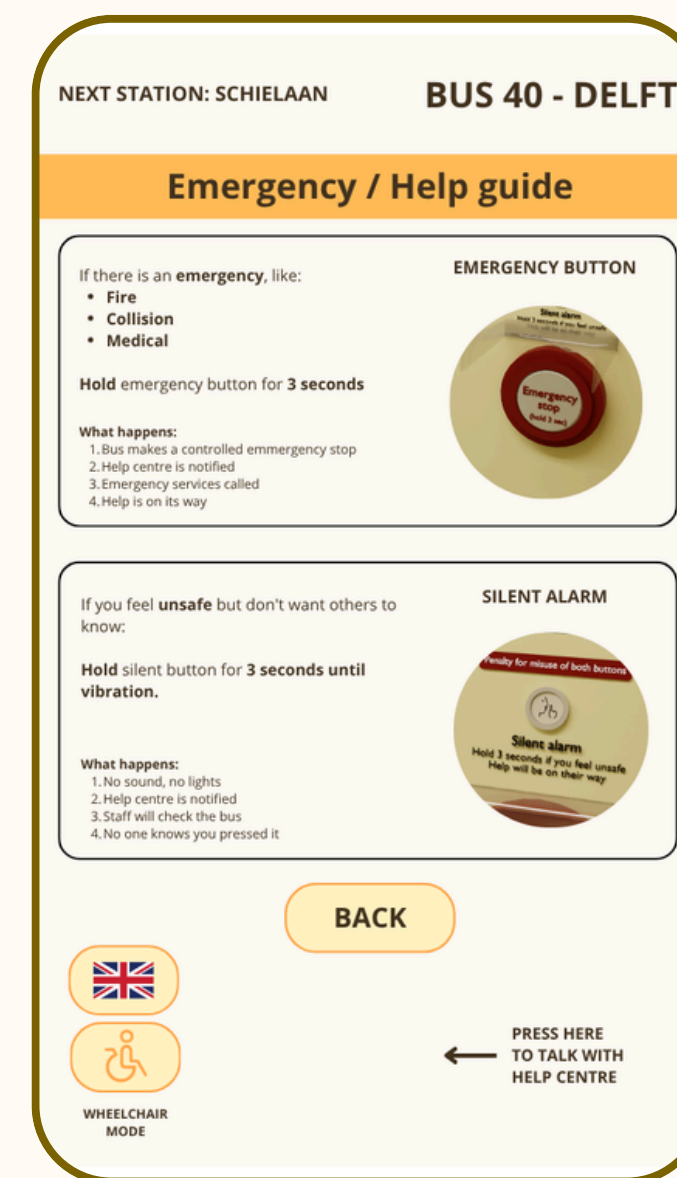


Figure 54: Possible interface to show the procedures / guide in case of an emergency or feeling unsafe due to passenger behaviour for example



Figure 55: Route information that is displayed on the screens on top of the ring on both side, in the front of the bus and in the back.



The help ring directly tackles support, one of the three main problems identified in the refined problem definition. The survey showed that passengers worry most about having no one to talk to when something happens. The ring solves this by offering multiple ways to get help: simple interface with information via the screen, or direct contact with a real person via the physical button. The QR code at every seat ensures that help is also available when the bus is crowded and the ring is hard to reach.

At the same time, the ring addresses predictability. By showing the route and final destination proactively, passengers know exactly where the bus is going and when to get off. They can find the information they need as soon as they step in, which reduces uncertainty and prevents them from accidentally staying in the wrong bus.

The location of the ring between the two doors, combined with the open standing zone and tip-up seats, ensures that the ring is always visible and accessible. Passengers do not have to push through fixed seating to reach help or information. This layout directly addresses the "no contact" concern from the survey, while also contributing to predictability and social safety.

BREATHING CEILING

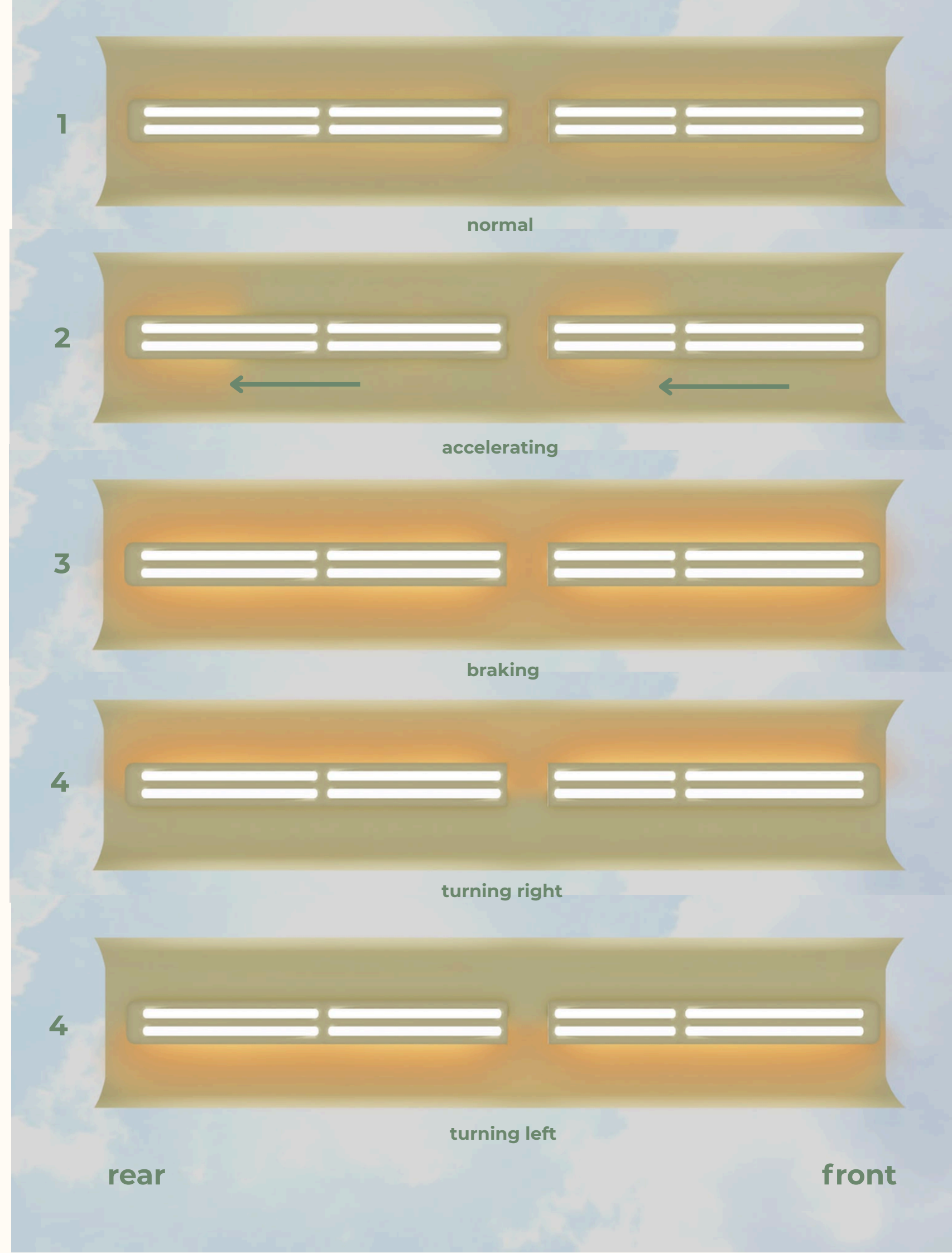
The ceiling of the bus is fitted with soft LED lighting that pulses gently. This is the breathing ceiling. Its function is to make the bus behaviour visible and predictable, so passengers always know what the bus is about to do and to prepare for the movement by grabbing the handrail for example. The light therefore shows a signal 5 seconds before the actual movement of the bus. Of course, in cases of a sudden unpredictable stop this is not possible, but all other cases can predict movements through HD maps.

The breathing ceiling has four states:

1. **Normal (static):** Nothing special is happening. The light is on very softly, like a calm background glow.
2. **Accelerating:** Just before the bus starts moving (from a stop or traffic light), a soft light streak moves from the front of the bus towards the back. This movement starts in two places at once: from the back to the ring in the middle, and from the ring to the front. This way, passengers in every part of the bus see the signal at the same time.
3. **Braking:** Just before the bus brakes (for a stoplight, station, or traffic situation), the light slowly becomes a little brighter. This happens a moment before the actual braking, because the bus already knows its route and upcoming stops. The brightness increases gradually, not suddenly, so it is not stressful. For emergency braking, the bus cannot warn in advance, but the light will still indicate the action on the moment itself.
4. **Turning:** A few seconds before a turn, the light on the left side of the ceiling will glow softly when the bus turns left, and the right side will glow when the bus turns right. This is possible because the bus already knows its route. The light is subtle, not flashing, and only one side lights up at a time.

All movements are slow and gentle, to avoid overstimulation. The light is not very bright, so it never feels harsh or distracting. Passengers subconsciously pick up the signals without being overwhelmed.

The breathing ceiling tackles predictability. The survey showed that uncertainty about what the bus will do is a major concern. By showing its intentions before they happen, the bus becomes understandable and predictable. Passengers are never surprised, which reduces stress and gives a sense of control. The breathing ceiling takes over the role of the driver's intentions, making the bus feel safe and transparent.



FRONT SCREEN: WHAT THE BUS SEES

At the front of the bus, next to where the driver would normally sit, a screen shows what the bus "sees". This screen displays simple, abstract shapes round moving objects the bus recognises.

When the bus brakes or turns, passengers can see on the screen what caused the action. This makes the bus behaviour completely transparent. Passengers no longer have to guess why the bus stopped or swerved.

The front screen is placed at a height that is visible from most seats, and the graphics are kept simple so they are easy to read even from a distance. The rounded shape of the screen matches the round camera screens and mirrors and all other rounded elements elsewhere in the bus, creating a consistent visual language.



MIRRORS AND SURVEILLANCE

The left side of the bus has fixed-location camera screens, not rotating feeds like in current buses. Rotating images would add unnecessary movement and increase visual overstimulation. The bus already has a breathing ceiling, pulsing lights, and a front screen showing road views. Adding more moving images would make the interior chaotic and stressful, especially for elderly or sensitive passengers. Also, a fixed feed feels more honest. A rotating feed can feel like "hiding" something because the image changes before you can see details.

By showing only the live feed from that specific bus section, the image is stable. Passengers know what to expect, which reduces cognitive load, while recognizing they are being watched.

The mirrors on the right side are convex, showing a wide-angle reflection for social overview. This creates natural social monitoring without adding digital screens.

Both cameras and mirrors are placed at four clear locations: front, on both sides of the ring in the middel and rear. This makes the surveillance visible. Research from the industry research and interviews with bus operators showed that safety measures only work when passengers are aware of them. Visible cameras deter bad behaviour. The round shapes soften the technology and make it feel less intrusive.





EMERGENCY BUTTONS

In the Heartbeat Bus, every passenger is never more than an arm's length away from help. Therefore, emergency buttons are placed at every seat.

Each pair of seats (two seats together) has an emergency button on the wall side, not on the pole where the regular stop button is located. This prevents confusion: the stop button is used to request a stop, the emergency button is used to call for help and makes an emergency stop. The designs are completely different (see render on the next page for the usual stop buttons). By placing the emergency

button on the wall side, passengers do not accidentally press it when they mean to stop the bus. To add to this the seal should be folded up and the button should be pressed for 3 seconds before it activates.

In the middle section of the bus, there are no fixed seats. However, there are tip-up seats (foldable against the wall) and standing places with handrails. In these areas, emergency buttons are placed on the wall at regular intervals at a height that is reachable for both seated and standing passengers.

This ensures that even in the standing zone, help is always within reach. All emergency buttons are clearly recognisable by their shape and colour. This consistency makes them easy to find in a stressful situation.

Above the main emergency button, there is a small silent alarm button. It is designed for situations where a passenger feels unsafe but does not want others to know they are asking for help. When pressed for 3 seconds, the button sends a discreet alert to the help centre. No alarm sounds, no

lights flash, and no one else in the bus is notified. The passenger receives a short tactile feedback (a gentle vibration or a subtle click) to confirm that the button has been pressed. This way, they know help is on the way, but no one else notices. The silent alarm gives passengers a way to call for help without escalating a situation or drawing attention to themselves.

Misuse

To prevent accidental or intentional misuse of the emergency buttons, a transparent protective cover must be folded up before the button can be accessed. This makes it physically clear that pressing the button is a serious action, discouraging casual or accidental pressing while still allowing quick access in a real emergency. In addition, both buttons require a 3-second press to activate, which makes it difficult for children to activate them by accident. The bright red

colour and clear labelling further signal that these are not ordinary buttons. A warning label is placed next to the buttons stating that misuse may result in a penalty, providing an extra deterrent. Together, these measures ensure that the buttons are only used intentionally and in genuine emergencies.





VISIBILITY: LARGE WINDOWS AND OPEN LAYOUT

Feeling trapped or having a limited view were major concerns in the survey. To address this, the bus has open windows without many things blocking the view to the outside. These windows make the bus feel open and transparent. Passengers can see the outside environment, which helps them orient themselves and reduces the feeling of being closed in.

The ring follows the contour of the bus interior across the floor, up the side walls, and across the ceiling. Because it follows the existing shape of the bus, the ring does not block sightlines. Unlike a thick column or a wall, the ring is a thin band that adds visual structure without obstructing views. Passengers can see through the ring, across the bus, and out of the windows.

The combination of open looking windows, an open layout, mirrors and a thin ring ensures that passengers always have a clear view of both the outside and the inside of the bus. This directly addresses the "feeling trapped" concern.

BUS LAYOUT: ENTRY AND MOVEMENT

In a conventional bus, passengers usually enter through the front door, passing the driver (appendix B). This creates a moment of social control. Passengers enter at the front and must walk through a narrow aisle past rows of fixed seats to reach the middle or back. However, in an autonomous bus, there is no driver, so the front area can be redesigned. Therefore, this concept places two doors in the middle of the bus, centred on the right side (the curb side) for efficient boarding and alighting and fits up to 39 seating places.

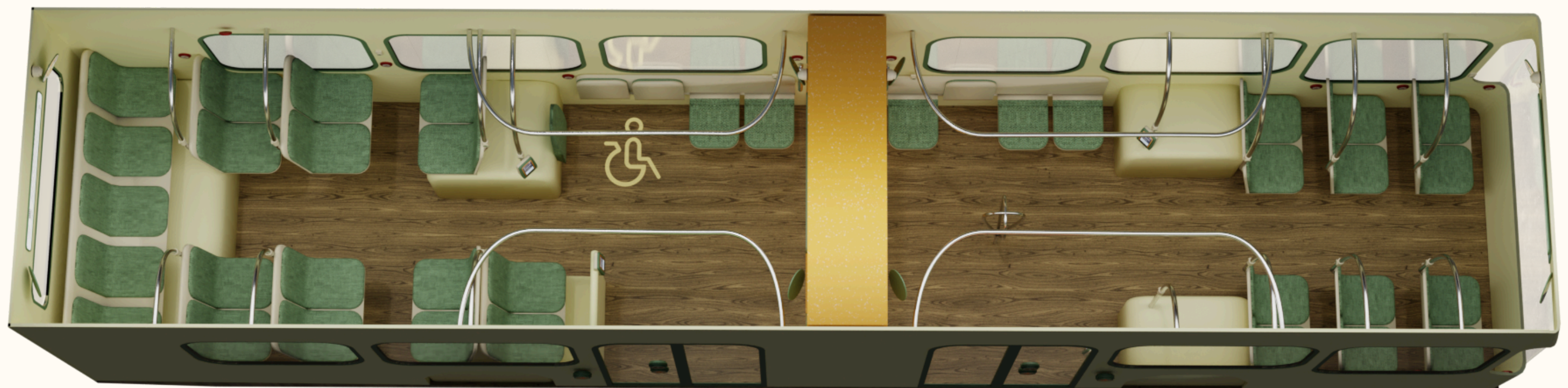
This configuration is inspired by metro and train layouts, where doors are grouped in a central zone.

Placing doors in the middle allows passengers to enter and exit more naturally without forcing them to pass a specific point like the busdriver in current buses. It splits the bus into a front and rear half. Passengers can walk forward or backward, spreading people evenly. The distance to the front or back is roughly equal, so no one has to walk the full length.

The space around the doors is kept open, with no fixed seats in the immediate area. This creates a standing zone and improves passenger flow. It also makes the help ring easier to reach from both doors. You will in fact see the ring immediately when entering the bus

so people know exactly where to go if they have a question.

Instead of fixed forward-facing seats near the doors, the concept uses tip-up seats that fold against the wall. These seats are oriented perpendicular to the direction of travel. When folded up, they create more space for standing passengers, wheelchairs, and pushchairs (Ang, 2018). This improves ingress and egress during busy hours (Thoreau et al., 2016). Fixed seats are mostly placed at the front and rear sections of the bus, where you can sit if you have a long journey.



DOOR SYSTEM

To further improve passenger flow, the concept uses a Plug & Rapid Sliding door system (Figure 56). This type of door slides outward before moving along the bus body, keeping the interior completely clear (Ventura Systems, 2025). Unlike inward-gliding doors, which take up interior space and cause congestion, outward-sliding doors provide an unobstructed entryway, enabling faster boarding and alighting. They also offer better sealing and insulation, reducing noise and weather exposure (Ventura Systems, 2025).

Above the door, a light indicates what the door is about to do. A blinking green light signals that the door is opening. Once fully open, the light becomes static green. A few seconds before closing, a red light starts blinking and continues until the door is fully closed. This is similar to the door lights on NS trains. When the bus is moving, the light is turned off. Together with the lights audio is included for the visually impaired passengers. When the door is fully open you will hear a soft long beep so you can enter or leave the bus and when the door is about to close repeated short beeps will sound until the door is fully closed.

This system makes the bus behaviour more predictable. When passengers understand what the bus is going to do, they experience less stress and feel more in control.



Figure 56: Rapid Sliding door system. (Ventura Systems, Innovative door systems, 2024)





ENTERING THE BUS

Passengers enter the bus through the doors in the middle. There are no gates or barriers. This keeps the flow smooth, as people do not have to wait for each other to pass through a narrow gate. A standard OV-card scanner is placed next to the door. Passengers are trusted to check in. This trust is supported by the fact that inspectors may board the bus occasionally, similar to train conductors. Their presence reminds passengers to behave and check in, as they risk a fine. A sticker can be placed near the door that indicates that fare evasion is monitored and can result in a fine.

The doors have two buttons: one for opening the door, and one for wheelchair users to open the door. When the wheelchair button is pressed, a short ramp slides out automatically. In the future, for this design to work the assumption is made that autonomous buses will be able to park very close to the curb, making the step almost level with the platform. Only a small gap will remain, so the ramp does not need to be large. It is short and narrow, just enough to bridge the gap. This is safer and less intimidating than the large ramps that drivers currently have to push out manually.

The ramp only deploys when the bus is stopped. It automatically retracts when the wheelchair user has moved onto the designated wheelchair space. The doors will not close until the system detects that the wheelchair is in the correct position. This prevents the doors from closing too early and ensures the passenger is secure before the bus moves. Sensors in the floor or seatbelt indicators can confirm when the wheelchair is properly positioned. This system could be implemented with current technology, using weight sensors or simple infrared beams to detect the wheelchair.

STAFF PRESENCE

The Heartbeat Bus is designed to support perceived safety as much as possible through interior design. However, it is important to acknowledge that design and technology cannot solve every situation. This project investigates to what extent interior design can make passengers feel safe in a fully autonomous bus, but in some cases, human presence remains necessary.

In serious incidents, such as aggressive behaviour or physical conflicts, technology cannot intervene. A camera can record, and a help button can call for assistance, but neither can remove a threatening person or stop a fight. Therefore, this project does not assume that all staff can or should be removed. Instead, it explores how much of the driver's psychological and social role can be taken over by the interior, while recognising that certain situations still require human intervention.

This is why the Heartbeat Bus includes a flexible approach to staff presence. During the day, occasional ticket inspectors can board the bus for a few stops, similar to train conductors. Their presence reminds passengers to behave and check in, as they risk a fine. This also provides a moment of social control without requiring permanent staff on board.

In the evening and at night, when the bus is quieter and social safety risks are higher, a staff member can be on board. This person acts as a visible authority figure, providing reassurance to passengers and intervening if something happens. This is especially important for passengers travelling alone at night, who may feel vulnerable in an empty bus with strangers.

By adding staff during specific hours, the Heartbeat Bus offers the best of both worlds: a fully autonomous experience during busy, safe hours, and extra human supervision when it is needed most.



Figure 57: Staff on board controlling the bus. (Risa & Ingemundsen, 2024)

MATERIALS

The material choices for the Heartbeat Bus balance durability, sustainability, passenger comfort, and ease of maintenance. The recommendations below are based on the feasibility interview with BYD and industry standards for bus interiors. The bus operator ultimately decides which materials to use, but the following suggestions aim to support both perceived safety and practical operation.

STRUCTURAL PLASTIC PARTS: RECYCLED PC/ABS

For the structural plastic components, such as the help ring, wall panels, and trim elements, **recycled PC/ABS** (Polycarbonate/ABS blend) is recommended. This material is already widely used in automotive interiors because it balances impact strength, heat resistance, and surface quality. It provides high impact strength and good dimensional stability, making it suitable for parts that need to withstand daily use in a bus environment (PC/ABS Interior Grade – Automotive Interior Engineering Plastic Solution - YONG JIN HONG PLASTIC, z.d.).

For this project, the advice is to use **recycled PC/ABS** (Hein, 2023). Using recycled material aligns with sustainability goals and makes the concept more attractive to operators who are increasingly required to meet environmental standards. As the BYD expert noted, recyclable materials are appealing to bus operators.



Figure 58: Recycled PC/ABS. (Müller-Guttenbrunn Gruppe, 2019)

FLOORING: PVC WITH WOOD-LOOK FINISH

The floor should be made of **PVC (vinyl) flooring**, as this is standard in buses due to its durability and ease of maintenance. PVC flooring is durable, waterproof, easy to clean, and anti-slip. It is also fire-resistant and can be produced with a high recycled content. The BYD expert recommended PVC for the floor and the floor part of the help ring, as it would wear out quickly if a separate plastic part was used for the ring.

To create a warm, home-like feeling, the PVC floor can have a **wood-grain finish** (Eternal Bus & Coach Flooring | Forbo Flooring Systems, z.d.). This provides a realistic wood aesthetic while retaining the practical advantages of vinyl.



Figure 59: Wooden vinyl flooring. (Wooden Design PVC Floor Covering For The Coach Interior, 2022)

SEATING: CUSHIONED, EASY-CLEAN FABRIC

The seats should be cushioned for passenger comfort which increases perceived safety. For the upholstery, a durable, easy-to-clean fabric is recommended. The fabric should be resistant to wear and tear, stain-resistant, and flame-retardant to meet public transport safety standards. Polyester fabrics (Baosm, 2023) or synthetic leather (Kumar, 2024) are often used for bus seats because they balance durability, comfort, and easy maintenance.

While a stitched fabric or synthetic leather seat may not be as durable as solid plastic, it significantly improves passenger comfort, which is a key factor for perceived safety. For easier cleaning, a material that is stain-resistant or has a protective coating is preferable. The choice between fabric and synthetic leather (as used in NS trains) is up to the operator, but the recommendation is to prioritise a material that looks clean and well-maintained, as a clean bus interior is perceived as safer.



Figure 60: Leather and fabric bus seat material.

SCENARIOS

To show how the Heartbeat Bus addresses the three core problems, a set of scenarios has been developed. Each scenario focuses on one problem: support (no one to turn to), social safety (fear of other passengers), and uncertainty (not knowing what the bus will do).

For each problem, two versions are presented. The first shows the situation in a normal bus without a driver. The second shows the same situation in the Heartbeat Bus, demonstrating how the design elements work together to solve the problem.



Figure 61: Some scenario drawings that were made.



Figure 62: Scenario about support in a autonomous bus without design changes.

NORMAL AUTONOMOUS BUS (WITHOUT DESIGN CHANGES):

You step onto the bus. The doors close behind you. You want to know what time you will arrive at Delft Station, but there is no driver to ask. You look around for a screen, but there is only a small display showing the next few stops. You sit down and wait, feeling uncertain about how long the journey will take. You spend the whole ride looking at this tiny screen seeing only five stops at a time slowly scrolling down to reveal the other stops.

HEARTBEAT BUS (WITH DESIGN CHANGES):

You step onto the bus. Immediately, you notice the warm-coloured ring in the middle of the bus. It feels like the heart of the bus. You walk towards it. On the vertical screen, you see three simple categories:

- "All stops + time"
- "Transfers"
- "Emergency/Help guide"

You want to know at what time you will be at Delft station, so you tap on "All stops + time". A clear list appears showing every stop on the route, with the estimated arrival time next to each one. You see that Delft Station is the fifth stop and you will arrive in 12 minutes. You feel relieved.

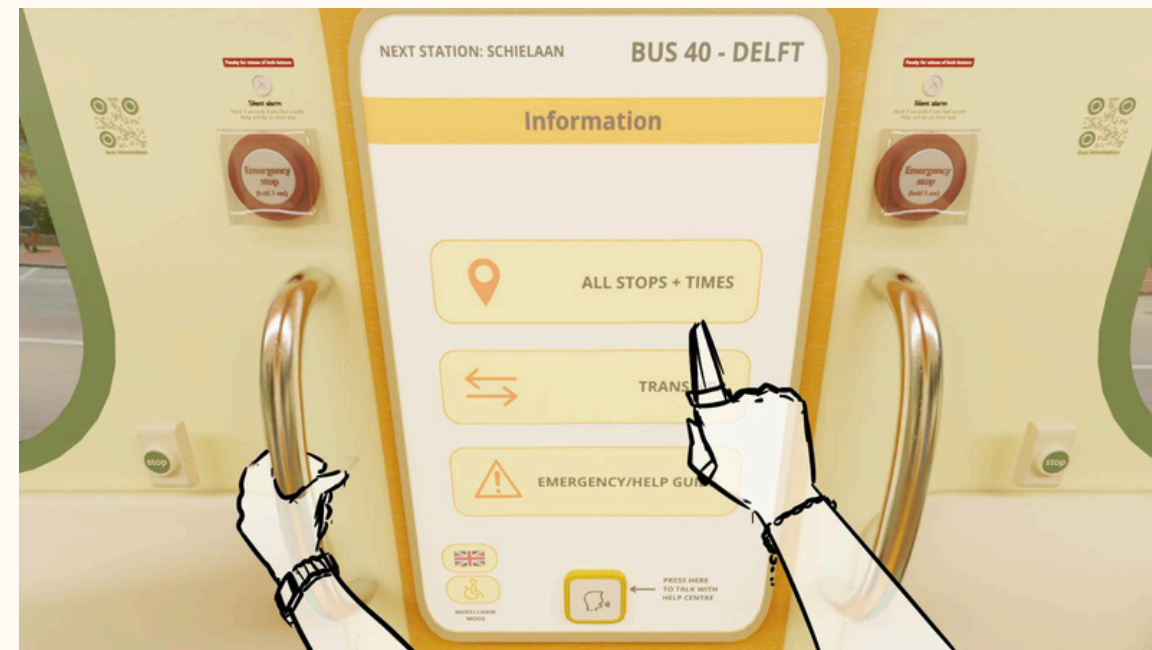
As you turn to find a seat, you notice a large physical button on the ring labelled "HELP". A sign next to it says: "Press to speak to a real person." You do not need it now, but you feel reassured knowing that if you ever prefer to talk to someone instead of using the screen, you can. Also on the screens throughout the bus you notice many of the following stops are displayed so you can check those during the ride.

HOW THIS SCENARIO SUPPORTS THE PROBLEM

This scenario shows how the Heartbeat Bus solves the **support** problem. In the normal bus, the passenger has no one to ask and no clear information. The small display only shows a few stops at a time, leaving the passenger uncertain and anxious. In the Heartbeat Bus, the help ring provides immediate access to information about the route, transfers or a help guide in emergencies through simple categories. The physical help button offers a direct line to a real person, ensuring passengers never feel completely alone. The stops displays at four different locations can be checked while seated that shows at least 18 stops at a time. The passenger feels relieved and reassured, knowing help is available if needed.



Walk inside and see the ring immediately



You see three categories for information



Search when you will arrive at Delft station

**NORMAL AUTONOMOUS BUS**

It is late at night. You are returning from work. It is dark outside. You step into the bus. There is only one other passenger: a man sitting near the front. He looks at you as you enter. You feel uncomfortable. You sit as far away as possible, but because the bus is narrow and the seats are arranged in long rows, you cannot see him properly. The bus feels cramped and dark. You feel trapped. You cannot see the doors clearly. You spend the whole ride tense, looking around, hoping nothing happens.

Figure 63: Scenario about social safety in a autonomous bus without design changes.

HEARTBEAT BUS

It is late at night. You are returning from work. It is dark outside. You step into the bus. There is one other passenger, a man sitting near the back. The bus is open and bright. You can see exactly where he is. Convex mirrors on the side walls show you a wide view of the bus, so you can always keep an eye on him without turning around.

You notice cameras with screens showing live footage of the bus interior. You know you are being recorded. A staff member has also boarded. The bus operator has added extra personnel during the evening hours. You see them entering the bus just a little after you entered. Their presence makes you feel safer.

You choose a seat where you can see both the staff member and the other passenger. You notice a small button next to the emergency button on the wall. A small icon shows a person with a finger to their lips. You read the label: "Silent alarm, hold for 3 seconds if you feel unsafe, help will be on their way." Because there is staff on board right now you don't need it now, but knowing it is there gives you peace of mind. You could use it during the day when there might be no staff. You feel in control, and the bus feels like a safe place to be.

HOW THIS SCENARIO SUPPORTS THE PROBLEM

This scenario shows how the Heartbeat Bus solves the **social safety** problem. In the normal bus, the passenger feels trapped, cannot see the other passenger, and has no overview. The narrow layout and lack of visibility increase anxiety. In the Heartbeat Bus, the open layout, mirrors, and cameras provide full overview. The presence of staff during evening hours adds a layer of social control. The silent alarm gives the passenger a discreet way to call for help without escalating the situation. The passenger feels in control, supported and safe.



Late at night and you enter the nearly empty bus



POV: you notice a strange man in the front looking at you



Because it's late extra staff enters the bus for a night shift



NORMAL AUTONOMOUS BUS

You step onto the bus. The doors close behind you, and the bus suddenly pulls away. You lose your balance and grab a pole just in time. You find a seat. A few moments later, the bus brakes sharply. You lurch forward. You look up, but there is no explanation. It was just a traffic light. Then the bus turns left, and you see a cyclist crossing in front of the bus. You hold your breath, wondering if the bus has seen the cyclist. The bus does stop, but you had no way of knowing it would. Every movement feels unpredictable. You feel anxious and tense throughout the ride.

Figure 64: Scenario about uncertainty in a autonomous bus without design changes.

HEARTBEAT BUS

You step onto the bus and take a seat. The light above the door blinks red and a fast beeping sound follows. A few seconds later, the doors close smoothly. Then, you notice the ceiling lights begin to move. A soft, flowing light moves from the front of the bus towards the back. A few seconds later, the bus accelerates smoothly from the stop. You had time to prepare.

A few minutes later, the ceiling light slowly becomes a little brighter and you know the bus is about to brake. You hold the handrail gently. The bus brakes smoothly. You were not surprised.

You look at the front screen, which shows what the bus "sees". Simple shapes appear around the objects it recognizes: a cyclist, a car, a pedestrian. The bus slows down for a cyclist crossing the road. You saw it on the screen, and you saw the light change just before. Then the bus turns left. The left side of the ceiling glows softly. A few seconds later, the bus turns smoothly.

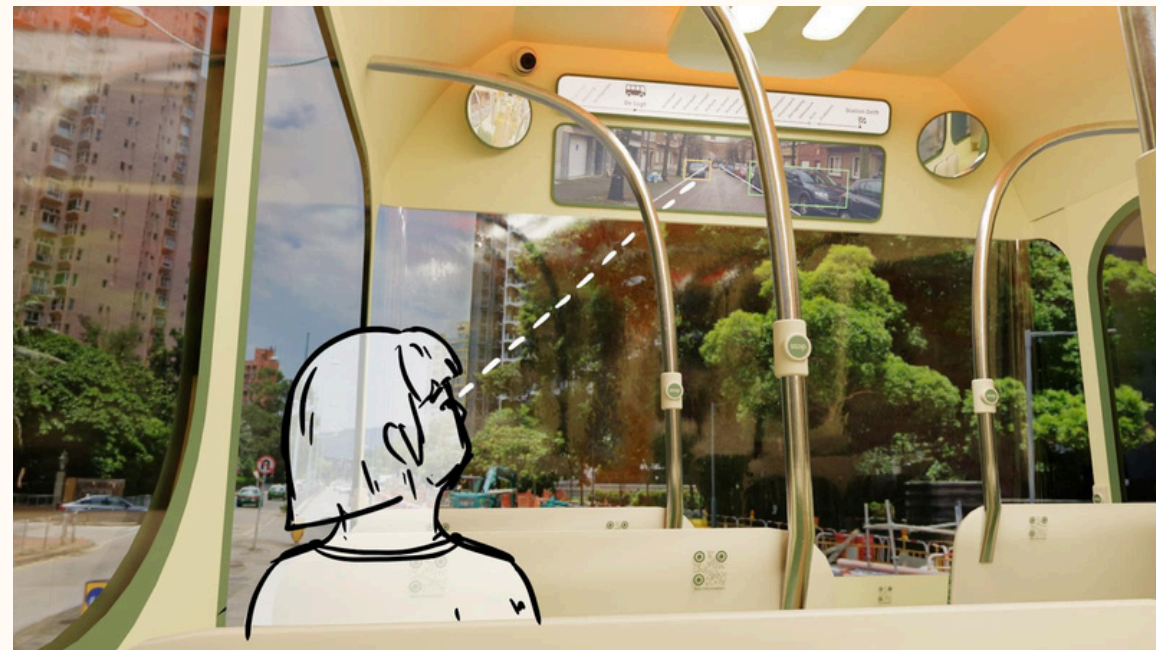
You feel calm. The bus is not hiding anything. You understand what it is doing and have time to prepare for it if needed, so you won't be surprised, therefore you feel safe.

HOW THIS SCENARIO SUPPORTS THE PROBLEM

This scenario shows how the Heartbeat Bus solves the **uncertainty** problem by showing overview and predictability. In the normal bus, the passenger is constantly surprised by sudden movements, has no explanation for the bus's actions, and feels anxious and tense. It is just a cold technology that drives you with no feedback at all. In the Heartbeat Bus, the door light prepares the passenger for door movements. The breathing ceiling signals acceleration, braking, and turning before they happen. The front screen shows what the bus sees, explaining its actions. The passenger feels calm because the bus is predictable and transparent.



The light turns red behind you to close the door



You gain trust seeing that the bus sees everything



You notice the light lights up before the actual movement

Evaluation

HOW THE HEARTBEAT BUS SOLVES THE CORE PROBLEMS

The Heartbeat Bus is designed to address the three core problems identified in the research: support, social safety, and uncertainty. Each element of the bus contributes to one or more of these solutions.

SUPPORT: PASSENGERS CAN ALWAYS GET HELP

The research showed that passengers worry a lot about having no one to talk to when something happens. The Heartbeat Bus solves this in multiple ways.

The help ring is the central point for support. The vertical screens offer simple categories where passengers can find answers to common questions without needing to talk to anyone. If a passenger prefers to speak to a real person, the large physical button on the ring connects them directly to a human-staffed help centre.

The QR code at every seat ensures that help is also available when the bus is crowded and the ring is hard to reach or when they just want to talk to a real person. Passengers can use their own phone to access the same information and ask questions.

The emergency button gives passengers the feeling of control when something happens. The silent alarm also reassures them with a feeling of having something they can use in case of feeling unsafe.

Together, these elements ensure that passengers never feel completely alone, even when no staff is present.

SOCIAL SAFETY: PASSENGERS FEEL SAFE AROUND OTHERS

The research showed that passenger behaviour is the biggest concern already in current buses even with a driver. People feel unsafe because of others, not because of the bus itself. The Heartbeat Bus reduces this threat through spatial design.

The open layout with open windows and mirrors ensures that passengers can see each other at all times. There are no hidden corners where someone can hide. Convex mirrors give passengers a wide view of the bus, so they know what is happening around them.

Camera screens show live footage of the bus interior, making passengers aware that they are being recorded. Visible surveillance deters bad behaviour.

The presence of staff during evening hours adds an extra layer of social control. When the bus is quieter and social safety risks are higher, a staff member is on board to intervene if something happens.

During the day, occasional ticket inspectors board the bus for a few stops. Their presence reminds passengers to behave and check in. This creates moments of social control without requiring permanent staff.

The silent alarm button also contributes to social safety. Passengers who feel threatened can call for help discreetly, without escalating the situation or drawing attention to themselves.

UNCERTAINTY: PASSENGERS UNDERSTAND WHAT THE BUS WILL DO

The research showed that uncertainty about what the bus will do is a major source of anxiety. The Heartbeat Bus makes bus behaviour transparent and predictable.

The breathing ceiling shows passengers what the bus is about to do: accelerate, brake, or turn. The movements are slow and gentle, not stressful and gives passengers time to prepare if needed.

The front screen shows what the bus "sees". Passengers can see cyclists, cars, and pedestrians on the screen. This helps them understand why the bus brakes or steers and gives them more trust about the system of the bus that is working.

The door light indicates when the door will open or close, similar to train doors. This prevents passengers from being surprised by sudden door movements.

The route information on the ring and at the front of the bus shows passengers where they are and where the bus is going. This prevents them from accidentally staying in the wrong bus.

The breathing ceiling and front screen work together. The passengers see what the bus sees and feel what the bus will do. They are never surprised and are able to prepare themselves for the movement by grabbing on to something for stability if needed.

REQUIREMENTS AND WISHES CHECK

The Heartbeat Bus concept was developed based on the design framework and evaluation criteria established in earlier chapters. Before proceeding to the final validation, the concept must be checked against the requirements (must-haves) and wishes (nice-to-haves) that were defined during the ideation phase. The requirements ensure that the concept meets the basic needs that emerged from the literature review, survey, and interviews (Table 5).

The wishes help to identify how well the concept performs on additional desirable qualities such as rich communication, learnability, and visual appeal (Table 6). This chapter evaluates whether the final concept meets all requirements and how it scores on the wishes. The evaluation confirms that the concept is a valid direction and provides a foundation for the final validation.

	Requirements	Question	How the Heartbeat Bus meets it
Overview & Comprehensibility	1.1 Communication of intention	Is it made visible or audible before the bus brakes, turns or accelerates that it is going to do this?	The breathing ceiling shows acceleration, braking, and turning before the action happens. The door light shows when doors will open or close.
	1.2 Predictability of movement (during action)	Can the passenger feel or see braking, accelerating and turning through an external signal at the moment it happens?	The breathing ceiling pulses during movement, and the front screen shows real-time road detection, so passengers see and feel what the bus is doing.
	1.3 Route and position insight	Does the passenger know at all times what and when the next stop is and how many stops are left?	The top screen on the help ring on both sides shows all stops with the current stop highlighted. A similar display is at the front and back of the bus.
Control & Support	2.1 Visible help access	Is there a way to ask for help from every seat without standing up? The button or help point should be within arm's reach of a seated passenger which is 81 centimetres (arm reach mean international)	The help ring is visible from every seat. Emergency buttons are at every seat, within arm's reach. QR codes at every seat provide an alternative.
	2.2 Low-threshold help request	Can a passenger from a seated position locate and press a help button within 3 seconds ?	The help ring screens offer simple categories with two-tap answers. The physical help button connects directly to a help centre. Also in case of emergencies or feeling unsafe emergency buttons and silent alarms are located within arm reach.
	2.3 Avoid overstimulation	Does the idea avoid excessive, bright, flashing or loud stimuli that could cause stress?	The breathing ceiling uses slow, gentle pulses, not flashing or bright lights. No loud alarms. The design is calm and subtle.
Social safety	3.1 Prevent anonymous zones	Are there no places where passengers can sit completely out of sight of other passengers?	The open layout with open windows, mirrors, and cameras ensures there are no hidden corners. Passengers can see each other from almost every seat.
	3.2 Support 360° social visibility	Can seated passengers easily see passengers in the seats directly in front of them, next to them, and behind them?	Convex mirrors and camera screens give passengers a view of passengers in front, next to, and behind them without turning around.

Requirements		Question	How the Heartbeat Bus meets it
Accessibility & Inclusivity	4.1 Help for everyone	Is the help function usable for deaf, blind, people with physical disabilities and wheelchair users ?	The help ring has a wheelchair mode that moves menu items to the lower half of the screen. Blind people can use the physical button and people who rather talk with a real person. The screen can be used by deaf people. Also emergency buttons can be reached by everyone, no matter the disability.
	4.2 Works without language	Can essential information (help request, stop info, bus behaviour) be understood without reading text ?	The screens use simple icons and categories, not long texts. The breathing ceiling and door light use visual signals. Language selection is available for the help ring.
	4.3 Works for first-time use	Is the concept understandable for a first-time user (elderly, tourist, child) with the help of clear, intuitive cues such as pictograms, light signals, or short animations? Long texts or complex menus should not be needed.	The ring is a clear landmark with simple categories. No manual is needed. Testing showed high understanding scores (around 4 out of 5).
	4.4 Capacity	Does the concept allow at least the minimum of 70 passengers (including 30 seats)?	The 12-metre bus layout with tip-up seats near the doors and fixed seats at the front and rear maintains sufficient capacity for 39 seats which is more than average for 12 meter buses. The standing area in the middle makes room for a lot of passengers standing, especially with the tip-up seats tipped up.
Feasibility	5.1 Visualisable	Can this concept be sketched, modelled in 3D, or tested with a prototype within the time of this graduation project?	The concept was fully visualised in Blender, with renders and a 360° photo used for testing.
	5.2 Technically feasible	Does the technology exist or is it realistic within 15 years ?	The BYD feasibility interview confirmed that all elements (help ring, breathing ceiling, front screen) are realistic within 5-10 years.
	5.3 Fits inside interior	Is it an interior element (no app, no external infrastructure)?	All elements are interior components.
	5.4 Operationability	Can the concept be cleaned, maintained, and operated by the bus operator using standard equipment and routines? It should be resistant to normal wear and tear and incidental vandalism, without requiring extra staff or specialised tools .	The concept uses standard materials (PVC flooring, PC/ABS plastics, durable fabrics) that are easy to clean and maintain. No extra staff are required for operation, except optional evening staff for social safety.

Table 5: Requirements check

	Wishes	Question	Score	Comments
Overview & Comprehensibility	Rich communication	Does the concept use multiple senses (sight, sound, touch)?	1	The concept uses multiple senses: sight (breathing ceiling, screens, door light), touch (emergency buttons, silent alarm with tactile feedback), and hearing (audio signal for doors). But not for every element.
	Familiarisation speed	Do passengers understand the concept better on their next ride compared to their first use? The faster this improvement happens, the better.	1	The intuitive design and simple categories make the concept easy to learn. Testing showed high understanding scores even for first-time users. Participants quickly understood the breathing ceiling signals, the idea of the help ring. The concept was improved using the feedback from multiple surveys to create the most intuitive design. But this should be tested more.
Control & Support	Feeling of being supported	Do passengers feel not alone , even without direct help?	2	The help ring, emergency buttons, silent alarm, and QR codes provide multiple ways to get help. The central location of the ring and the warm colours create a sense of presence.
Social safety	Discourages antisocial behaviour	Is antisocial behaviour made less attractive by the concept?	2	Visible cameras, open layout, mirrors, and the presence of staff during evening hours all discourage antisocial behaviour. The silent alarm allows discreet reporting.
	Social choice freedom	Can passengers choose between social or private spaces ?	0	The open layout offers a mix of seating and standing zones. Passengers can choose where to sit, but the design prioritises overview over complete privacy.
	Social overview (whole bus)	From your seat, can you see most other seats in the bus (e.g., 80%) without standing up?	2	The open layout, open windows, convex mirrors, and camera screens give passengers a clear view of the entire bus.
	Social norm visible	Is it visible what normal behaviour is in the bus?	1	The presence of staff and cameras reinforces social norms. The clear zones (standing vs seating) signal expected behaviour to have in that area.
	Material durability and maintenance	Are the materials easy to clean, scratch-resistant, and durable enough to stay looking well-maintained over time ?	2	The recommended materials (PVC flooring, PC/ABS plastics, durable fabrics) are chosen for durability and ease of cleaning. The wood-look floor combines aesthetics with practicality.
Accessibility & Inclusivity	Works for blind people	Can blind people use all functions of the concept?	0	The silent alarm provides tactile feedback, the door has an audio signal, and the help ring has a physical button. The breathing ceiling uses light, which can't be noticed by blind people. You could add background noise for these people just like the doors do. the front screen that shows what the bus sees and the cameras en mirrors won't work for blind passengers. Only the button to ask for help at the ring works for them.
	Works for deaf people	Can deaf people use all functions of the concept?	2	Most of this redesigned bus is visual so deaf people will understand everything. The breathing ceiling, door light, screens, and visual alarms provide visual signals. No information is solely audio-based.
	Works for people with physical disability? (e.g. Wheelchair)	Can people with physical disabilities use all functions of the concept?	1	The wheelchair mode on the help ring screen, the low-floor design, the automatic ramp, and the open layout with tip-up seats make the bus accessible for people with physical disabilities. But they can't see the screen of what the bus sees.
Feasibility	Small space usage	Does the design take up little floor space ?	2	The ring follows the contour of the bus and does not take up extra floor space. Tip-up seats save space when folded. The overall layout is efficient.
	Visually attractive	Does the concept contribute to a calm, inviting interior ?	2	The warm colour palette, wood-look floor, soft lighting, and rounded shapes create a calm, inviting interior. Testing showed that participants found the bus "attractive" and "welcoming".
	Future-proof	Is the concept easy to adapt or modular ?	1	The elements can be replaced because they're all screens. The use of recyclable materials and adaptable technology ensures the concept remains relevant over time.
			19/28	

Table 6: Wishes check

The Heartbeat Bus concept meets all sixteen requirements and scores well on all fourteen wishes. The evaluation confirms that the concept is technically feasible, operationally practical, and addresses the core problems of support, social safety, and uncertainty. The high scores, 19 points out of 28 points (Table 6), on the wishes show that the concept is not only safe but also comfortable, accessible, and visually appealing.

Final validation

SCENARIO BASED TESTING

To further validate the Heartbeat Bus concept, a qualitative scenario test was conducted. While the earlier surveys provided quantitative data on understanding and perceived safety, this test aimed to explore the emotional and cognitive responses of participants in more depth. The goal was to understand how participants experience the three core problems (support, social safety, and uncertainty) in a normal autonomous bus and to what extent the Heartbeat Bus design solves these problems.

The test used three scenarios, each describing a specific problem. For each problem, participants first heard a description of a normal bus interior which would be fully autonomous, without design changes, followed by a description of the same situation in the Heartbeat Bus. Both scenarios were supported by pictures of such scenario. After each pair, participants were asked: **"To what extent are the problems in the second bus solved and in what way? And what feeling does this new design give you?"**

The test was conducted with four participants, ranging in age and gender (two in their twenties, one aged 72, one aged 50). The results are qualitative and are meant to provide insight into how people experience the concept, not to measure statistical significance. The findings will be used in the discussion and are not intended to change the design. The test setup and answers can be found in Appendix I.



SCENARIO 1: SUPPORT – GETTING INFORMATION ABOUT YOUR JOURNEY

In the normal bus scenario, participants described feelings of uncertainty and stress. One participant noted: "Before you know it, the doors close and you're stuck if you're on the wrong bus." Another participant mentioned: "I would have trouble recognising the small screen among all the handrails due to the lack of overview and busy design."

In the Heartbeat Bus, the help ring with clear route information was seen as a major improvement. Participants appreciated the large, central screen: "The help ring is very visible and it's great that you can find all the stops and information there." The physical help button was valued as a backup option, though most participants said they would not use it frequently: "I wouldn't use it quickly because I would be afraid I'm calling for a stupid reason."

The overall feeling was one of calm and reassurance. One participant described: "This bus would make me feel calmer, because I know that the worries I have can be answered quickly." Another noted: "It gives a pleasant and reassuring feeling to know that there are options to ask questions." One participant raised a concern about silence, preferring audio feedback, like a audio or background music for example to avoid a completely quiet environment.



Scenario in normal autonomous bus without design changes

Figure 65: Image created to use as a comparison for the test. (Schreiber, 2024) and (Suárez, 2025)



Scenario in redesigned autonomous bus with design changes

Figure 66: Scenario about support

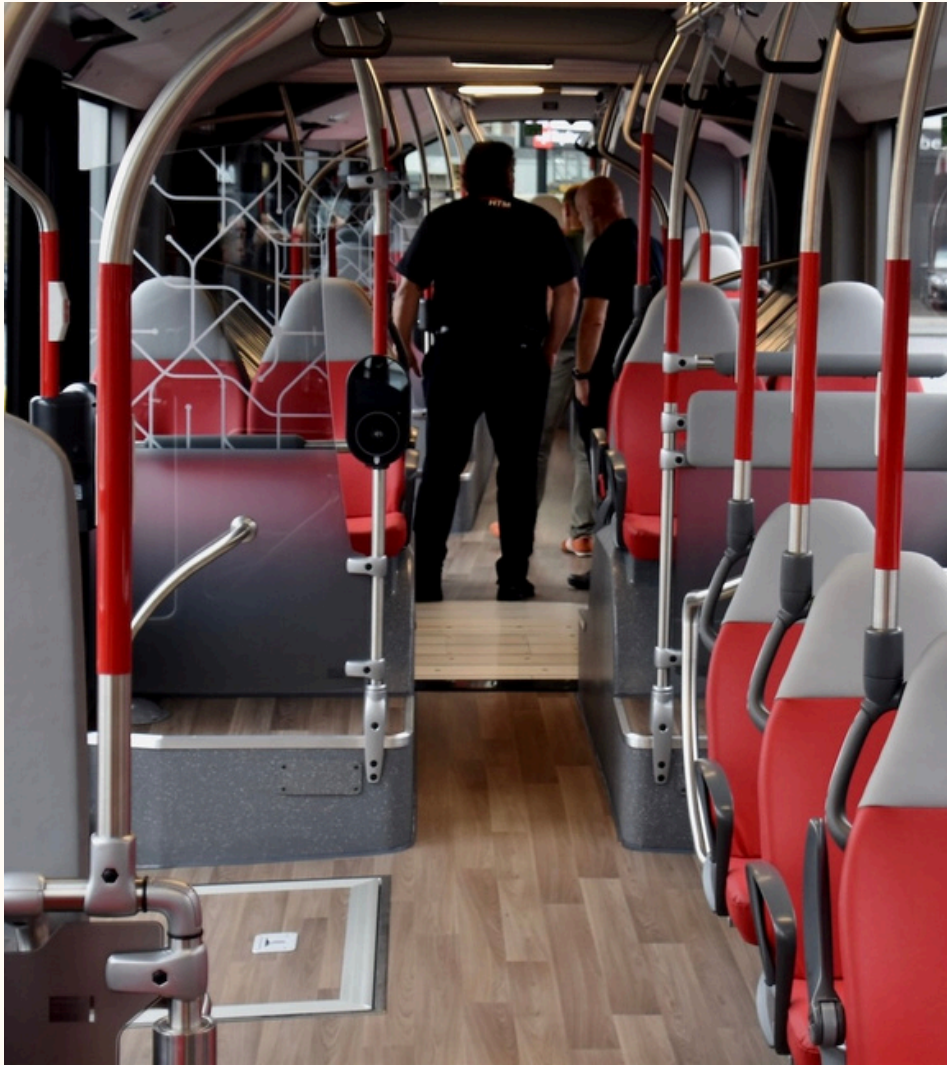


SCENARIO 2: SOCIAL SAFETY – TRAVELLING ALONE AT NIGHT

In the normal bus scenario, participants expressed feelings of vulnerability and lack of control. One participant described the situation as: "A dark, cramped box." Another noted that without visibility, they could not monitor the other passenger: "You don't know what he is doing."

In the Heartbeat Bus, the open layout, mirrors, cameras, and staff presence were all seen as effective solutions. One participant explained: "The fact that the security person can see everything and the cameras give me an extra feeling of safety." The silent alarm was valued as a discreet way to call for help: "I can take action if I think that guy is going to do something." Another participant, a woman, emphasised: "The emergency button is essential. I would almost say that if a bus doesn't have that, I as a woman wouldn't even use it in the evening."

The open design itself was seen as crucial: "If the bus design is not open, you get less benefit from staff because the staff member cannot see everything." Participants also appreciated the warm lighting and absence of dark corners: "Warm colours, everything is well lit, no dark corners. I find that really important."



Scenario in normal autonomous bus without design changes



Figure 67: Image created to use as a comparison for the test. (Van Der Spek, 2025) and (Bus Aesthetic | Pinterest | Scuola, Trasporto Pubblico, z.d.)



Scenario in redesigned autonomous bus with design changes



Figure 68: Scenario about social safety

SCENARIO 3: UNCERTAINTY – UNDERSTANDING WHAT THE BUS WILL DO

In the normal bus scenario, participants described feeling surprised and anxious. One participant summarised: "You actually have zero warnings or indications."

In the Heartbeat Bus, the breathing ceiling and front screen were seen as clear and calming. Participants appreciated being able to anticipate the bus's actions: "You already know what the bus is planning, so you don't get surprised anymore." The front screen with object detection was seen as a trust-building tool: "Being able to see what the bus sees is like an extra check, for when you don't trust the bus yet."

One participant noted the potential for confusion among older passengers: "I wonder if older people who don't know what those squares are would understand what the bus is doing." However, the subtlety of the breathing ceiling was appreciated: "The signals from the ceiling are calm and not too distracting."

The overall feeling was one of reassurance and building trust over time. One participant described: "After I have taken this autonomous bus enough times, I will trust it just like a normal bus. It's nice that the bus gives these subtle signals that I can also ignore if I want to." Another participant noted: "It gives me a confident feeling. I can prepare for what is coming."



Scenario in normal autonomous bus without design changes

Figure 69: Image created to use as a comparison for the test. (Jeremy Baus, 2015)



Scenario in redesigned autonomous bus with design changes

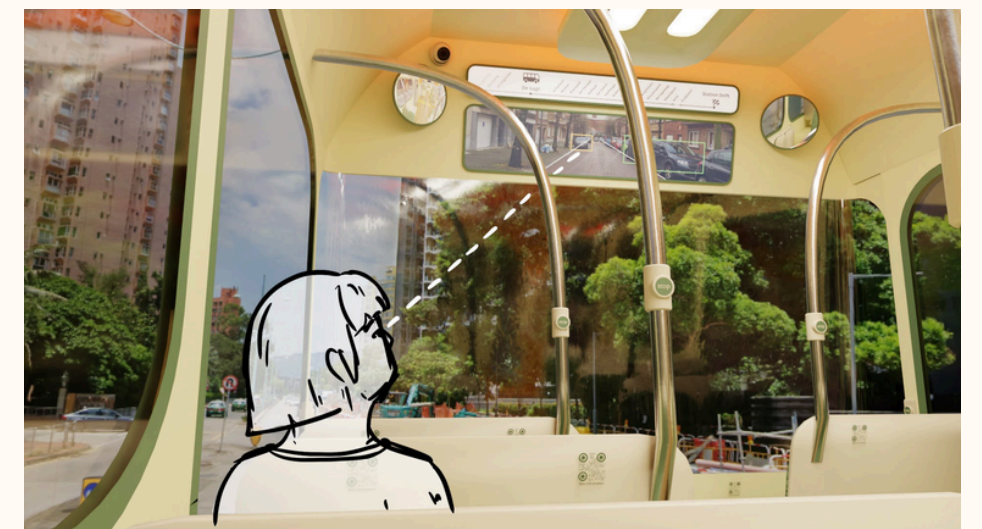


Figure 70: Scenario about uncertainty

CONCLUSION

The scenario test confirms that the Heartbeat Bus concept effectively addresses the three core problems. Participants consistently felt that the redesigned bus solved or significantly reduced the problems of support, social safety, and uncertainty. The elements that were most frequently mentioned as contributing to this were the help ring, the open layout, the cameras and mirrors, the breathing ceiling, and the front screen.

The test also revealed some areas for further consideration: one participant preferred not to sit in complete silence and requested audio, another noted that older passengers might not understand the object detection screen, and one participant suggested that the silent button could be made more visible to ensure it is easily found in stressful situations. These observations will be taken into the discussion.

The findings from this test will be used in the discussion chapter to reflect on the strengths and limitations of the concept. The results are not intended to change the design again, but to provide qualitative insight into how people experience the concept and for future iterations and research.

KEY FINDINGS	
Problem	Key finding
Support	The help ring with clear route information was seen as a major improvement. The physical help button was appreciated as a backup. One participant requested audio feedback to avoid complete silence, which is not looked into in detail and could be considered for future iterations.
Social safety	The open layout, mirrors, cameras, and staff presence were all seen as effective. The silent alarm was valued as a discreet way to call for help. One participant noted that the silent button could be made more visible, as its current colour might blend into the background, making it harder to find in a stressful situation.
Uncertainty	The breathing ceiling and front screen were seen as clear and calming. Some concern was raised about older passengers understanding the object detection screen.

Conclusion

THE WHOLE PROJECT SUMMARY

This graduation project explored how interior design can support perceived safety in fully autonomous buses. The research showed that passengers feel significantly less safe without a driver, mainly because they lose a point of contact, help, and authority. However, the research also showed that uncertainty about what the bus will do and concerns about other passengers are already problems in normal buses, and these are amplified when the driver is removed.

The project identified three core problems that an autonomous bus must address: support (passengers need to know they can get help), social safety (passengers need to feel safe around others), and predictability (passengers need to understand what the bus will do). These three problems formed the foundation for the design.

Through an iterative process of ideation, concept development, and validation, the Heartbeat Bus was developed. The concept combines two core elements: the help ring and the breathing ceiling. The help ring provides a visible, central point for help and information, addressing the support problem. The silent buttons, camera's, mirrors and staff addresses the social safety problem and controls passenger behaviour. The breathing ceiling makes bus behaviour visible and predictable, addressing the uncertainty problem. Supporting elements such as open windows, mirrors, camera screens, emergency buttons, silent alarms, and QR codes further enhance perceived safety while still being accessible for everyone.

The concept was validated through multiple rounds of testing. A first survey confirmed that the concept works in principle, with 71% of respondents rating the redesigned bus as better or much better than a normal autonomous bus. A colour survey showed that warm, home-like colours with a wood-look floor were preferred, as cool blue tones felt clinical. A feasibility interview with BYD confirmed that the concept is realistic to manufacture within a 15-year timeframe. A final validation test with 24 participants showed that 83% would feel comfortable using the bus without a driver, and all elements scored high on understanding and contribution to safety.

The evaluation against the requirements and wishes confirms that the Heartbeat Bus meets all sixteen must-have requirements and scores well on all fourteen wishes. The concept is technically feasible, operationally practical, and addresses the core problems of support, social safety, and uncertainty. The high acceptance rate shows that passengers are willing to use this bus, even without a driver.

The project demonstrates that interior design can significantly support perceived safety in autonomous buses. While design cannot completely replace the human driver and solve the problems of perceived safety, it can support perceived safety a lot in different ways through interior design. The Heartbeat Bus offers a coherent, integrated solution that makes passengers feel safe, informed, and in control.

Discussion

DISCUSSION AND RECOMMENDATION

While the Heartbeat Bus concept has been validated and shows promising results, several points require discussion and could be improved in future work.

THE CONCEPT AS A FLEXIBLE PACKAGE

The Heartbeat Bus should be seen as a package of design elements, not a fixed mandatory design. Bus operators can choose which elements to implement based on their specific needs, budget, and regional context. For example, some operators may prefer to use their own colour palette while keeping the warm, calm atmosphere. Others may choose to add the QR codes but not the camera screens, or vice versa. The modular approach ensures that the concept remains flexible and adaptable to different operators and contexts.

Future research could explore how the Heartbeat Bus package can be adapted to different brand identities while maintaining the same calming effect. For instance, operators like HTM, EBS, and RET all have their own colours and visual styles. Research could test whether the core elements still work when the colours are adjusted to match the operator's house style. The challenge is to preserve the warm, home-like feeling while using the operator's signature colours. This could be achieved by using the operator's colours in small accents while keeping the overall interior calm and neutral.

ADDITIONAL STOP DISPLAYS AT THE ENTRANCE

Based on feedback from the final validation test, an additional stop display could be added at the entrance. Some participants expressed a desire to see route information immediately upon boarding, to confirm they are in the right bus before the doors close. While this problem should ideally be solved outside the bus, which is outside this project's scope, a small screen could be placed on the slanted panel near each door as an extra confirmation. This screen would show the upcoming stops, serving as a quick reference for boarding passengers, while the existing displays on the ring and at the front remain for those already inside. To find all stops you could still use the ring. This addition would further reduce uncertainty and help prevent passengers from accidentally staying in the wrong bus.

LAYOUT AND DOOR PLACEMENT

The layout of the Heartbeat Bus places two doors in the middle of the bus, with a central open standing zone and tip-up seats. This is a departure from the current layout where passengers enter at the front and pass the driver. The new layout improves passenger flow and makes the help ring immediately visible. However, this layout also represents a significant change for passengers who are used to the traditional bus layout. Some passengers may initially find the new layout unfamiliar, which could cause confusion. The design could therefore include clear visual cues to guide passengers, such as floor markings or signage. The open layout was well-received in testing, but the unfamiliarity may require a period of adaptation. Operators could consider introducing the layout gradually, or starting with pilots in specific cities or routes where the new layout is clearly explained.

STILL A FUTURE VISION

The Heartbeat Bus is designed for SAE Level 4 and 5 automation, which is still a future vision. Both HTM and EBS indicated that fully driverless buses are not a short-term reality. This means that the concept is speculative, but grounded in what is realistic within a 15-year timeframe. The materials, technologies, and design principles used in the concept are all feasible within this period. However, the timeline may shift depending on technological developments, regulatory changes, and public acceptance. The design should therefore remain flexible and adaptable to changes in technology or regulations.

TRADE-OFFS AND LIMITATIONS

Some design choices involve trade-offs. For example, the open layout and mirrors improves overview but reduces privacy. The breathing ceiling makes bus behaviour predictable but may not be noticed by all passengers, especially on the first ride. The silent alarm offers discreet help but requires clear explanation to be used correctly. Future work could explore how to balance these trade-offs more effectively. For instance, a short animation or introductory message before the first ride could explain the breathing ceiling and silent alarm to first-time users.

LIMITATIONS OF THE VALIDATION

The validation of the Heartbeat Bus was conducted using 360° photos and questionnaires, not a physical prototype or real bus. While this method is valid for testing perceived safety, it does not capture the full experience of being in a moving bus. Future work should test the concept in a physical mock-up or a real autonomous shuttle to validate the findings. The tests were also conducted with a limited number of participants, and the sample was skewed towards older adults. While this is a relevant demographic, future testing with a more diverse group, including younger passengers, people with disabilities, children and people with different cultural backgrounds, could provide additional insights and could use more research. The scenario-based qualitative test also provides valuable insights into emotional responses and should be used to refine the concept further. The survey results showed that understanding of the breathing ceiling and front screen was generally high, but that some users may need more explanation.

FUTURE RESEARCH DIRECTIONS

Several directions for future research emerge from this project. First, the exact implementation of the breathing ceiling signals could be tested in a dynamic mock-up to measure passenger response times and comfort levels. Different pulse speeds and intensities could be compared to find the optimal settings. The influence of colour and light intensity on passenger comfort could also be studied in more detail.

Second, the help ring interface could be further developed with user testing to find the most intuitive layout. The language selection feature, wheelchair mode, and emergency button could be tested with specific user groups to ensure accessibility.

Third, the silent alarm button could be tested in simulated scenarios to measure its effectiveness and user trust. To add to that, the colour of the silent alarm button, could be made more visible through colour than in the current design to ensure it is easily found in stressful situations, as one participant noted that it might blend into the background.

Fourth, audio feedback could also be considered to address the concern raised by one participant who preferred not to sit in complete silence. A soft audio background melody or a gentle chime when the bus announces its actions could make the bus feel less "empty" without being intrusive. This project did not investigate audio in detail which could be interesting for future research.

Fifth, the use of QR codes could be further explored, especially regarding privacy concerns and what it show exactly. This project focused on the overall picture of the interior and didn't go in full detail designing the interfaces. This requires a lot of time designing and should be a seperated project. This was not the aim of this graduation project.

Finally, the concept should be tested with real bus operators to understand practical implementation challenges. The modular approach should be evaluated for cost-effectiveness and ease of installation. Future research could also explore how the concept performs in different contexts, such as night-time, crowded buses, or in combination with remote monitoring.

An interesting question that emerged from the first survey test (Appendix A) is whether participants would trust the bus more if they could see how crowded it is before boarding. This is an external feature (e.g., an app) and outside the interior scope, but it is worth considering as a complementary measure.

FINAL REFLECTION

This project has shown that interior design can significantly support perceived safety in autonomous buses. The Heartbeat Bus demonstrates that it is possible to design a bus that feels safe, predictable, and supportive, even without a driver. The project contributes to the growing body of research on autonomous vehicle acceptance and offers concrete design recommendations for future autonomous buses.

The ultimate goal is not to remove all staff but to create a bus that feels safe enough that staff are only needed in exceptional cases. The Heartbeat Bus is a step towards that future.



Thank You

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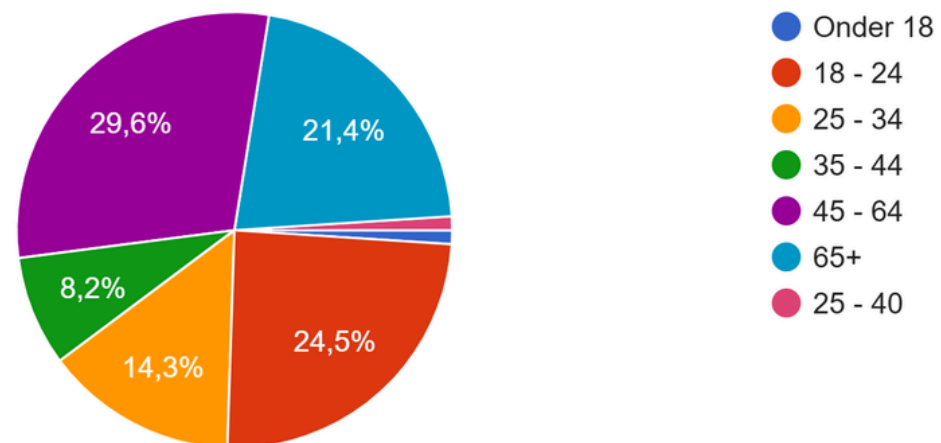
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Appendices

A: FORM TESTING PERCEIVED SAFETY FACTORS

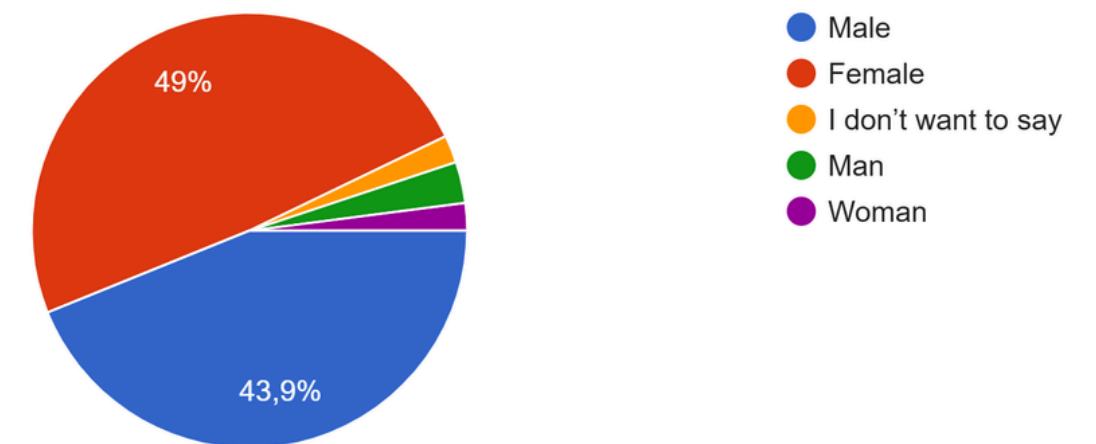
How old are you?

98 antwoorden



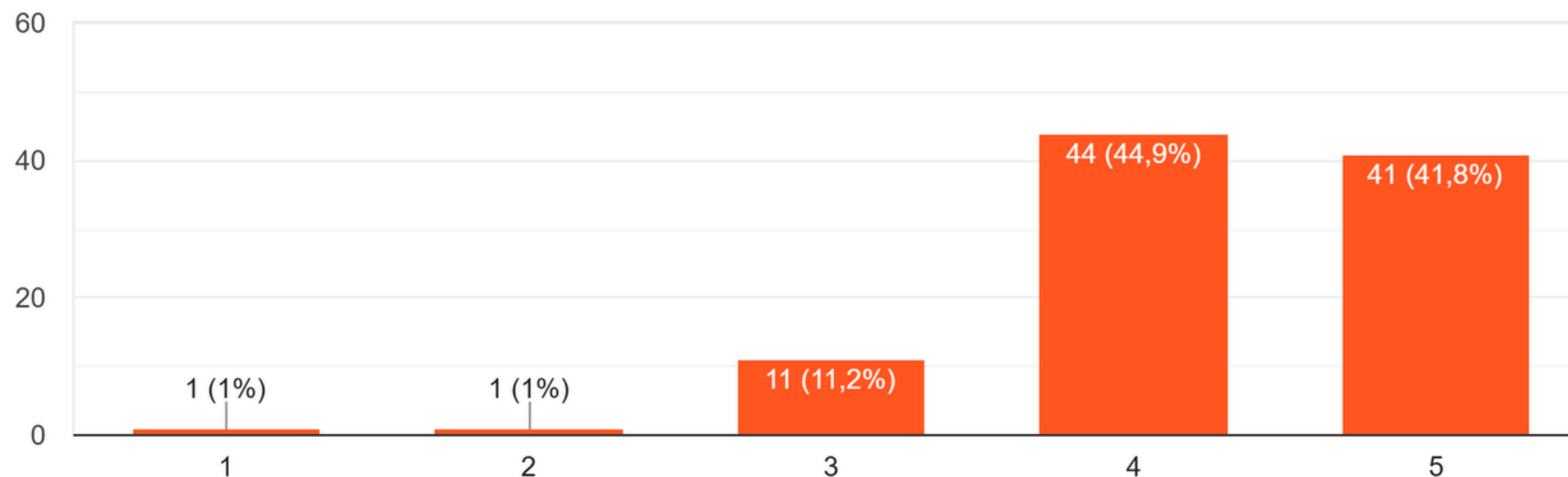
Which gender do you have?

98 antwoorden



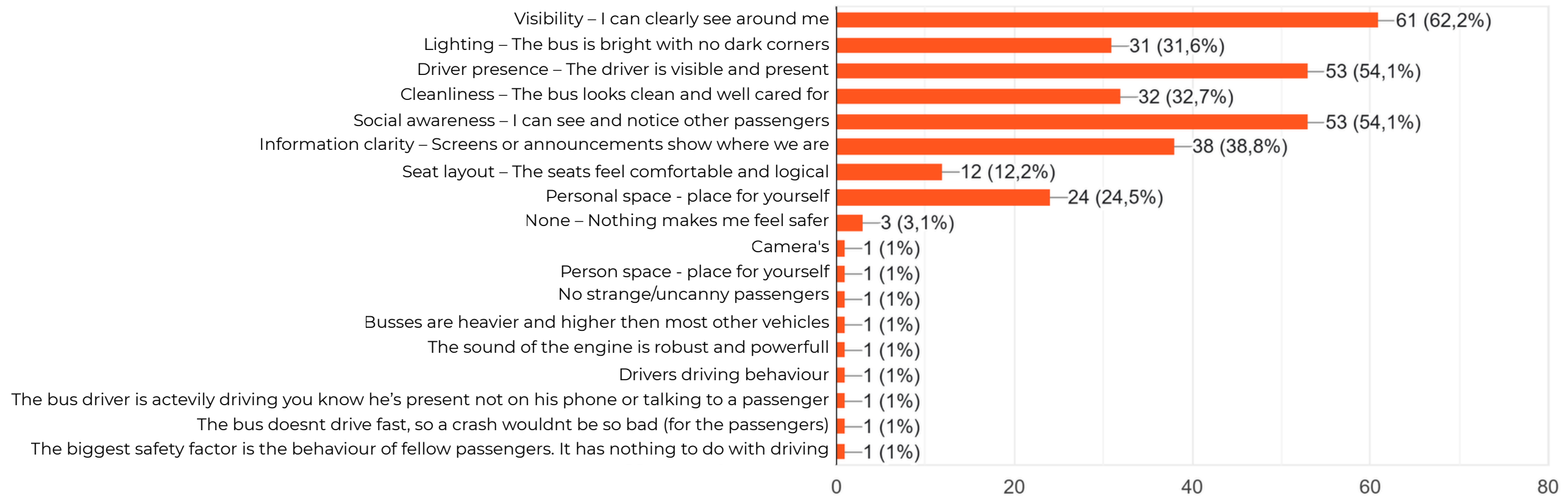
How safe do you usually feel in a normal bus with a driver?

98 antwoorden



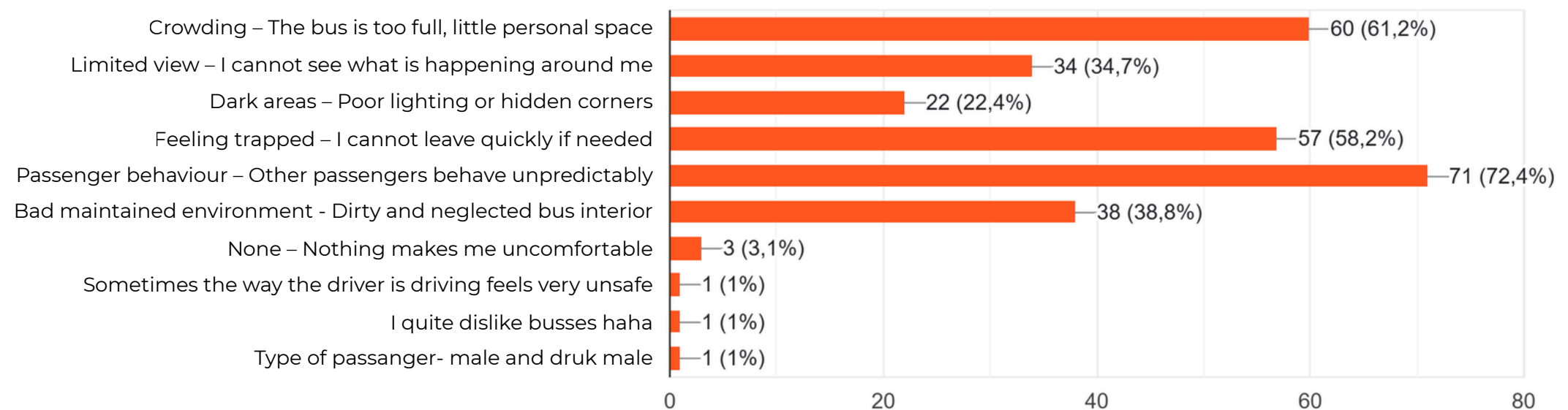
What makes you feel safest inside a normal bus? (Select 3 answers)

98 antwoorden



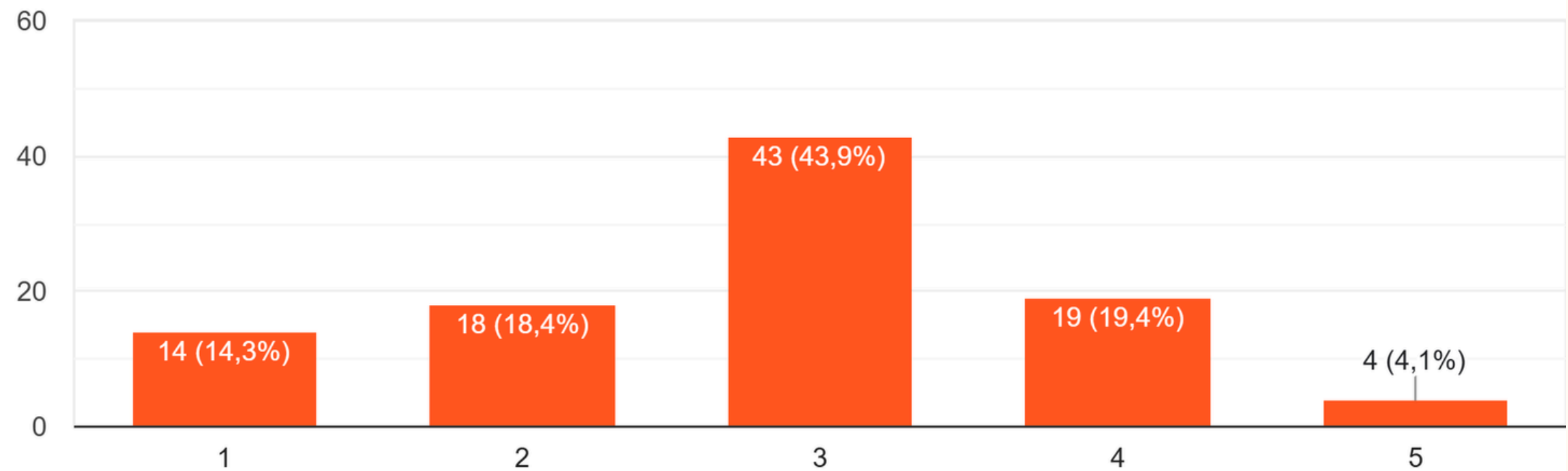
What makes you feel most uncomfortable or unsafe in a normal bus? (Select 3 answers)

98 antwoorden



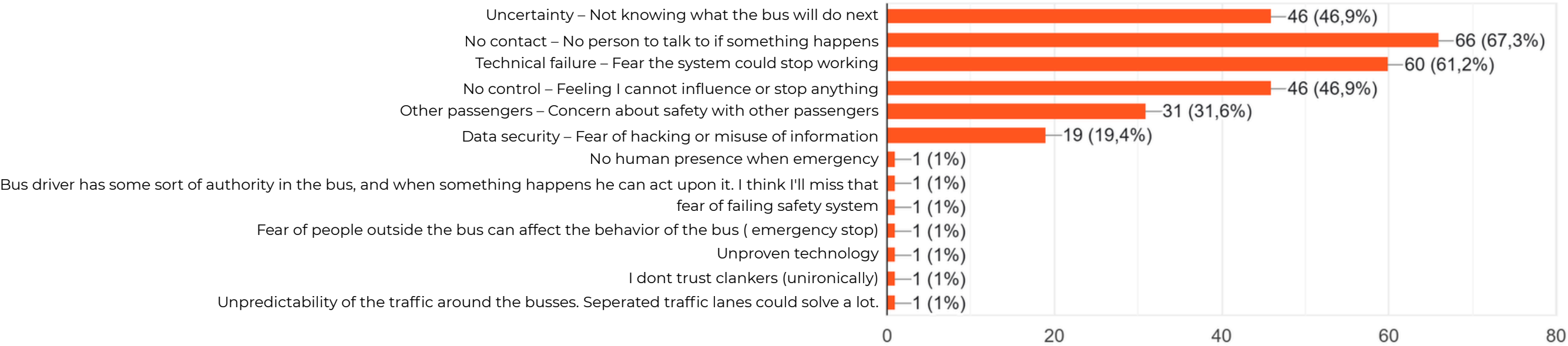
How safe would you feel in a driverless bus?

98 antwoorden



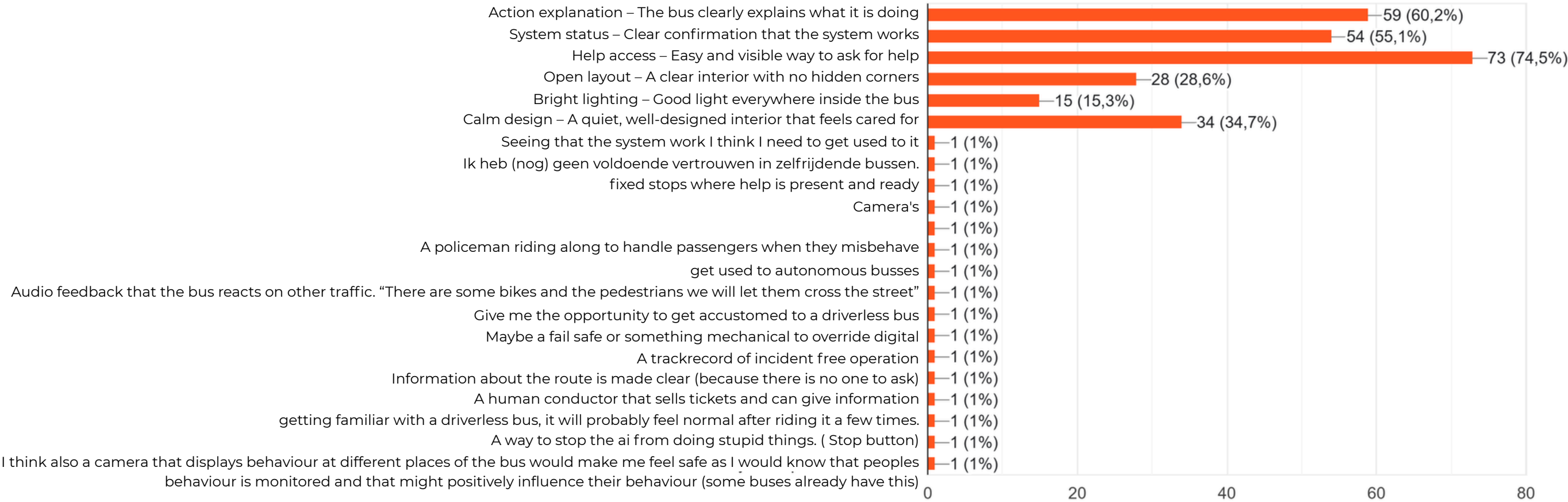
What would make you feel most unsure or worried in a driverless bus? (Select 3 answers)

98 antwoorden



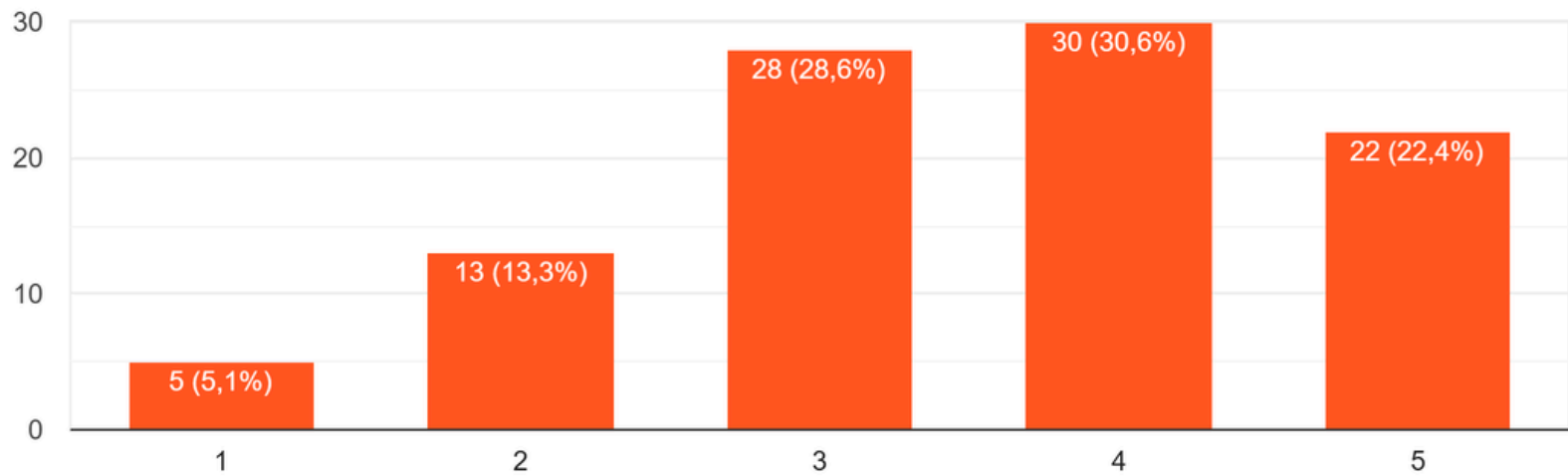
What would increase your trust most in a driverless bus? (Select 3 answers)

98 antwoorden



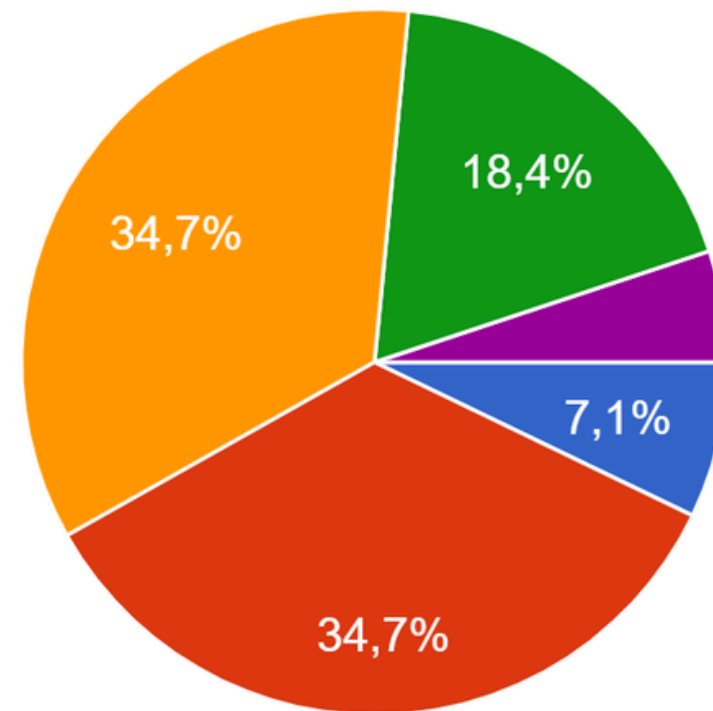
How important is it for you to understand why the bus makes certain decisions (like braking or turning because of a biker on the road)?

98 antwoorden



If you must choose one main priority for designing a driverless bus, what should it be?

98 antwoorden



- Overview – Clear visibility of the entire space
- Transparency – Technology explains what it is doing
- Assistance – Easy access to help
- Social safety – Feeling safe with other passengers
- Atmosphere – A calm and comfortable environment

Do you have any other ideas or thoughts that could help make a driverless bus feel safer?

Having a security guy on board

een soort vervanger voor buschauffeur dus dat het nog steeds een beetje persoonlijk voelt

Maybe a security guard to ensure nobody misbehaves or is bothering anyone.

Perhaps turn the bus stop into a metro station, where passengers can only pass through the gate with a ticket. This is to filter out some sketchy fare dodgers. And a strong, broad security guard to throw aggressive types off the bus if necessary.

Some of these questions makes you choose, even tho you might not think any are good at all.like the question before. I had to choose one, but none would made me feel safer if the bus is driving automatically. Please give the option ' none'

And the question, how safe do you feel in a driverless bus, is very hard to answer. It depends on so many things

Like I mentioned earlier I think having a bus that has a screen where live camera footage of different places in the bus would increase my feeling of safety as people know they are being monitored (although perhaps this could also make other people feel less safe)

I would also feel safer if I can see beforehand how crowded the bus will be in for example NS app. If I know the bus will be empty except for one person and the next will have a bit more and I am not in a rush I might choose the second bus.

Possibly the mechanical fail safe or atleast some way to get out if you really have to

Noodknop bij elke stoel voor snelle communicatie met hulpdiensten

The answers and questions in this interview are slightly directive. Before drawing conclusions based on the data it would be good to review some of the scenario's with your professor.

It would be interesting to compare experienced safety of autonomous metros/trains with those of regular traffic.

It would be interesting to compare your outcomes with the percieved safety of the item of autonomous taxis/cabs in San Francisco (like Waymo)

Why do we need driverless busses? Feels impersonal

Knowing there is a human remotely monitoring, so when the system fails a human can override and take control.

As a passenger I would feel the safest if the routes of the bus are not through very busy areas. I would also be worried from a pedestrian or cyclist perspective as I don't know if I could trust a bus to detect everything (like someone falling in front of it). That would also worry me about a normal bus as well though.

Misschien een gewenningsfase en een rustige rijstijl en camera met contact mogelijkheid.

No because i do not want it

The route the bus takes is not toot crowded, not too complex to interpret

When I actually experience autonomous busses a couple of times and all goes well, I quickly get used to it.

Own bus lanes as much as possible

Navigatiescherm zodat je route kan volgen

Generally accepted and independent Safety certification

Better control of who can access the bus

Maybe an app so you can see what the bus is seeing around it. Like the screen in a Tesla with all the bikes and other traffic arrou d the car. If tou want you can see it on your phone

A couple of buttons to stop the bus

ALGEMENE CONTEXT

De productmanager is verantwoordelijk voor de inrichting van trams en bussen bij HTM. Zij heeft recent nieuwe elektrische bussen aangebesteed en ingericht, en is bezig met nieuwe trams.

De innovatiemanager houdt zich bezig met visievorming rond innovatie en autonomie. HTM doet zelf nog geen autonome pilots, maar is via DAM Shuttles (een bedrijf waar HTM stakeholder in is) betrokken bij ontwikkelingen zoals de autonome bus in Rotterdam (Rivium – Metro Schiedam).

VRAAG 1: WORDT VEILIGHEIDSGEVOEL ACTIEF MEEGENOMEN BIJ ONTWERPEN OF SELECTEREN VAN BUSSEN? OP WELKE MANIER?

Ja, actief en bewust.

HTM heeft bij de laatste aanbesteding van bussen en trams bewust veel punten toegekend aan interieurkenmerken in het gunningsmodel.

- Niet alleen harde eisen (aantal stoelen, beenruimte, etc.), maar ook subjectieve aspecten zoals uitstraling, sfeer, beleving en doorstroming werden beoordeeld.
- Leveranciers moesten aantonen hoe zij aan deze eisen voldeden, en de beste (meest passende) oplossing kreeg de meeste punten.
- HTM werkte met een interieurgids en sfeergids om de gewenste beleving vast te leggen.

Belangrijk mechanisme: Als een vervoerder veel punten geeft aan interieur en veiligheidsbeleving, worden leveranciers gestimuleerd om daarin te investeren. Bij puur prijsgestuurde aanbestedingen gebeurt dat niet.

"Als jij zegt van nou ik heb 100 eisen over dat interieur, maar ik geef er uiteindelijk maar 10 punten voor van de 100, dan gaat de inschrijver niet heel veel moeite doen om aan jouw wensen te voldoen. Als jij 90 punten geeft voor de goedkoopste prijs en 10 punten voor het interieur, dan krijg je niet wat je wil."

VRAAG 2: SPECIFIEKE ONTWERPKEUZES IN BUSINTERIEUR DIE BIJDAGEN AAN VEILIGHEIDSGEVOEL

De Productmanager noemde een aantal concrete

ontwerpkeuzes die in de aanbesteding van HTM waren opgenomen:

Zichtlijnen

"We hebben gezegd dat je vanaf elke zitplaats minimaal twee meter vooruit moet kunnen kijken. En dat je door een raam moet kunnen kijken. Dus we willen geen zitplaats tegen een muur."

Verlichting

"Elke zitplaats moet minimaal zoveel lux verlichting hebben. En ook een maximum, want het moet ook niet een ziekenhuisgevoel hebben. Want dan is het niet meer een aangename sfeer."

Ook kleurtemperatuur (warmte van het licht) was onderdeel van de eisen.

Noodvoorzieningen

Tram: "In de tram hebben we bij elke deur een deurnoodknop. Bij elke tramdeur zit ook een noodspreekverbinding met de bestuurder. Als je die indrukt, dan krijg je meteen contact met de tramstuurder."

Bus: "Bij de bus hebben we die alleen bij de rolstoelplek. En een buschauffeur kun je als reiziger naartoe lopen en aanspreken. En de tramstuurder zit bij ons in een afgesloten cabine."

Cameratoezicht

Trambestuurder kan alle camerabeelden in het voertuig zien.

Bus: "We projecteren die beelden ook op de schermen in de bus zelf. Dus een reiziger ziet ook zichzelf op die beelden. Mensen die kwaad in de zin zijn, denken: oh, ik sta op beeld. Dat helpt heel erg in het veiligheidsgevoel."

Dit wordt volgens HTM gezien als een zeer effectieve maatregel voor het veiligheidsgevoel.

Sfeer en rust

Rustig kleurgebruik, hoogtelijnen die op elkaar aansluiten, geen bonte kleurencombinaties.

Redenering: "Wij zijn er ook wel een beetje van overtuigd dat veiligheid ook te maken heeft met een aangename sfeer. Op het moment dat je een rustig voertuig hebt, met op elkaar afgestemde kleuren, dat je bijvoorbeeld

hoogtelijnen met een kleurgebruik op dezelfde hoogte hebt, zodat je een rustig beeld hebt. Dat helpt indirect ook gewoon. Mensen voelen zich aangenamer en dus ook veiliger."

VRAAG 3: BEKENDE KLACHTEN, ZORGEN OF UITDAGINGEN VAN PASSAGIERS

Uit het HTM-panel (feedback via app) en gesprekken kwamen de volgende punten naar voren:

Overlast van medereizigers

Grootste bron van onveiligheidsgevoel: groepen jongeren, met name rond scholen (druk, rennen, schreeuwen). "En dat is ook zowel een gevoel van onrust als gewoon ongemak, als ook een stukje onveiligheid."

Rijstijl van de chauffeur

Veel feedback gaat over rijgedrag: hard remmen, optrekken, etc. Dit wordt direct gerelateerd aan (on)veiligheidsgevoel. Positieve feedback: als een chauffeur alert reageert op situaties in de bus, wordt dat als veilig ervaren.

Zitplaatskeuze als copingmechanisme

Passagiers kiezen bewust een plek vlak achter de buschauffeur als ze zich onveilig voelen. Bij de tram is dit lastiger (chauffeur zit in afgesloten cabine).

Dit wordt door HTM niet actief gestuurd met ontwerp, maar is een bekend gedrag.

Zwartrijden

Zichtbaarheid van BOA's (handhaving) wordt door reizigers gewaardeerd; zwartrijden geeft een onveilig gevoel, ook al is de directe impact op veiligheid beperkt.

VRAAG 4: RICHTLIJNEN OF CRITERIA MET BETREKKING TOT PERCEIVED SAFETY

HTM hanteert een combinatie van:

Aanbestedingscriteria (zelf opgesteld):

- Meetbare eisen: beenruimte, stoelbreedte, gangpadbreedte, lux-waarden verlichting, zichtlijnen.
- Subjectieve eisen: sfeer, uitstraling, beleving – beoordeeld door expertteam.

Wettelijke eisen:

- RDW-goedkeuring voor voertuigen.
- Regels voor openbaar vervoer (o.a. toegankelijkheid, veiligheid).
- Astrid gaf aan dat perceived safety niet expliciet in de wet staat, maar dat de optelsom van eisen (zicht, verlichting, noodvoorzieningen) bijdraagt aan sociale veiligheid.

Kern: Perceived safety wordt bij HTM geoperationaliseerd via concrete, meetbare en beoordeelbare ontwerpkenmerken in het aanbestedingstraject.

VRAAG 5: WORDT ER AL NAGEDACHT OVER VEILIGHEIDSBELEVING IN AUTONOM OV?

Ja, maar nog in visiefase.

- HTM doet zelf geen autonome pilots, maar volgt ontwikkelingen via DAM Shuttles.
- De autonome bus in Rotterdam (Rivium – Schiedam) wordt genoemd als praktijkvoorbeeld. Innovatiemanager adviseert om daar zelf mee te reizen en ervaringen van reizigers te observeren.

"Die bus in Rotterdam, daar mag je eigenlijk niet staan in de bus. Als hij remt, dan doet hij dat soms best wel plotseling. En dat is ook wel heel gek, want dat ben je ook niet gewend van een bus. Dus daar had je ook op een hele andere manier safety."

Reflecties op autonome bussen

Een autonome bus lijkt meer op tram of metro (geen chauffeur in de buurt).

Belangrijke thema's:

- Drempel voor reizigers: geen bestuurder aanwezig voelt voor veel mensen als onveilig.
- Rijgedrag: autonome voertuigen kunnen onverwacht remmen (ervaring met testritten), wat wennen is.
- Zicht op omgeving: bij een bus kijk je nog naar buiten, bij metro vaak niet. Dit kan verschil maken in oriëntatie en comfort.

Aandachtspunt van de innovatiemanager

Vanuit afdeling Reizigers wordt gekeken: hoe beleven reizigers de overgang naar voertuigen zonder bestuurder? "Ik denk dat het een grote vraag is in hoeverre mensen zich fijn voelen om zo'n voertuig in te stappen, en weten dat er geen bestuurder in zit."

Dit wordt gezien als een grote ontwerp vraag voor de

toekomst.

VRAAG 6: WAT ZOU VERBETERD KUNNEN WORDEN ROND VEILIGHEIDSBELEVING?

Er werd geen expliciete wishlist gegeven, maar wel een aantal inzichten:

- Bus vs. tram: in de bus is er direct contact met de chauffeur; bij tram is er een noodspreekvoorziening nodig. Voor autonome bussen is dit een ontwerpuitdaging.
- Handhaving: zichtbare BOA's dragen sterk bij aan veiligheidsgevoel. Bij bussen gebeurt controle minder vaak (chauffeur heeft overzicht).
- Instapregime: HTM kiest bewust voor instappen alleen voorin (bij chauffeur), om menselijk contact te creëren. Dit wordt gezien als een bewuste keuze voor sociale veiligheid.
- Meer onderzoek nodig: Astrid en innovatiemanager geven aan dat het interessant zou zijn om bij metro's (vaak al autonoom) te kijken naar veiligheidsbeleving, en om zelf ervaring op te doen bij bestaande autonome shuttles.

1. WORDT HET VEILIGHEIDSGEVOEL VAN PASSAGIERS BINNEN JULLIE ORGANISATIE ACTIEF MEEGENOMEN BIJ HET ONTWERPEN OF SELECTEREN VAN BUSSEN? OP WAT VOOR EEN MANIER?

Meestal wordt het ontwerp van bussen bepaald tijdens de aanbesteding. De opdrachtgever (vaak de provincie, soms een vervoerregio/samenwerkingsverband) geeft tijdens de aanbesteding aan wat zij belangrijk vinden en waar zij de vervoerders op beoordelen in een materieelplan. Afhankelijk van de beoordelingscriteria wordt de nadruk op bepaalde elementen gelegd. Comfort is hier vaak één van de belangrijkste van, duurzaamheid kan ook zoiets zijn. Sociale veiligheid kan hier alleen indirect onderdeel van zijn. Ik zeg hierbij indirect, omdat in Nederland is afgesproken dat tijdens aanbestedingen niet geconcentreerd mag worden op sociale veiligheid. Nu is sociale veiligheid vaak wel te vertalen in een vorm van beleving of sfeer, dus dan kan het wel nog terugkomen.

De beoordelingscriteria en dus de aandachtspunten vanuit ons zijn vaak gebiedsspecifiek. In steden is sociale veiligheid vaak meer een ding dan op het platteland. De algehele passagierservaring wordt meegenomen in het ontwerp van het businterieur. Dit zal altijd een afweging zijn tussen alle elementen, waaronder comfort, sociale veiligheid en budget.

In een beperkt aantal gevallen worden bussen tijdens de looptijd van een concessie besteld. Dan wordt in overleg met de opdrachtgever het ontwerp vastgesteld. Afhankelijk van de lokale problematiek zal hier in meer of mindere mate aandacht zijn voor sociale veiligheid. Daarnaast is er aandacht voor sociale veiligheid op andere vlakken dan het busontwerp.

2. ZIJN ER SPECIFIEKE ONTWERPKEUZES IN HET BUSINTERIEUR DIE BEDOELD ZIJN OM PASSAGIERS ZICH VEILIGER TE LATEN VOELEN? (BIJVOORBEELD VERLICHTING, ZICHTLIJNEN, INDELING VAN STOELN, CAMERAGEBRUIK, ETC.)

Ja zeker, je noemt al een aantal goede. Verlichting an sich (waaronder lichtintensiteit) kan hier een rol spelen, alsmede de toepassing van sfeerverlichting/gekleurde verlichting en

kleurgebruik in de bus als geheel. Camera's hangen door heel de bus, die beelden worden vaak ook op de beeldschermen getoond om reizigers duidelijk te maken dat ze gefilmd worden. Dit is ook speciaal voor de sociale veiligheid.

Wat je tegenwoordig steeds vaker ziet is de toepassing van hoge rugleuningen (bij alle vervoerders). Hiervoor wordt gekozen vanwege het comfortaspect. Dit heeft wel een negatieve uitwerking op de sociale veiligheid, want je zit veel sneller verstopt achter een rugleuning. Ditzelfde geldt voor 2-zits versus 4-zits opstelling van de stoelen. Bij stedelijk vervoer wordt nog wel met enige regelmaat voor 4-zits gekozen, maar over het algemeen krijgt 2-zits de voorkeur vanwege het comfortaspect. Dit maakt de bus wel minder overzichtelijk.

Je kunt ook nog denken aan de tussenwanden in de bus (bij de deuren). In sommige bussen is dit een lage tussenwand, wat de bus overzichtelijker maakt.

De binnenspiegel voor de chauffeur is belangrijk, deze houdt zo zicht op de reizigers in de bus. Afhankelijk van het ontwerp van de bus en de hoogte van de rugleuningen zijn er meer of minder dode hoeken. In gelede bussen kan je maar zeer beperkt achterin kijken als chauffeur, je zou hier kunnen overwegen camera's te hangen die de chauffeur ziet (de reguliere camerabeelden zijn voor de chauffeur normaal niet te zien).

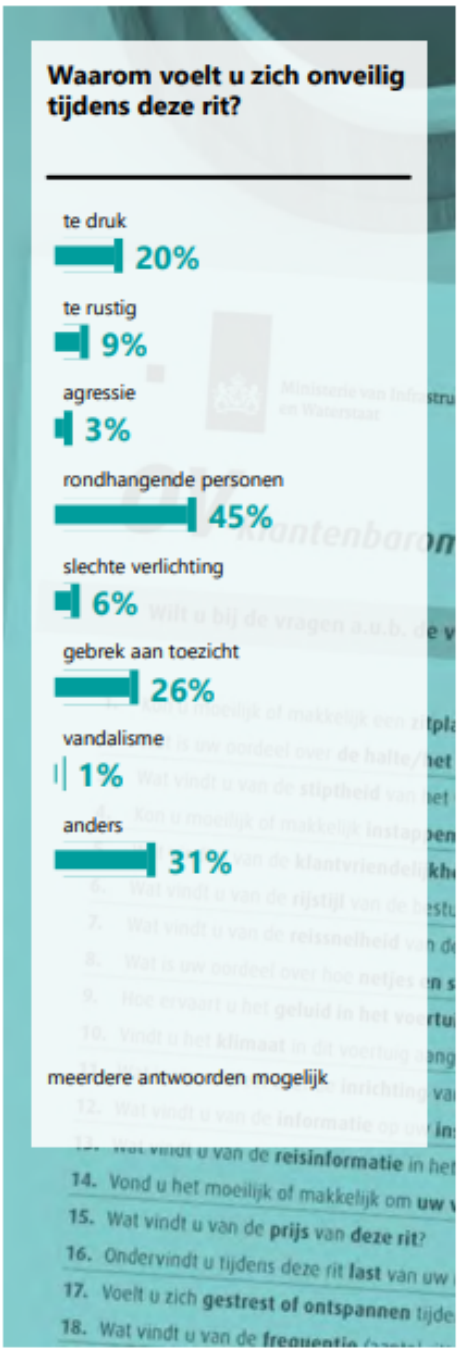
Daarnaast is door materiaalgebruik de bus wat meer vandalismeproof te maken. Hoe minder tafeltjes, voetensteunen, multimediaconsoles etc., hoe minder vandalismegevoelig. Dat heeft vaak ook indirect invloed op het gevoel van sociale veiligheid.

3. ZIJN ER BEKENDE KLACHTEN, ZORGEN OF UITDAGINGEN VAN PASSAGIERS MET BETREKKING TOT HET VEILIGHEIDSGEVOEL IN BUSSEN? ZO JA, WELKE ZIJN DAT?

Dat er passagiers zijn die zich (soms) onveilig voelen speelt natuurlijk ook in de praktijk. Vandalisme wordt regelmatig

aangekaart als een probleem door reizigers wat hen onveilig doet voelen; maar veruit het meest door gedrag van medepassagiers.

Wat wellicht interessant is, in de ov-klantenbarometer is bijvoorbeeld in de concessie Haaglanden Streek gevraagd waarom mensen zich onveilig voelen tijdens de rit, met de volgende motivatie:



Deze vraag is gesteld bij de concessies in de MRDH (metropoolregio), dus dan kun je ook de grote steden en wat meer de rustigere dorpen er omheen vergelijken.

4. ZIJN ER RICHTLIJNEN OF CRITERIA WAAR REKENING MEE WORDT GEHOUDEN BIJ HET ONTWERP OF DE INRICHTING VAN BUSINTERIEURS MET BETREKKING TOT PERCEIVED SAFETY (VEILIGHEIDGEOVOEL)? WELKE ZIJN DAT?

Deze vraag zou je het best bij een busleverancier kunnen stellen. Er zijn zeker wettelijke eisen en richtlijnen waar bussen aan moeten voldoen, bijvoorbeeld op het vlak van toegankelijkheid. Of er voor perceived safety ook zoiets is durf ik niet te zeggen. Het is de busleverancier die er normaliter voor zorgt dat wij met onze wensen binnen de richtlijnen blijven.

5. WORDT ER BINNEN JULLIE ORGANISATIE AL NAGEDACHT OVER VEILIGHEIDSBELEVING IN MEER GEAUTOMATISEERD OF AUTONOOM OPENBAAR VERVOER? ZO JA, OP WAT VOOR EEN MANIER?

Nee niet echt, de eerste stap is autonoom vervoer waarbij er nog een personeelslid in het voertuig blijft. Zolang dit het geval is zal de sociale veiligheid toenemen (minder aandacht nodig voor het besturen van het voertuig). Pas wanneer er helemaal geen personeel meer aanwezig is, zal sociale veiligheid significant anders worden dan in bestaande bussen. Het is overigens wel een interessant onderwerp, waar zeker aandacht voor nodig is.

6. WAT ZOU VOLGENS JULLIE VERBETERD KUNNEN WORDEN RONDOM DE VEILIGHEIDSBELEVING VOOR PASSAGIERS?

Kijk hiervoor vooral ook naar de OV-klantenbarometer van het CROW en er zijn ook veel aanverwante onderzoeken. Hieruit blijkt dat overlast door medereizigers vaak wel een aandachtspunt is, die ook significante impact heeft op de sociale veiligheidsbeleving. Incidenten komen (helaas) nu eenmaal met enige regelmaat voor, wat veelal ook een maatschappelijk probleem is. De aanwezigheid van personeel, of het nu de chauffeur is of door frequente controles, is belangrijk voor het veiligheidsgevoel.

1. WORDT HET VEILIGHEIDSGEVOEL VAN PASSAGIERS BINNEN JULLIE ORGANISATIE ACTIEF MEEGENOMEN BIJ HET ONTWERPEN OF SELECTEREN VAN BUSSEN? OP WAT VOOR EEN MANIER?

Er wordt wel gekeken naar de veiligheid van passagiers en chauffeurs in bussen, maar het belangrijkste ontwerp van de voertuigen wordt gedaan door de producenten, waardoor er slechts beperkt mogelijkheden zijn om te wijzigen (bijv. kleurstelling, locatie camera's, veiligheidsglas). Door de menselijke aanwezigheid van een chauffeur (m/v) speelt het veiligheidsgevoel in de bus minder bij passagiers dan op de halte of in de metro. Echter, tegen onveiligheid vanuit agressieve reizigers zijn er voor de chauffeurs extra alarmesystemen, voertuigcamera's, rug-en spuugscherm en aanpasbare voertuigtemperatuur.

Bij de nieuwe metro's wordt meer naar het veiligheidsgevoel van reizigers gekeken. Naast alarmesystemen, worden reizigers via camera's in beeld gebracht en getoond, worden zichtlijnen zo gevormd dat men andere reizigers kan zien en wordt banken zo geplaatst dat er sociale controle mogelijk blijft.

Naast veiligheid spelen bij het interieur van bussen en metro's ook de doorstroming, comfort, en de mogelijkheid tot schoonmaken een rol. Wanneer comfort of reinheid minder zijn wordt het gevoel van onveiligheid vergroot.

2. ZIJN ER SPECIFIEKE ONTWERPKEUZES IN HET BUSINTERIEUR DIE BEDOELD ZIJN OM PASSAGIERS ZICH VEILIGER TE LATEN VOELEN? (BIJVOORBEELD VERLICHTING, ZICHTLIJNEN, INDELING VAN STOELN, CAMERAGEBRUIK, ETC.)

Camerabeelden worden live getoond op schermen, sfeerverlichting is feller op bepaalde donkere momenten, stoelen in coach opstelling verhinderen languit liggen met schoenen op tegenoverliggende bank, folie op wanden en gladde vloeren kunnen sneller worden gereinigd bij graffiti. Inzet van AI bij camera's om ongewenst agressief gedrag op perron snel te herkennen en hier op in te spelen. Ook speciale bekleding zodat graffiti en ander vandalisme eenvoudiger te herstellen is.

3. ZIJN ER BEKENDE KLACHTEN, ZORGEN OF UITDAGINGEN VAN PASSAGIERS MET BETREKKING TOT HET VEILIGHEIDSGEVOEL IN BUSSEN? ZO JA, WELKE ZIJN DAT?

Alleen in het voertuig zijn. Nachtelijke reizigers (stappers) met veel alcohol op en drugs gebruikt. Agressieve zwartrijders. Genderonvriendelijk gedrag. Teveel fietsen of kinderwagens in de voertuigen. Te grote drukte.

4. ZIJN ER RICHTLIJNEN OF CRITERIA WAAR REKENING MEE WORDT GEHOUDEN BIJ HET ONTWERP OF DE INRICHTING VAN BUSINTERIEURS MET BETREKKING TOT PERCEIVED SAFETY (VEILIGHEIDSGEVOEL)? WELKE ZIJN DAT?

Nee.

5. WORDT ER BINNEN JULLIE ORGANISATIE AL NAGEDACHT OVER VEILIGHEIDSBELEVING IN MEER GEAUTOMATISEERD OF AUTONOOM OPENBAAR VERVOER? ZO JA, OP WAT VOOR EEN MANIER?

Beperkt. Gaat dan vooral over fysieke veiligheid (aanrijdgevaar, brandgevaar, deursluitingsgevaar, etc.) omdat in een onbemande metro voor de passagier niet veel verandert. Wel kan de servicemedewerker anders dan een bestuurder veel meer tijd op klantgerichtheid, controle en verhoging veiligheid worden ingezet. Bij onbemande bus wordt hier nog naar gekeken. De huidige chauffeur heeft meer taken dan alleen veiligheid, ook informatie, verwelcoming en kaartverkoop.

6. WAT ZOU VOLGENS JULLIE VERBETERD KUNNEN WORDEN RONDOM DE VEILIGHEIDSBELEVING VOOR PASSAGIERS?

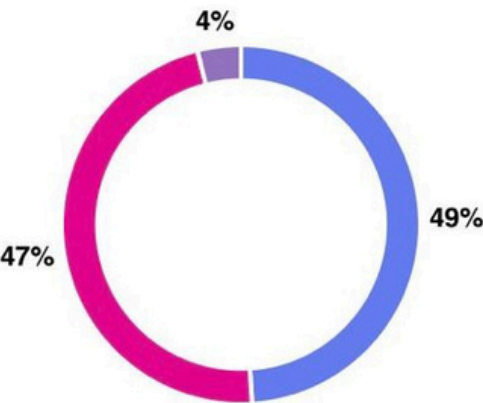
Sfeer en communicatie richting reiziger. Mooiere dingen worden minder snel kapot gemaakt. Daarnaast steviger handhaving en sneller ingrijpen bij misdragingen via bijv. cameratoezicht. .

E: FORM TESTING CONCEPT OPEN & CLOSED QUESTIONS

1. What is your gender?

[Meer details](#)

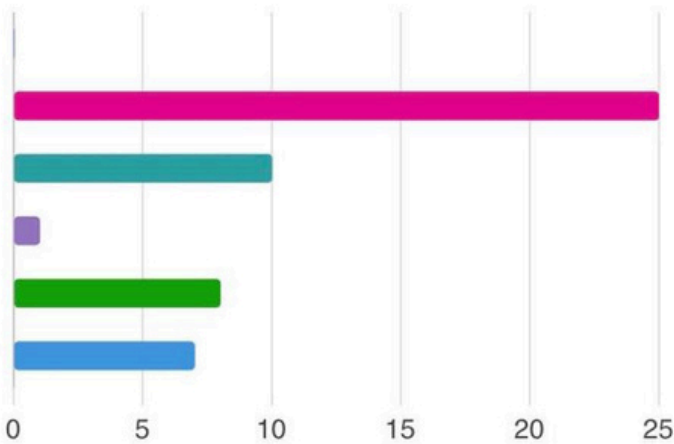
Woman	25
Man	24
Non-binary	0
Prefer not to say	2



2. How old are you?

[Meer details](#)

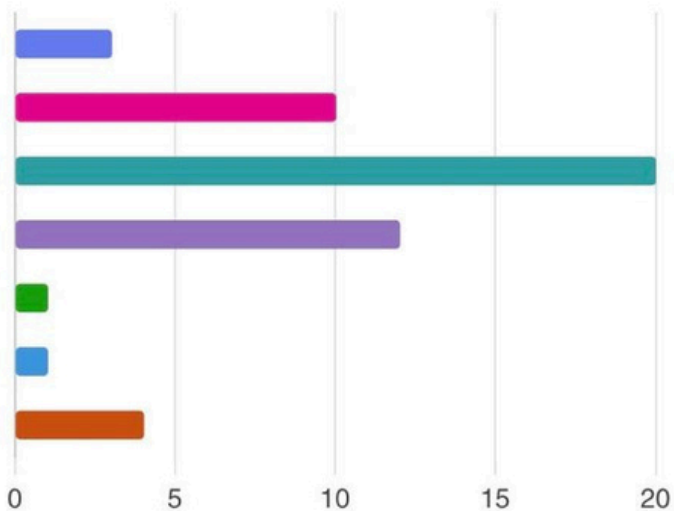
< 18	0
18 - 24	25
25 - 34	10
35 - 44	1
45 - 64	8
65+	7



3. How often do you travel by bus?

[Meer details](#)

Daily	3
Weekly	10
Monthly	20
Seasonal	12
Yearly	1
Never	1
Andere	4

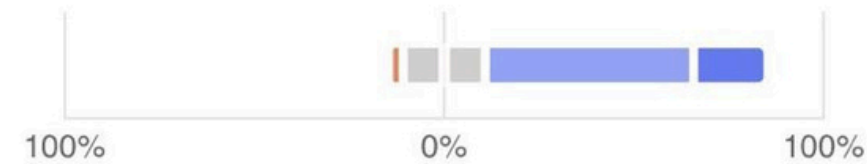


5. Compare Image A (normal autonomous bus) with Image B (redesigned bus).

[Meer details](#)

● Much worse ● Worse ● Same ● Better ● Much better

Compared to a normal autonomous bus (image A), how safe does this redesigned bus feel to you?



6. Questions about the Help Ring (1 = strongly disagree, 5 = strongly agree)

[Meer details](#)

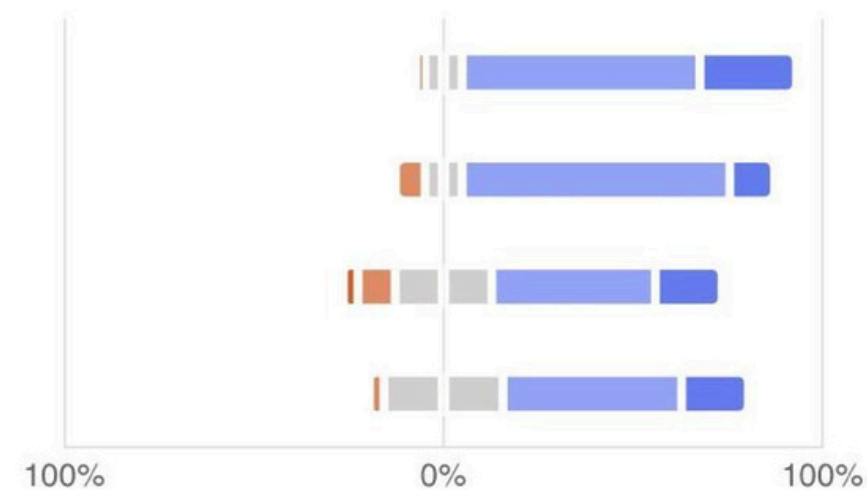
● Strongly disagree ● Disagree ● Neither agree nor disagree ● Agree ● Strongly agree

The ring helps me know where to find help if I need it.

The ring feels reassuring; I know I can get help

I like being able to ask questions via the screen (e.g. "Do I get off here?").

This element makes me feel safer in an autonomous bus than without it.



8. Questions about the Breathing ceiling (1 = strongly disagree, 5 = strongly agree)

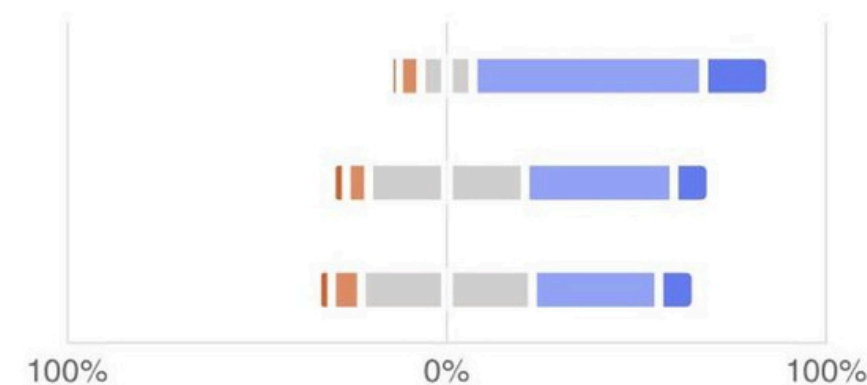
[Meer details](#)

● Strongly disagree ● Disagree ● Neither agree nor disagree ● Agree ● Strongly agree

The pulsing ceiling helps me understand what the bus will do (brake, drive).

The ceiling makes me feel calmer because I know what is coming.

This element makes me feel safer in an autonomous bus than without it.



What would you still need to understand or trust this help ring? Or would you change something about this element?

I would say perhaps not just one screen (maybe on opposite to it as well? As when I want to ask questions promptly and the screen is occupied/ the bus is really busy it might prevent me from using it

No change

People with hearingproblems, people with visual problems. Is there a special attention for them?

I would trust this help ring. Would be great if there more help ring in the bus.

Nothing. The function is clear to me

The ring is probably a good help,but i feel better to speak to a real person.

An app that is on your phone that is connected to the bus. So you dont have to walk trough the moving bus to get the help you need

De gele vorm om de ring heen heeft nog steeds scherpe randen, dat zou wat mij betreft zachter mogen.

The problem is with asking out loud, if you do not feel save, you do not want your environment to know that you are insecure about where you are going and this way make yourself a possible target.

-

Does it provide more information than the smartphone app? If this should replace the bus driver as a reassurance maybe it is helpful to have this screen close to any entrance.

Niets

-

Maybe of you put the button a real person is on the screen that helps you.

I could handle this. Perhaps the possibility of translating the text for tourists or expats.

What would you still need to understand or trust this breathing ceiling? Or would you change something about this element?

I do wonder what the threshold is for the bus breaking, because if I see feedback even after a small break that I would otherwise not notice it might be too much, but it sure would be nice for bigger breaks?

No change

Nvt

I agree with it.

Is this going to be the same for every bus? Will it become common knowledge? How will I know what each type of light means?

I rather look outside myself then looking at the seiling.

It has to feel natural and it is possible the breathing ceiling will inform in a natural way

Zou t niet weten...

No, good idea, makes it more organic

-

How will it work if there is unforeseen things like a car braking. Will it still blink before that?

Geen opmerkingen!

The change is lighting in de bus would annoy me I think

Nothing to change

I do want to know what the signals mean before I use the bus.

The ability to access it from the outside, if I wanted to know if it was the right bus, I would like to know before I get on, instead of when I'm in it and it were te drive off

If you use the speaking option it may be very loud in the bus so the ring can't understand you or the ring shouts through the bus if it's more quiet?

Hoe does it answer everyone's questions if multiple people need it simultaneously? Can imagine some people will stand next to it and (unconsciously) claim it the whole ride

It would feel to me a but akward to walk up to it while the bus is driving and people are looking at me. i wouldnt use the voice function, and even the screen function would be nicer for me if i have it in front of my own seat. I think its a good element that you thought of with the "where do i get off?", because that would be something i would like to know. Like if i put in where i need to get out, it puts a timer for example with how long i still have to wait, and a reminder to start getting up.

I think it is difficult to get there when the bus is driving. Maybe it would help of once in a way a voice over informs passengers about the ring and the option to ask questions. Otherwise I don't know if passengers know they can use it for their questions

For questions such as "Am I in the right bus?", it makes more sense to ask before or right after you get on the bus, rather than after you are already inside.

When the bus is crowded or the passengers are new to this bus, they might not see the screen. So it would be nice to have some more visible cues (e.g. on the top of the structure), so the existence and the location of a help center would be clearer to the passengers.

Vooralsnog lijkt mij dit prima als een start met deze mogelijkheid.

I would like to have the possibility to typ my question and get a written answer

Misschien een whatsapp lijn toevoegen dat mensen ook vanuit hun telefoon om hulp kunnen vragen bij noodgevallen

I think I would just use my phone instead of the ring

How well can you see it in daylight? And instead of memorizing the pattern, wouldn't it be better to have 4 lines? The left and right ones for turning, and the middle ones red and green to indicate accelerating and stopping for example. Or three lines where the middle can change colors between green and red

How bright are the lights? That it's not gonna feel like you're in a disco club with constantly changing lights

I think i would understand quite easily, especially if the light kind of flows in accordance with the direction of the bus. If it smooth you could follow it with your eyes. Some people might try to follow the light constantly if they are scared, what about neck pain? Maybe design it in a way it is visible form every position so you don't have to look straight up?

I am curious how this would work in my body. like what if this makes me more distracted or overwhelmed or even nausious? or maybe it has the opposite effect. It might make the journey feel more smooth, then its okay, otherwise it wouldnt per se make me feel more safe.

Passengers might not know what the different lights means. Maybe a strong brake (emergency brake) can have a different colour/light as well?

These lights are the main lighting source in this bus, so patterns would affect the overall brightness in the bus, and frequent changes might cause discomfort (especially when the environmental light intensity is low). Personally, what exact maneuver the bus is performing is not something I want to be aware of all the time, so a more subtle cue is preferred.

Vooralsnog zo proberen...

I would first like to have the experience begore I know if it works for me. The idea is compelling

.

maybe include colors

Im afraid itll be very busy, so i would prefer a screen with the necessary information so i dont have questions

is it also accesible for people in wheelchairs?

I don't think I would change anything

Nothing

No

Is the panel a real person or a bot?

M

Maken more than one

I just Hope it can really help. I feel like often technology like this breaks or doesn't work properly.

Als een bus remoerig is, kan het ding je dan verstaan? En sowieso hoort de hele bus je dan? Maybe ook een chat functie.

Soms stap je ook maar heel even in een bus om iets te checken, rijdt de bus dan niet al gelijk weg?

th

language button, and maybe to know if it speaks out loud or just shows you jnformation?

I can imagine if youre a woman at night in a bus, you dont want everyone to know that you don't know where you are (if you ask for directions for exmpl) or where you get off

Dat het mogelijk is om zowel je vraag te typen als spreken zodat je evt stil je vraag kan stellen en dus ook stil (in tekst) je antwoord krijgt. En als je je antwoord gesproken krijgt is het ook handig als het in tekst erbij staat

I don't think it adds anything

what about night busses and there's a dangerous situation what happens than?

I think it would be better if there would be multiple screens in the bus and not just one so people won't feel stressed to know where they are when it's occupied.

It feels impersonal to me, I'm not sure if I would use it

Personalized travel advice or experience based on OV-card travel history

I dont know if i could understand the lights quickly enough to actually anticipate the bus' actions

I think I need a video showing the exact effect or I need to experience it before being able to agree to this

Does it combine pulse types? Such as left turn and accelerating for instance

Nothing

No

.

Maybe some sounds

Sounds good

Lijkt mij redelijk misselijk makend?

i don't know if some people night get triggered due to the light switchinh

i dont think i this has additional value for me

Ik weet niet of het zo veel toegevoegde waarde heeft, want als je uit het raam kijkt kan je ook al zien of de bus naar links of rechts gaat en het is misschien vervelend als de bus remt dat het licht vrij snel knipperd voor mensen die daar gevoelig voor zijn.

I don't think it adds anything

nope

Nope everything is understandable

The ceiling should not be too intrusive, otherwise it would just create unrest for me

This is too much cognitive states for me. A maximum of 3 states is easier to understand and makes it more intuitive.

I would like to know if the info provided from the screens come from a trusted verified source or an ai chatbot. The ring itself is nice, but the use is not clear without additional written instruction. like the modernised train ‘stiltecoupé’ used to be démarcated by a very clear “STILTE” sign. Now there’s only a vague coloured light indicator, for which no one knows what it means.

I'm curious about the feedback of the screen. Is help offered straight away, or would the device first need a moment to think? Is there someone live on the other end of the line? If not, do we expect bots to be able to answer these kind of short questions quickly, like a bus driver would? And what would happen if there is a line or if the screen gets broken?

I am however very interested in the concept and I think it's definitely a nice addition to implement a kind of feedback hub like this to enable some communication in a transport modality that otherwise might feel lifeless and cold!

Use an app

Maybe like a sign with an i for info?

is one screen enough for all passenger??

It seems clear, feels more secure to talk to a person rather than to an automated screen

Barrier still feels to high to ask for help, id rather look up info on my phone, or if present ask the driver.

In a real bus the screens don't always work, so maybe also an paper option with stops

Choosing between talking or typing for safety reasons.

The left and right indicators could be nice if the fading in and out isn’t programmed to go on/off too abruptly. This way you could anticipate and brace, when having to stand, to avoid bumping into other people. However, I think for braking, it would only make the situation more stressful if the bus breaks out of the blue and the lights would show bright red or something.

I'm curious about the intensity of the pulses as I can imagine that some passengers might find pusling lights distracting or not too appealing. I'm also wondering about emergence stops: what happens in such cases? In what way does the breathing ceiling account for that?

I know the challenge of motion sickness is greatly related to the passenger's connection to the movement of a vehicle, so I really think that implementing a kind of visual stimulus like this is a must-have in an autonomous bus like yours!

It can also confuse you. And it is terrible if you can see the coming accident, while you are not able to do anything.

I think i would have the experience it to fully understand its effect on me and my safertt

what if you're not familiar with the meaning of the different lights? Is it visible during daytime, especially with the bigger windows?

It shouldn't be too much, overwhelming in the face but rather give lowkey noticeable directions

If all the ceiling light is changing constantly and the light level with it it can be annoying (some flicking the light switch). Maybe less intrusive light / extra light / different coloring light?

x

Maybe you are more aware of the driving than you are now.

Is there anything you do not understand or would change about this redesigned bus interior? What is it?

I think there being an emergency button at every seat would be nice, but I also think that 1 press is enough to trigger it might end up causing either bad actors abusing the button or people pressing it by accident, so maybe if it needs you to press it for 5 seconds to trigger?

No change

No

I understand it. Nog comment.

No

If the bus is very full,how can I ask for help??

It look like there is no glass in the windows

De kleur vd vloer is nu mooi, maar zal die zo blijven? Misschien meer gemarmerd, o.i.d. ?

No, it feels very welcoming

-

I feel like the helpscreen should mainly be for people that are handicapped, children that don't have a smartphone yet or are very unsure about how to use the bus and elderly people. It should be designed with those groups in mind, as I think that the majority of normally abled people nowadays will just use their smartphones for information.

Nee

The seats look like they have very hard edges. When I am standing in the bus and it's moving, bumping into them seems not to fun

Nothing yet

no

What would still be needed for you to feel safe in this bus without any staff on board?

Knowing that there are other women on the bus

No idea

Nvt

Yes!!!

Proof that the concept has been thoroughly tested and deemed safe by an authority

Safety Bellts. Wheelchair place. Camera's.

Maby something that improves social connection between travellers

Geen idee.

Wie kan de bus stilzetten? Op afstand te regelen?

Maybe something that empowers the other riders on the bus to help out if something happens

-

In a way it should feel like that there is a person still supervising what's happening inside the bus. Maybe like in the metro with the screens that show what the cameras are filming. Maybe a real person speaking through the speakers every now and then if something is not right?

Geen opmerking. De nieuw ontworpen bus ziet er goed uit. Ik maak nooit gebruik van het OV maar deze bus ga ik zeker een keer proberen.

Emergency button

Emergency button if something bad happens on the bus like someone want to steal of a person it will signs the police.

I am an enthusiast of new technology and have confidence in autonomous vehicles.

124

How are changes communicated with the passengers? For example if there is a obstruction on the road or if the bus is broken?

No, I feel like this bus would be much safer and nicer

Maybe it comforts people if they can look through the front window of the bus? It seems to be closed of now but could be nice.

Yeah that in the render right now theres a big open space, which people would fall at if they walk there and the bus is driving. normally a bus driver waits for someone to sit if its an older person for example. maybe this one wont do that.

No

/

Vooralsnog lijkt mij dit prima.

No idea if larger windows make me feel safer or less safe

No

Maybe for people that have less mobility make something that they know the bus will wait for them to step out

Monitoring and a quick connection to police. If there are people with malicious intent in the bus, that are standing next to the help ring, you would not feel safe approaching the ring

-

I think I would just need the proof of it by going once. I am quite excited for these things so I don't really feel insecure about its quality. For me it would be mostly about the lack of social control with the absence of a bus driver. What if a crazy person loses it? Is there a way this person gets removed from the bus? Can there be 'bus safety guards' hopping on and off on buses to guard social safety?

a little robot that explains how this bus works when you get in.

Nothing else, I like how it is open and light inside.

/

De positieve statistieken na een periode van rijden zonder bestuurder.

a positive experience and by that: getting used to this no-driver-concept

Whatsapp lijn

yes I would, it would still ofcourse take a bit of time to get used to but I am in for the challenge

No
maybe some signs or arrows indicating where to get help (the ring)
.
Sometimes less is more - too many features might be too expensive or just not needed
No
Are there still lussen for standing spots
X
Not really. I would be excited to use this bus :)
.
is the bus on a fixed road? like as a tram or a car?
Love the interior! is there a night light?
-
I wonder if it feels safe without a driver or security
not really
How would you be able to buy tickets in the bus as a tourist?
No
Seats look to fragile. In my opinion, safety starts with comfort and peace of mind.

I think if i see it go well for a while i would trust it more. I feel usually more safe in a bus where the driver drives calmy, and less safe in a bus where the driver drives fast or breaks suddenly. Maybe being able to see the speed is a way to convey this to passengers?
How long does it stay at a bus stop? How does it know to wait longer if something goes wrong or people need more time to get in? How will people in wheelchairs get on the bus without staff helping them with a ramp?
.
I am not sure
Staff member
.
Be able to call someone
I think I would trust it
Noodrem, hulp knuppen
i think people need some time to adapt
Who is going to help when there are annoying passengers? expl if someone is smoking? zwartrijders? harrasment?
Dat de route van buitenaf ook zichtbaar is. Dus bv een rode streep midden op de weg, een beetje zoals een tram, dan is het voor overig verkeer ook voorspelbaar wat de bus gaat doen dus voelt het in de bus ook veiliger
See answer above
no idea
Perhaps the bus announcing itself with a friendly voice? So it still have something “human” in it
I think a bus with staff would be preferable
Personalized experience and welcome

Handles on the ceiling and sides of the chairs to grab onto seem crucial to me as well. To avoid strangers grabbing onto my chair/backrest when I'm seated.

I think the interior has already been done really nicely. It looks very clean, but also fitting to the wants and needs of the people of today (styling-wise).

Don't use those silly curved vertical elements and also not the horizontal u- forms.
Use an app with all the info: cameraviews of the traffic, questions about stops, emergency, etc.

I think the ceiling indicating visually what the bus is doing is nice, how will you communicate the different states to people is it hard to learn them?

curious how the front would look like

Give more space where the help screen is, now it may be uncomfortable to be standing in between two passengers and talking to a screen

No

X

No

Maybe some rearview mirrors would be nice, to check what sketchy men behind me are up to.
or maybe a women's only bus somehow.

This would of course greatly affect interior space, but the thing about buses that always "frightens" me the most is the thin walls. I'm not sure how I would implement this, but maybe adding some kind of perceived thickness might improve the feeling of safety inside!

If possible a servant- robot on board.
Intelligent speed adaptation (ISA) and make the speed visible.

Maybe show the literal navigation of the bus , so you understand where you go

with a chauffeur, it feels like people behave more polite/normal. What if someone misbehaves, is there an employee who can help?

Open space, feeling like you can get out easily when you need to, in case there is scary passengers on the bus etc.

Not much really, train is mostly the same experience

I need to know the system has been tested quite a while

I would wonder about the safety amongst passengers. The bus driver usually also controls situations where for example drunk behaviour or homeless people have to leave the bus. How do you handle that?

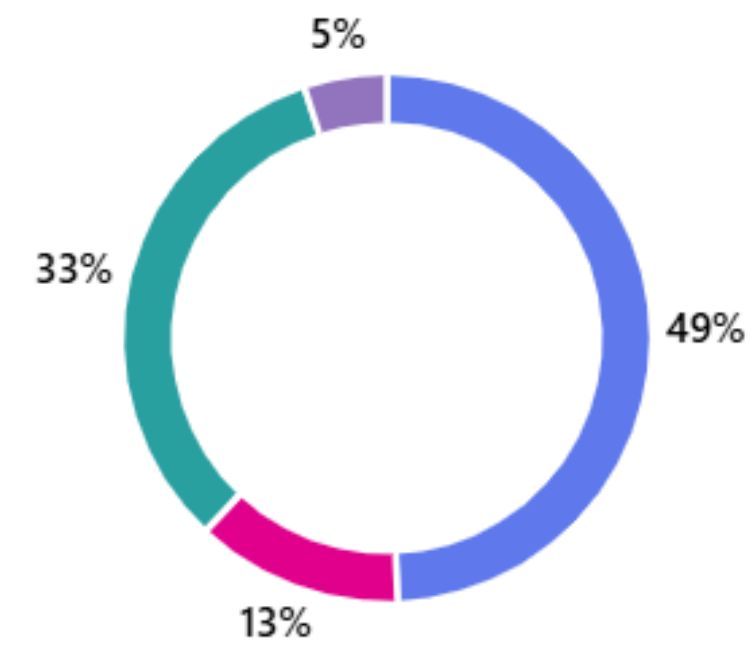
F: BYD INTERVIEW QUESTIONS

1. Looking at the help ring (the ring across floor, walls and ceiling with screens): is it realistic to build this into a bus? What are the biggest technical challenges (e.g., wiring, durability on the floor, mounting on walls and ceiling)?
2. Looking at the breathing ceiling (ambient LED lighting that pulses in different ways to show bus behaviour): is this technically feasible?
3. The screen at the front shows what the bus sees. Is this realistic to install at a readable size without blocking the view? Are there regulations about screens in general/near the front window?
4. Which part of this concept do you think would be the most expensive or difficult to maintain (cleaning, vandalism, wear and tear)?
5. Looking at the concept as a whole: do you think this is realistic for a bus in 15 years? What would need to change to make it work?

1. **In which bus would you feel safest?** Below, you can find all options and color/texture palettes.

[Meer details](#)

● Bus A	39
● Bus B	10
● Bus C	26
● No difference / they all feel equally safe	4



Id	Begintijd	Tijd van voltooien	E-mail	Naam	In which bus would you feel safest? Below, you can find all options and color/texture palettes.	Why does that bus feel safest to you?	The final bus design will try to combine the best elements from these versions. Which specific colors or textures from any of the three buses do you think should definitely be included to make passeng
1	14-6-2026 21:01	14-6-2026 21:02	anonymous		Bus A	Bright happy colour, vibrant lighting	Warm feeling of the orange bus
2	14-6-2026 21:01	14-6-2026 21:03	anonymous		Bus A	Feels warm and kind. Wood floor feels like home	Wood floor
3	14-6-2026 21:03	14-6-2026 21:04	anonymous		Bus A	More cosy and aesthetically pleasing	First bus is perfect
4	14-6-2026 21:03	14-6-2026 21:05	anonymous		Bus B	Feel calm	Non-wooden floor (it feels like private place for home) The cold tone color (like blue)
5	14-6-2026 21:07	14-6-2026 21:08	anonymous		Bus C	I like green. Is rustig	Wood with green
6	14-6-2026 21:06	14-6-2026 21:08	anonymous		Bus A	Because of the warm colours it feels the coziest therefor I'm less on guard. Middle one feels a bit like a hospital.	I think the warm (red/orange/yellow) colours autumnly, feel more secure than the hospital blues or the nature like greens!
7	14-6-2026 21:14	14-6-2026 21:18	anonymous		Bus A	b feels like a hospital, too clean A just feels right for some reason, I think because it looks cozy	I like the floor of C (no wood that feels wrong in a bus) I like the orange ring
8	14-6-2026 21:20	14-6-2026 21:22	anonymous		Bus A	Warm en gemoedelijk	Zoals gezegd het warme gemoedelijke wat minder agressie op. Misschien kalmeert het zelfs
9	14-6-2026 21:18	14-6-2026 21:23	anonymous		Bus B	Feels more spacious. Feels like you would have a better overview there. Also because it is lighter I feel like you would be able to see more of your surroundings in the bus (light will reflect)	I think the blue bus in general feels the safest. Maybe the darker colour around the windows as in het greenbus could also be applied to the blue one to accentuate the exits.
10	14-6-2026 21:22	14-6-2026 21:24	anonymous		Bus C	Natural positive colors. The warmth of 1 made me doubt though. 2 is too clinical	Wooden floor and soft warm colors
11	14-6-2026 21:25	14-6-2026 21:27	anonymous		Bus A	It feels cozy compared to the other options	Wooden finishes, warm color palettes
12	14-6-2026 21:21	14-6-2026 21:27	anonymous		Bus C	Modern. Geeft de indruk van goede en stevige materialen gemaakt te zijn	De wanden

13	14-6-2026 21:23	14-6-2026 21:29anonymous	Bus C	Probably because of a personal preference of the color green, but interior I also feel the combination of yellow and green gives a warm and calm feeling at the same time.	The overall yellow or orangish-yellow
14	14-6-2026 21:31	14-6-2026 21:35anonymous	Bus B	Clear and open	Green is a peacefull, soothing colour.
15	14-6-2026 21:34	14-6-2026 21:36anonymous	Bus B	helder, veel licht	witte wanden
16	14-6-2026 21:35	14-6-2026 21:38anonymous	Bus A	Bus A has a cozy feel to it, resembling a living room, like at home. I think that makes it feel the safest. The others look a bit like a hospital/dentist. Which should theoretically feel safe, but is not a place you would like to be	Wood floor, warm lightning and colors
17	14-6-2026 21:37	14-6-2026 21:39anonymous	Bus A	Feels cosy and warm	The color orange, the wooden floor
18	14-6-2026 21:36	14-6-2026 21:39anonymous	Bus B	It has a clinical atmosphere	The clours of B, but a natural texture or material would be nice
19	14-6-2026 21:38	14-6-2026 21:40anonymous	Bus C	The orange one relates more to red which doesn't calm me down. seats! Blue seems more like a hospital color. Green feels more calming which I think is important in a new autonomous bus.	The green ones floor and the green soft
20	14-6-2026 21:40	14-6-2026 21:43anonymous	Bus C	i like green alot, reminds me of nature which calms me	the wood flooring with green accents would be nicest
21	14-6-2026 21:41	14-6-2026 21:44anonymous	Bus A	Warm colours	The wooden floor
22	14-6-2026 21:04	14-6-2026 21:46anonymous	Bus C	It feels very calm	-
23	14-6-2026 21:47	14-6-2026 21:50anonymous	Bus C	C Groen is rust, sereen A te amicaal B steriel koud	Green
24	14-6-2026 21:54	14-6-2026 21:54anonymous	Bus A	Warm colours	Warm colours
25	14-6-2026 22:05	14-6-2026 22:08anonymous	Bus A	The warmth of the orange colour adds calmness	Warm colours and wood
26	14-6-2026 22:11	14-6-2026 22:11anonymous		No difference / they all feel equally safe	-
27	14-6-2026 22:12	14-6-2026 22:13anonymous		No difference / they all feel equally safe	They all give of the same vibes, so I don't really feel a difference in my perceived safety.
28	14-6-2026 22:34	14-6-2026 22:36anonymous	Bus A	Homely	warm colors
29	14-6-2026 22:36	14-6-2026 22:37anonymous	Bus A	Warm	Wood floor
30	14-6-2026 22:36	14-6-2026 22:38anonymous	Bus A	Warmer	The orangy walls

31	14-6-2026 22:43	14-6-2026 22:45anonymous	Bus A	It feels warm and cozy	Bus c accents with the window, colored seats. Bus a the warmth and color palette
32	14-6-2026 22:49	14-6-2026 22:50anonymous	Bus A	Primitieve look	Thec wood floor
33	14-6-2026 22:56	14-6-2026 23:01anonymous	Bus C	De kleur groen oogt rustiger en het kleur contrast met het middendeel is het grootst, waardoor ruimte in twee delen wordt opgedeeld en de ruimte beter te overzien voelt.	Het indelen in twee ruimtes door middel van kleur contrast. De groene rustige kleuren.
34	14-6-2026 22:59	14-6-2026 23:02anonymous	Bus C	i think the green details are most i chill/friendly/vibey	i preser the floor of the blue and orange one, orange most i think. also, the yellowish ceiling makes it look a bit more 'dirty' and dated, less fresh/clean
35	14-6-2026 23:01	14-6-2026 23:03anonymous	Bus A	The blue feels sterile like a hospital or mental institution Green feel like greenwashing and I don't like it	The soft warm lighting and wood flooring
36	14-6-2026 23:00	14-6-2026 23:05anonymous	Bus A	. The design looks great and it gives more space around the customer.	It gives me quite feelings
37	14-6-2026 23:10	14-6-2026 23:14anonymous	Bus A	Warmer colours	The wooden floor, less bright lighting, green or orange ring, warm colours (they make me feel comfortable)
38	14-6-2026 23:13	14-6-2026 23:15anonymous	Bus A	Warmte	The orange wall
39	14-6-2026 23:21	14-6-2026 23:24anonymous	Bus A	Warm colours feel safer	I love warm tones, for some reason I don't really like the wood Floor
40	14-6-2026 23:24	14-6-2026 23:27anonymous	Bus A	I think the warm colour palette feels like an embrace.	Wooden floors
41	14-6-2026 23:25	14-6-2026 23:29anonymous	Bus A	The cosiest, most like home	The wooden floor
42	14-6-2026 23:48	14-6-2026 23:49anonymous	Bus C	The green is soothing. The others are nice as well, it's close.	I like the warmth and the wooden floor of 1. I also like the tone of the wall at 2 and the fact the help ring is a light colour. In 3 the help ring feels maybe to dark?
43	15-6-2026 00:52	15-6-2026 00:55anonymous	Bus A	Fijn licht en de meest 'Cozy vibe'	Het hout en het licht
44	15-6-2026 01:47	15-6-2026 02:01anonymous	Bus C	Frisse, moderne en toch rustgevende uitstraling.	De crème-kleur van bus C.
45	15-6-2026 04:14	15-6-2026 04:16anonymous	Bus A	Je gooit dit antwoord maar in translate (liefs limai) De warme kleuren zorgen voor een fijne en vertrouwde huis omgeving	De kleuren en de houten vloer geven een huiskamer gevoel

46	15-6-2026 04:14	15-6-2026 04:18anonymous	Bus A	deze heeft de warmste kleuren :)	Donkere vloer met de warme sfeer en groene tinten. Geen felle kleur lampen
47	15-6-2026 06:58	15-6-2026 07:01anonymous	Bus A	Feels the most like a living room	Wooden floor looks the best, but the third one would be better for a longer period seeing as the wood will not stay clean. The orange lighting, orange ring, chairs don't is matter
48	15-6-2026 07:17	15-6-2026 07:19anonymous	Bus C	Earthy, forest, nature like tones that give peace and safety. The red-ish one makes me feel irritated and hurried	The wood floor of Bus A and the window edge covers of Bus B
49	15-6-2026 07:54	15-6-2026 07:55anonymous	Bus C	Don't know	Green
50	15-6-2026 07:54	15-6-2026 07:57anonymous	Bus C	The colours seem neutral, but not too cold. Option A is too old fashioned for me	The design of bus C combines the best combinatiion in terms of colour and textures
51	15-6-2026 08:00	15-6-2026 08:04anonymous	Bus C	Because of the warm and relaxing colors	The green seats and colors inside the bus, because green is the color of nature. People feel more relaxed. If you walk in a green forest after a walk you feel more grounded.
52	15-6-2026 08:17	15-6-2026 08:19anonymous	Bus A	warm colours, natural	wood floor and green ring and brown seats
53	15-6-2026 08:57	15-6-2026 09:01anonymous	Bus C	The floor looks like cork and thus softer. Blue looks too cool / like a warm and too cool tones. Public hospital, very sanitary, which is a transport that looks poorly maintained bit kill and not safe to me. A looks and isn't well illuminated tends to a bit gribby and thus grimy.	C is just a good balance in not too attract the weirdo types, which makes it feel more dangerous.
54	15-6-2026 09:06	15-6-2026 09:07anonymous	Bus C	Because of the green colour	The wooden floor from the first one!
55	15-6-2026 09:11	15-6-2026 09:22anonymous	No difference / they all feel equally safe	I feel like the colors make not that i think fresh colors, but a hint of a much difference. Its just personal warm color because too fresh is not preference for the vibe of the bus. nice to sit in but too warm feels more old.	
56	15-6-2026 09:23	15-6-2026 09:24anonymous	Bus A	Warm colours	Wood!!
57	15-6-2026 10:00	15-6-2026 10:05anonymous	Bus B	It looks clean, the others look a bit like the backrooms. But if B isn't clean i would prefer C, because it better hides dirtiness. Dirty feels unsafe, like it isn't watched and cared for.	I don't like the brown. Lighter colours are nice! Don't make it too "cosy" with warm colours. I also like the green, but would prefer a blue undertone light and wall and don't like the grey floor.
58	15-6-2026 10:35	15-6-2026 10:36anonymous	Bus B	I don't know	I don't know
59	15-6-2026 10:37	15-6-2026 10:38anonymous	Bus C	Ligtere kleurzetting. Groentinten. Ik zou aan c niets veranderen.	

60	15-6-2026 10:39	15-6-2026 10:41anonymous	Bus A	Warme bruine kleurstelling	De hele kleurstelling van bus A
61	15-6-2026 10:57	15-6-2026 11:04anonymous	Bus A	I think it is less bright, therefore it looks less stressful and more relaxing.	I'm not sure I would mix them, because then they would give a different feeling again. For example I would prefer the floor from bus C for a bus (it looks more durable and easy to clean), but the wood reminds me more of the interior of a house and that makes me feel safer.
62	15-6-2026 12:36	15-6-2026 12:37anonymous	Bus A	Warm and cozy	wooden floor and warm colors
63	15-6-2026 12:53	15-6-2026 12:57anonymous	Bus C	Light and colourfull. But not medical vibe like bus B. Bus A feels homey but is a bit darker with makes it cosy. The combination of a light and colours feels safe.	Combined cosy and colour.
64	15-6-2026 12:56	15-6-2026 12:58anonymous	Bus B	B because I feel like the contrast will make me see everything easier.	high highlight / strong light gives a perception of safety (it might not be true but that is the feeling I get)
65	15-6-2026 14:48	15-6-2026 14:51anonymous	Bus C	The texture of the floor feels most familiar to other modes of public transportation, and the blue one feels too clean and hospital like	The floor texture of bus C
66	15-6-2026 16:08	15-6-2026 16:11anonymous	Bus B	Because the colors are brighter. The other 2 are darker which feels less safe	I love the wooden floor. Feels a bit like home, and the blue walls cuz, bright and happy.
67	15-6-2026 16:30	15-6-2026 16:34anonymous	Bus A	It has warm colours, feels like home, cosy and safe environment, like somebody is giving you a hug	I like the soft brown seats, and the warm colours, so for example the orange ring, so it feels more cosy and safe. The wooden floor does the same thing for me. The floor in the green bus feels more like a hospital floor
68	15-6-2026 17:32	15-6-2026 17:33anonymous	Bus B	lighter color	light colors
69	15-6-2026 20:21	15-6-2026 20:23anonymous	Bus A	I think warmer colours	I am not sure, difficult to know just from the picture.
70	15-6-2026 23:51	15-6-2026 23:52anonymous	Bus A	Warm colours give a warm feeling. So that brings the feeling of safety	The dark wood floor
71	16-6-2026 00:32	16-6-2026 00:33anonymous	Bus A	a	the warm cozy colors and livingroom textures of a
72	16-6-2026 09:31	16-6-2026 09:33anonymous	Bus A	The warm colours make it feel like a protected space.	I feel in general the warm colours as well as the wooden elements give a living room vibe. This makes it feel like a safe space.

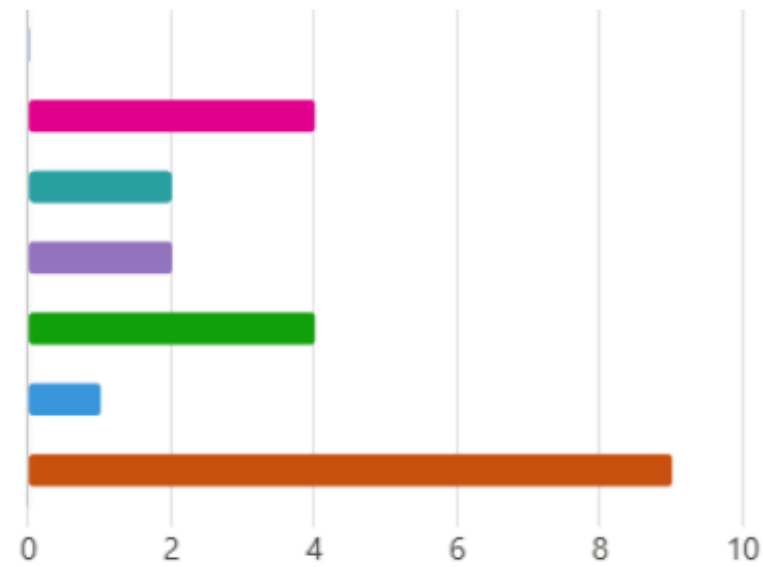
73	16-6-2026 11:01	16-6-2026 11:03anonymous	Bus A	The colors are most calm	The orange ring, the warm lights just everything from the Bus A options I like better than the other ones
74	16-6-2026 11:17	16-6-2026 11:22anonymous	Bus C	The earth tones make me feel more embraced, as if in a forest or other form of being surrounded by nature. The blue design feels too clinical and makes me feel like I'm in the waiting room of a hospital, which raises some subtle anxiety. The orange tones also feel warm and give a certain feeling of safety, but it doesn't have the same effect as the more earthy tones of bus C.	mixing the wooden floor with the earthy tones of bus C would be the perfect combination to really feel as if surrounded by a safe blanket of nature
75	16-6-2026 11:52	16-6-2026 11:53anonymous	Bus C	a feels more homey then safe b feels more clinical, almost too clinical c feels like a combination of clinical and homey, which is safe to me	warm coloured flooring
76	16-6-2026 16:36	16-6-2026 16:43anonymous	Bus C	warme kleuren maar wel veel licht. donkere ondergrond. voelt niet klinisch	• houten vloer bus A • gekleurde stoelen bus C • bus C geeft een dag vibe, bus A niet dus dat is nice (de dag vibe) • warme kleuren bus A en C, maar bus A is net too much
77	16-6-2026 18:10	16-6-2026 18:13anonymous	No difference / they all feel equally safe	A voelt gezellig b voelt clean/schoon/helder c voelt neutraal.	Bus b voelt helder en schoon, prettig voor ov

78	18-6-2026 09:01	18-6-2026 09:14anonymous	Bus C	I feel like it's the perfect combination between the two other options: it has the cozy/warm feel of A and the clean/high-tech feel of B, both having their own unique contributions to a safe feeling in general.	To be completely honest (and as I mentioned in the previous question), I already feel like bus C combines the best elements of all. The floor being a light brown-ish color resembles the warm feeling of a wooden floor, but the absence of the actual wooden texture makes it also more "clean" in a way and therefore more modern and up to its safety standards. I also think the green color is very inviting and signals to people that for example making use of the help ring is always a "go". Also, the brightness of the colors has the best balance in bus C, as it floats perfectly between the warm bus A and the more high-tech bus B. Not sure if this was all intended haha, but just my opinion and way of perceiving!
79	18-6-2026 18:16	18-6-2026 18:17anonymous	Bus C	B feels to sterile and A feels like a 70s serial killer type beat. I like the green in C	Green, i do like wood floor but i dont know if it would fit. Otherwise the floor of C is something id expect in a bus

H: FORM VALIDATION OF THE WHOLE CONCEPT

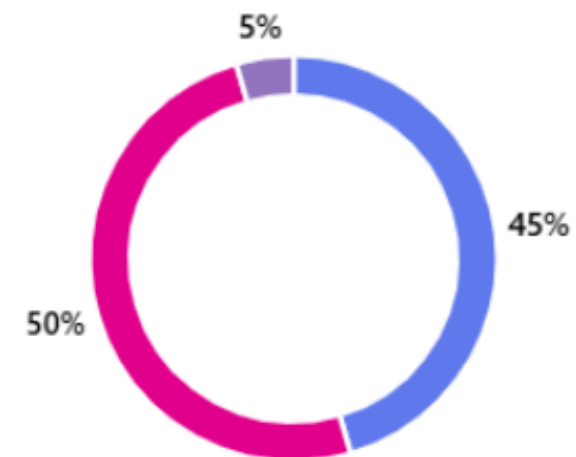
1. How old are you?

Under 18	0
18-24	4
25-34	2
35-44	2
45-54	4
55-64	1
65+	9



2. What gender do you have?

Woman	10
Man	11
Non-binary	0
Prefer not to say	1

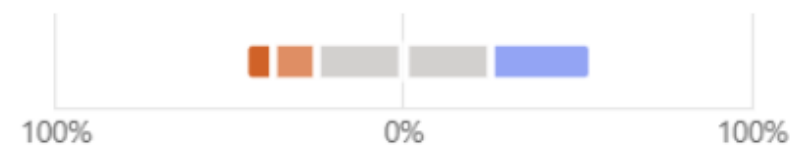


3. Normal bus (without design changes)

[M](#)

Very unsafe Unsafe Neutral Safe Very safe

How safe would you feel in this bus if there was no driver on board? (1 = very unsafe, 5 = very safe)



4. New designed bus (without all improvements)

You will now see a bus that has been completely redesigned for a future without a driver. The bus has several elements to make you feel safer.

Link to 360° photo of the new bus: <https://kuula.co/share/collection/7TqMp?logo=1&info=1&fs=1&vr=0&zoom=1&thumbs=1>

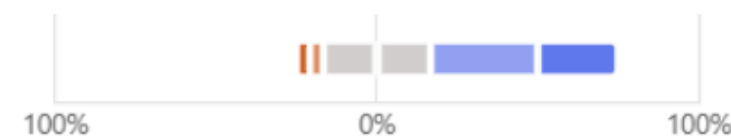
[Meer details](#)

Take your time to look around from the standing perspective or the seated perspective.

You can swipe around or move your phone if you unlock the movement icon.

● Much less safe ● Less safe ● Neutral ● Safer ● Much safer

Compared to the normal bus (which you just saw), how safe does this new bus feel? (1 = much less safe, 5 = much safer)



Any additional comments?

Nice atmosphere in the redesign

I think what I really like about the redesign specifically of the new chair configuration is that it reminds me of a metro where you typically don't see the driver either. It has a very open look and feel and like I said because it is recognisable due to similar design I would feel a lot safer.

You can see the road and other traffic so this helps.

Aantal zitplaatsen is kleiner lijkt het, dus meer passagiers moeten staan.

The open characteristics of the design is very comforting

It is more open. So passengers can help each other, if necessary

It's looks very comfortable en safety.

There is a lot of open space in the new design.

At the time of the day when/if i travel by bus this wil require a lot of People to stand

Open sfeer, geen blokkades in zichtlijnen, fijne kleuren en materialen.

It's very interesting that the redesigned bus has a much more "inviting" feel, which really influences the atmosphere of the bus!

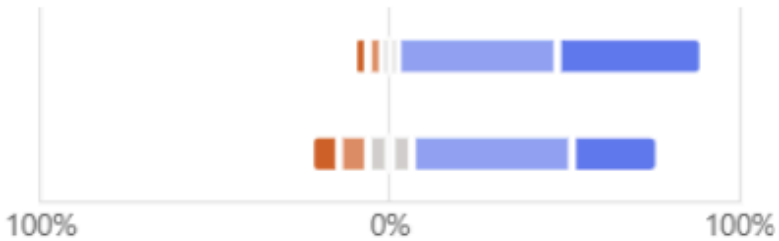
6. **Help ring**

Explanation: This is the help ring. It is a coloured band that runs around the entire bus in the middle. You can always go here for help or information. The ring has a screen where you can ask questions (e.g., "How many stops left?") through pressing buttons and a physical button to speak directly to a help centre if needed or preferred.

● Strongly disagree ● Disagree ● Neutral ● Agree ● Strongly agree

I understand what the help ring does and how to use it

The help ring gives me a reassuring feeling; I know where to find help

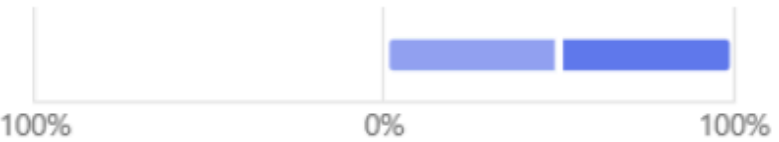


8. **Stops display**

A screen at four locations of the bus showing following stops. It always shows the end station and keeps revealing more stops when getting closer to the final stop. The bus icon shows at what station you currently are.

● Strongly disagree ● Disagree ● Neutral ● Agree ● Strongly agree

I understand the display and how to read it



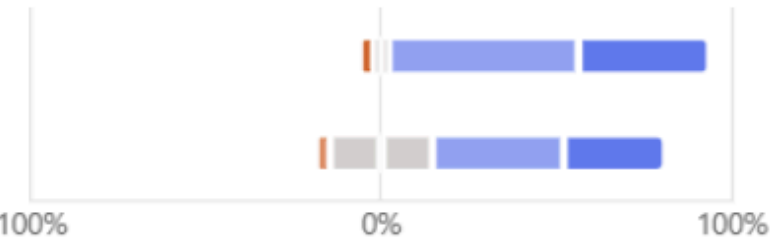
10. **The breathing ceiling**

Explanation: The ceiling has soft LED lighting that shows what the bus is about to do. The light moves gently: forward when accelerating, slowly brighter when braking, and left or right when turning. When nothing special happens, the light is soft and still.

● Strongly Disagree ● Disagree ● Neutral ● Agree ● Strongly agree

I understand what the breathing ceiling indicates (braking, accelerating, turning)

The breathing ceiling makes the bus more predictable and therefore calmer



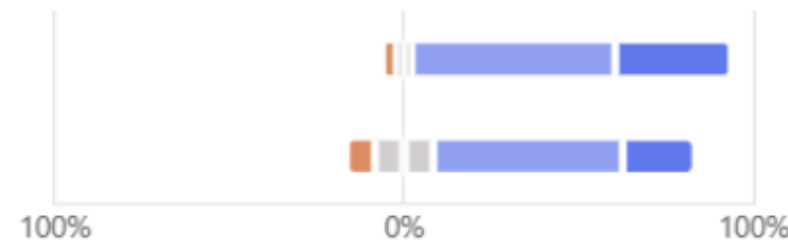
12. Frontscreen (What the bus sees)

Explanation: At the front of the bus, there is a screen that shows what the bus 'sees'. You see simple outlines around cyclists, cars, and pedestrians that the bus recognizes. This helps you understand why the bus brakes or steers.

● Strongly disagree ● Disagree ● Neutral ● Agree ● Strongly agree

I understand what this front screen shows

This screen gives me more confidence in the bus

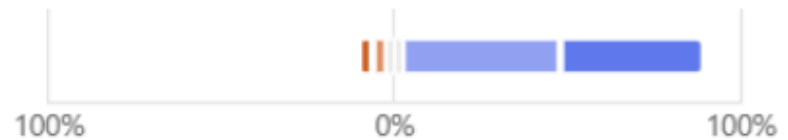


14. QR code

At every seat there is a QR code. You can scan it with your own phone to see the route, upcoming stops, and ask questions via a chat function. This is useful when the bus is crowded or if you prefer to use your own phone.

● Strongly disagree ● Disagree ● Neutral ● Agree ● Strongly agree

I understand what the QR code at my seat does (info on my own phone)



16. Emergency buttons

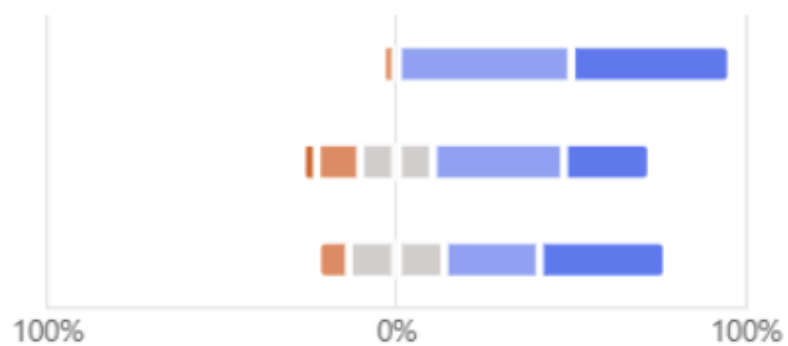
1. Every two seats has a red emergency button in arm reach (clearly different from the stop button). You can use it to raise an alarm immediately and make an emergency stop by pressing 3 seconds to prevent accidental pressing. Below is a silent alarm in case you feel unsafe and want to alert the help centre to come help you without everyone knowing.

● Strongly disagree ● Disagree ● Neutral ● Agree ● Strongly agree

I can clearly see the difference between the emergency button and the stop button

The emergency button at my seat gives me a safe feeling

The silent alarm would make me feel safer



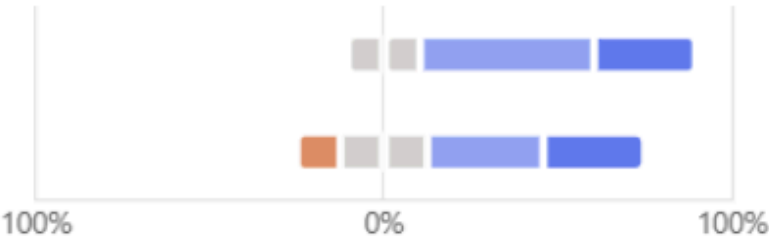
18. **Surveillance camera's and mirrors**

There are cameras with screens on the left side of the bus and mirrors on the right side of the bus, so you always have a good overview of what is happening behind and around you and know you are watched. Under the camera is the screen showing the live recording. This set up is placed in four locations throughout the bus.

Strongly disagree Disagree Neutral Agree Strongly agree

The cameras and mirrors give me a good overview of the bus

The cameras and mirrors make me feel safer than without

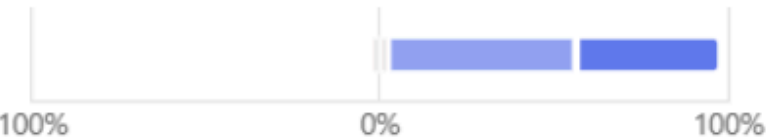


20. **Door light indicator**

Above the door, there is a light that shows what the door will do: green blinking when opening, static green when open, red blinking when closing. It is turned off when fully closed. This works just like on trains.

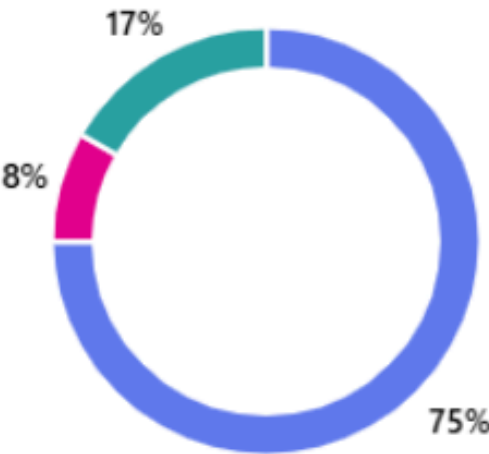
Strongly disagree Disagree Neutral Agree Strongly agree

The light above the door (green/red) helps me understand when the door opens or closes



22. Would you feel comfortable using this bus (without a driver) based on what you have seen?

- Yes 18
- No 2
- Andere 4



Helping ring. Any additional comments?	Stops display. Any additional comments?	Breathing ceiling. Any additional comments?	Front screen. Any additional comments?	QR codes. Any additional comments?	Emergency buttons and silent alarm. Any additional comments?	Mirrors and cameras. Any additional comments?
It's nice it's in the centre of the bus, easy to find.	Clear. It's also nicely located and easily readable.		It's reassuring			
Yeah this is great, also I like that I can just speak to it, that feels a lot more accessible	Very important to have this, it's clear feedback.	Yeah this is great also because it allows for feedback but at the same time it's not in your face so I it's both subtle while being informing too.	I personally have experience and understanding of how AI works. But I can imagine it can be distracting and confusing for other people. What do these squares around objects mean? And how does that relate to the action of the bus?	It's clear and nice to have a way to reach this info and it's right in front of you so hard to miss.	It's great to have a silent button option, it's not clear for me however whether I have to press that one for 3 seconds too to activate its functionality.	Yeah it's great to have a clear view of the bus.
			Knowing what an autonomous bus is processing (e.g. whether it recognizes cars or pedestrians) improves trust on it can react in time and properly			it may be a bit small and less noticeable for an overview of the entire bus, but the intention is nice!
Het zou ook fijn zijn als je je vragen kan typen, zodat je niet altijd hoeft te praten in bv een hele stille bus of als je dat ongemakkelijk vind	Het zou wat groter mogen zodat je het van een afstand ook kan lezen			Super slim bedacht! Dit mag in elke bus.		Ik weet niet of die spiegels zo veel doen, ik denk dat vooral de cameras het verschil maken omdat je bij een spiegel net via een verkeerde hoek kan kijken waardoor je niks ziet

			Tou can see the intelligence of the bus so thats gives you confidence		Mirrors look a bit old and overkill in control	
			I think it would make me feel unsafer if there are emergency brakes everywhere. Then I get the feeling as if it is normal to press it since they are everywhere which is not what you are typing to accomplish I think. Trains also have 1 emergency brake at the ends of a segment instead of near every seat. Next to this, I would have no idea what the silent alarm is for if I would only see the button with the title as is. Maybe include: “feel unsafe? Notify help center”			
			Ik zou voor het recht en links afslaan niet de boven- en onderkant van de het scherm gebruiken maar de rechter- en linkerkant. Ik zou dit laten knipperen. Dit sluit aan bij de huidige conventie voor richtingaanwijzers.			
			Ik denk dat een dergelijk scherm verwarrend werkt. Je kan toch niks doen met de info. Hooguit kan je je schrap zetten als je denkt dat de bus gaat botsen.			
Qua vragen stellen/beantwoorden vervangt dit de chauffeur, maar voor andere hulp lijkt me dit niet werken als je eerst naar deze helpring moet lopen	Lijkt wel op wat ook nu getoond wordt	Ik kijk niet naar het plafond als ik in de bus zit, ik durf niet te zeggen hoe ik dit zou ervaren in een bus. Ik denk dat het beter kan werken ziet... als dit (ook) lager in de bus duidelijk zichtbaar is. Maar dit lijkt me iets voor een praktijktest	Ik ben bang dat ik dan ga focussen op wat de bus detecteert en vooral op wat de bus misschien juist niet ziet...	Denk niet dat ik dat zou gebruiken	Ik vraag me af hoe vaak de knop gebruikt en misbruikt gaat worden, en ook hoe snel er hulp is	Waarom ook camera’s? Dat geeft me alleen het gevoel dat we overal gevolgd worden, maar niet een veiliger gevoel. Spiegels lijken me oké
				Good idea!!		
			I don't think this would help me. Looking upto the ceiling is hard with a stif neck.		It is good to see the other passengers.	
			I hope I have enough trust in the automatic bus that I don't feel the urge to look.			

Dat gives me a good feeling.	It's gives me even better the information		It's gives me more confidence en safety feeling.	That is great.	It's feels safe when it a emergency botten next to the to me.	It looks great en safety with two different cameras in different places.
I can help myself. But my young childeren or (old) mother dont understand english.	Very helpful	Excellent feature		I never scan public qr codes. (Cybersecurity risk for spoofing and rerouting to malisous websites)		
They should be adresssed in their native language						
Is het ook goed toegankelijk voor mensen met een beperking?	Een digitaal bord waarop alle stops altijd zichtbaar zijn en de kleur of toon verschuift om aan te geven waar je op dat moment bent, kan rust geven. omdat de reiziger dan altijd in een oogopslag kan zien waar die zich bevind tov de reis	Kan de kleur worden aangepast aan de weersomstandigheden om de gevoelstemperatuur in de bus te kunnen aanpassen aan omfevingsfactoren. In zomer koeler licht en in winter			Hoe kan ik zien dat ik de button heb ingedrukt en dat er iets mee gedaan wordt met deze actie?	
In hoeverre heb je direct contact met een echte medewerker ipv AI agent?	Het zou mooi zijn om zowel overzicht als drill down te zien			Liever geen QR gebruik	Begrijp niet helemaal waarvoor dit alarm dient. Persoonlijk gevaar of alarm gerelateerd aan eerder genoemd visueel scherm. Ingreep bij gevaarlijke situatie. Tevens erg makkelijk voor baldadige jeugd en andere verstoorders	Cameras redelijk standaard in de bus. Meer gevoel van in de gaten worden gehouden dan veiligheid

I really like the constantly updating station "map", but the current stop might be a bit small to read from both ends of the bus? Other than that, it's already a great improvement from what we have now in our subways.

I'm wondering whether passengers should be involved in the more "technical" functionings of the bus. I already think that the ceiling lights offer a great way to "understand" the movements of the bus in a "normal-people-friendly" way.

Very nice addition!

I really like the silent alarm option! Nice! A bit on the fence about pressing three seconds for an emergency stop, as an emergency stop would only happen in emergencies, right (so when a quick turn of events is needed)? Maybe separate the "raise alarm" and "emergency stop" features? (That might lead to a confusing amount of buttons though, so I'm not sure how to do this...)

Doors lights. Any additional comments?9	Which element did you find most convincing? And why?	Which element did you understand the least? And why?	What would you change about this bus to make you feel even safer?
	The breathing ceiling as it gives a direct sense of what the bus will do. It makes you feel like you can trust the bus more, also you can predict the motion of the bus more, and thus might reduce motion sickness.	The silent alarm. I'm curious what the exact consequences are of pressing that button.	Maybe hanging grab handles for when you have to stand, idk
Nice to have this feedback. It's clear.	The breathing light and the place where you can talk to the bus. The reason for that is that they are clear, and really helpful for 1 understanding the actions of the bus and 2 creating accessible way to ask questions	For me the object detection is confusing as I don't know what I'm supposed to do with that information. I understand that it's just detection but someone else might misunderstand it and get confused. Also the silent emergency button it's not super clear how long I should press it. Ideally you'd have a circle LED around the button that lights up as you press it to show the progress as a visual feedback of how long the 3 seconds is (for both the normal and the silent emergency button).	Knowing if other women are on the bus or whether it's just men
	The screen that shows what the bus detected, so I know it is detecting the things that need to be and that it can react properly	Probably the ceiling lights - it is nice to know what maneuver the bus is performing but I still think it makes more sense to make it more subtle	I can't think of anything specific to add
	De qr code. Daardoor voel je je zelfverzekerd waar je moet uitstappen en hoeveel haltes/hoe lang het nog duurt. Plus je kunt daar je vragen handig stellen. Mits het systeem natuurlijk goed werkt	De verlichting dat zich aanpast met remmen ect. Ik denk dat als je de eerste keer in die bus zou stappen, je dat niet meteen doorhebt en het kan ook vervelend zijn als het licht steeds veranderd	Op een rails rijden :) zoals een tram of met bedrading zoals een trolleybus. Dan is het ook eigenlijk een tram of trolley, maar dan is het heel voorspelbaar wat dus bus gaat doen, ook voor de rest van het verkeer. Verder qua interieur voelt het heel open en zichlijnen zijn door de hele bus duidelijk dus het voelt heel veilig. Doet mij denken aan de trams in Utrecht die hebben ook dat open gevoel, dat je vanaf de ene kant van de tram de andere kant kan zien (als het niet druk is)
	The front screen, yiu can see what bus sees	The breathing ceiling. You frist have to figure out what signal means what	Nothing
	De kleuren	Niets	Niets

	The route indication. Normally when there is a bus driver I know I can always ask him to stop at my destination if I am unsure about the route. Without a driver that would make me less likely to take this bus when I am, for instance, new to that town or city.	The break and turning signs. I would constantly be actively watching for danger.	The bus seems fine. I would think about specific lanes for these buses where no other traffic has 'voo rrang'
Red always on also when driving?	Looking outside when driving is nice. QR code overkill i think. Ceiling makes the bus alive. Very nice	Red green bar at the door	Vo ic e
	I think a combination of everything but mostly the yellow ring	The emergency buttons everywhere	Stickers on the floor directing me to the yellow ring
	Geen specifieke element. Het is de combinatie van elementen alsmede de 'frisse' uitstraling die mij aanspreken.	Geen specifiek element.	De indicatie pf de bus rechts of links afslaat. Zie mijn opmerking bij een van de voorgaande vragen.
	Sorry maar dat weet ik niet	Noodzaak camera's	Weglaten scherm met wat de bus detecteert, en ruimer aanbrengen van de verlichting die remmen etc aangeeft
	I can see what outside is happening and the QR codes.	None	Start producing!
	I don't know	The ceiling	I don't know, I have never tried a selfdriving object.

	De schermen die laten zien wat een Nvt denkbeeldige chauffeur zou. De wand in het midden met informatie, maar vooral ook de overzichtelijkheid in de bus. De kleuren zijn rustgevend.		Nice soft sounds
The light above the door makes me alert. How about the blind person? How can they recognize when the door open of closed? Doe you think about it?	The camera en the emergency botton.	The QR code.	Nothing. I would love it to travel with this bus in the future.
	All possible interferences Allemaal elektronische snufjes, niets me nselijk	Nothing really Silent alarm	Nog idea Nothing
	The windows	N.v.t	Nothing
Wat gebeurt er als iemand of iets tussen de deuren blijft zitten?	De mogelijkheid om bij een onveilige situatie hulp in te schakelen	De keuze om niet ten alle tijden alle stops in beeld te brengen	Muziek, rustgevende geluiden
	Zou mooi zijn als direct contact met persoon mogelijk is, zoals 112. Verder is de mogelijkheid om deuren of ramen zelf te kunnen openen in noodsituaties ook een pre. Extra lichtkleur als deuren ontgrendeld worden en handmatige bediening mogelijk wordt	Emergency button. Zie aldaar	Menselijk contact. Ingrep mogelijk op basis van screen. Camera beelden van omgeving bus, niet alleen front. Niet te luxe uitstraling. Wel reinheid, veel standaard onderhoud en scho onm aak .
	Help ring, silent alarm	For me the qr code would be the least meaningful. Because all the information is already in the bus	Windows that can be opened
	The ceiling lights provide a really nice way to show the intents of the bus I think!	I don't feel like I didn't understand something not well enough. Really clear questionnaire!	I'd say making the emergency stop triggerable immediately as I explained before, but that would mean some (possibly) lengthy re-thinking might be needed... :/

SCENARIO 1: INFORMATIE KRIJGEN OVER JE REIS

Normale autonome bus (zonder aanpassingen):

Je stapt in de bus. De deuren sluiten achter je. Je wilt weten hoe laat je bij Delft station aankomt, maar er is geen chauffeur om het te vragen. Er hangt een klein schermpje dat de volgende halte laat zien. Je gaat zitten en kijkt af en toe naar het schermpje.

Nieuwe bus (met aanpassingen):

Je stapt in de bus. In het midden van de bus zie je een warm gekleurde ring met schermen. Je wilt weten hoelaat je bij Delft station aankomt en loopt ernaartoe. Op het scherm staan drie eenvoudige categorieën: "Alle haltes + tijd", "Overstappen" en "Nood?". Je tikt op "Alle haltes + tijd". Er verschijnt een lijst met alle haltes en de geschatte aankomsttijd per halte. Je ziet dat Delft Centraal de vijfde halte is en dat je over 12 minuten aankomt. Naast het scherm zit een grote fysieke knop met een plaatje van een mannetje die spreekt. Een bordje ernaast zegt: "Druk om met een echt persoon te praten." Deze optie zou je dus ook nog kunnen gebruiken in het geval dat je liever een vraag stelt aan een echt persoon.

In hoeverre worden de problemen in de tweede bus opgelost en op welke manier?

En welk gevoel geeft dit nieuwe ontwerp je?

SCENARIO 2: SOCIALE VEILIGHEID – ALLEEN REIZEN 'S AVONDS

Normale autonome bus (zonder aanpassingen):

Het is laat op de avond. Je komt terug van je werk. Het is donker buiten. Je stapt in de bus. Er is één andere passagier: een man die voorin zit. Hij kijkt op als je binnenkomt. Je weet niet of dit uit nieuwsgierigheid is of dat er andere bedoelingen achter zitten. Je gaat zo ver mogelijk bij hem vandaan zitten. De bus is smal en de stoelen staan in lange rijen. Je kunt hem niet goed zien vanuit je stoel. Je weet niet precies waar hij is of wat hij doet. Omdat het donker is zie je ook uiteindelijk personeel aan boord komen. Echter is deze persoon niet heel goed te zien door de bus layout met de smalle gangen en hoge rugleuningen.

Nieuwe bus (met aanpassingen):

Het is laat op de avond. Je komt terug van je werk. Het is donker buiten. Je stapt in de bus. Er is één andere passagier: een man die voorin zit. De bus is open en licht. Vanuit je stoel kun je zien waar hij zit. Aan de wanden hangen bolle spiegels die een breed beeld van de bus laten zien voor overzicht. Er hangen camera's met schermen die live beelden van de bus laten zien. Er komt even later ook een medewerker aan boord omdat er in de avonduren extra personeel wordt ingezet. Je ziet de medewerker bij deur staan. Aan de muur naast je zit de noodknop een kleine knop met een icoon van een persoon met een vinger voor de mond. Het label ernaast zegt: "Stil alarm – druk als je je onveilig voelt, er komt hulp."

In hoeverre worden de problemen in de tweede bus opgelost en op welke manier?

En welk gevoel geeft dit nieuwe ontwerp je?

SCENARIO 3: ONZEKERHEID – BEGRIJPEN WAT DE BUS GAAT DOEN

Normale autonome bus (zonder aanpassingen):

Je stapt in de bus en gaat zitten. De deuren sluiten en de bus trekt plotseling op. Je grijpt je net op tijd vast. Even later remt de bus hard. Je schiet naar voren. Het was een verkeerslicht. Even later slaat de bus linksaf en je ziet een fietser oversteken. Je vraagt je af of de bus de fietser wel heeft gezien. De bus stopt wel, maar je wist van tevoren niet of hij zou stoppen.

Nieuwe bus (met aanpassingen):

Je stapt in de bus en gaat zitten. Het lampje boven de deur knippert rood. Even later sluiten de deuren. Dan merk je dat de lampen in het plafond beginnen te bewegen. Een zacht, stromend licht beweegt van voor naar achter. Even later trekt de bus rustig op. Je had tijd om je voor te bereiden. Even later wordt het plafondlicht langzaam iets feller. Je weet dat de bus gaat remmen. Je pakt de leuning vast. De bus remt rustig af. Voorin hangt een scherm dat laat zien wat de bus 'ziet'. Er verschijnen eenvoudige vormen om de objecten heen: een fietser, een auto, een voetganger. De bus vertraagt voor een fietser die oversteekt. Je zag het op het scherm en je zag het licht veranderen vlak ervoor. Dan slaat de bus linksaf. De linkerkant van het plafond licht zachtjes op. Even later slaat de bus soepel af.

In hoeverre worden de problemen in de tweede bus opgelost en op welke manier?

En welk gevoel geeft dit nieuwe ontwerp je?

Scenario 1

Het probleem wat genoemd is is dat ik wil weten of ik in de juist bus gestapt ben, en hoelaat ik aankom zo te zien, toch? Ook misschien wanneer ik uit moet stappen en na welke halte ofzo. Zo te zien is het bij de normale bus zo'n omslachtig klein frut schermpje waarbij je ff moet wachten totdat je jouw bestemming ziet. Voor je het weet is het te laat en gaan die deuren dicht en zit je vast in die bus, als je in de verkeerde bent ingestapt. Bij die nieuwe bus kan je via dat scherm heel snel die info vinden, lijkt mij zeer praktisch. Ik heb zelf denk ik niet snel de behoefte om met een echt persoon te spreken op luidspreker, maar als ik er echt niet uit kom of het scherm loopt vast ofzo, dan is het wel fijn dat die optie er is. Dat stelt me wel gerust.

Gevoel

Qua gevoel denk ik dat deze bus me wat kalmer zou laten voelen, omdat ik weet, zegmaar, dat de zorgen die ik heb, snel beantwoord kunnen worden. Zegmaar, als je begrijpt wat ik bedoel, ik heb soms intern stress, over kleine dingen waar je onzekerheid hebt of het wel goed verloopt of op tijd lukt, snap je? Dit met dat instappen en snel maar ff uitzoeken of je in de juiste bus zit en dan wanneer je aankomt en na welke halte je eruit moet is wel zoiets waarbij ik dat wel zou hebben. Bij die nieuwe bus heb ik in een paar tellen die info, en is het duidelijk en groot zichtbaar waar je die moet vinden, en dat geeft me dan al rust weet je wel.

Scenario 2

Ja, hierbij is het wel lekker dat die medewerker die instapt goed overzicht kan houden over de bus wegens de zichtbaarheid. Misschien ook wegens die grote ramen dat mensen van buitenaf ook alles kunnen zien. Die camera's met beelden die alles filmen vind ik ook wel prettig, dat alles vast wordt gelegd zegmaar. Die rare knakker daar voorin zal dat zich misschien ook wel realiseren, hoop ik.

Dat stil alarm zorgt ervoor dat ik iets van actie kan ondernemen als ik denk dat die vent mogelijk echt iets gaat doen, vind ik ook wel een prettige gedachte.

Ik kan die gozer in ieder geval vanuit mijn positie in die nieuwe bus ook goed in de gaten houden, alleen staar ik m liever ook niet teveel aan eigenlijk haha. Maar als ie een te rare blik heeft of net rare houding dan druk ik dat knopje lekker in.

Gevoel

Ja ik vind het wel wat beter aanvoelen dan bij die originele situatie. Het feit dat die handhaver alles goed kan zien en die camera's geven mij wel een extra gevoel van veiligheid. Daarnaast dat ik dat stil alarm hebt vind ik ook erg prettig. Zegmaar dit alles verbetert de situatie enigszins. Zo'n rare kwiebes in je bus die je raar aanstaart of iets dergelijks blijft hoe dan ook klote.

Scenario 3

In die originele bus heb je eigenlijk nul waarschuwingen/indicatie ofzo. En bij de originele bus heb je niks dat de buschauffeur als zichtbaar persoon vervangt. Dat is het probleem geloof ik. Die nieuwe bus lijkt dat wel aan te pakken. Met die deur, dat je weet wanneer die dicht gaat. En met acceleraties of bochten dat je al weet dat de bus die gaat maken. Ik denk dat dat ook helpt met wagenziekte trouwens. Heb al een soort rustiger beeld van die bus als ik het me zo inbeeld eigenlijk, door dat systeem.

En dat je kan zien wat de bus ziet, is gewoon een soort extra check, voor als je die bus niet of nog niet vertrouwt lijkt me. En dan als je dan ziet dat die bus die fietser heeft gezien, dan weet je ook dat die gaat remmen bijvoorbeeld, dus ook wederom toch een soort 'waarschuwing', of indicatie of iets in die trant in ieder geval.

Gevoel

Het gevoel is denk ik een soort geruststelling ofzo. Van 'je kan me wel vertrouwen', snap je? Je weet al wat die bus van plan is, dus je schrikt niet meer. Ik denk dat dit in het begin allemaal erg prettig is, als je nog weinig ervaring hebt met autonome voertuigen, ofzo. Dat je allemaal denkt van 'oeh gaat dat wel goed' etc.

Scenario 1

Nou ja een centrale plek voor informatie is op zich wel handig. Ik denk dat als ik m'n telefoon heb dat ik het ook wel daarop kan zien, maar als het. Bijvoorbeeld dat mijn telefoon dood is, dan is het wel handig als ik op zo'n bord kan kijken in plaats van zo'n klein bordje bij normale bussen, omdat alle informatie veel duidelijker zichtbaar is. Op zich is de optie met een echt persoon praten heel fijn en geruststellend maar ik persoonlijk zou het minder snel gebruiken omdat ik dan bang zou zijn dat ik er gebruik van maak voor domme redenen. Snap je wat ik bedoel? Dat ik denk van oh mijn vraag is het waarschijnlijk niet waard om een persoon te bellen.

Gevoel
Het nieuwe ontwerp geeft me zoals ik al eerder zei een meer duidelijk en geruststellend gevoel. Ik kan zelf de informatie opzoeken in de bus ook als mijn telefoon bijvoorbeeld niet werkt. Als ik er nu over nadenk trouwens, ik heb dat eigenlijk best vaak ook in normale bussen dat m'n telefoon op is en dat ik maar op het schermpje moet kijken. Maar ja dus zo'n centrale plek zou me gerust stellen, omdat de info die ik nodig heb beschikbaar is.

Scenario 2

Ik denk dat het probeem heel goed aangepakt wordt zo. Ook met de camera's dat die man zich dan gezien voelt en ik kan anticiperen waar hij zit en wat hij doet. Aan de andere kant zou die andere man dus ook kunnen zien wat ik doe en waar ik zit, maar ik heb dat veel liever dan dat ik in een soort donker smal hokje zit, dus ja ook de open design lost voor mij dan een deel van het probleem. Verder dat er dan een medewerker is is heel fijn, maar als het ontwerp van de bus niet open is dan heb je daar minder aan omdat de medewerker dan niet alles kan zien, snap je? Dus dan is weer die open design heel erg fijn. En ja die noodknop is eigenlijk essentieel, ik zou bijna zeggen dat als een bus dat niet heeft dat ik daar als vrouw in de avond niet eens gebruik van zou maken. Ja behalve als ik dan echt geen keuze heb. Enige wat ik denkt at mist is dat ik niet van te voren kan anticiperen dat de bus zo leeg is en maar 1 andere passagier heeft. Als ik weet dat mijn rit laat is en bijvoorbeeld lang, en ook al op bijvoorbeeld een app kan zien dat er maar een passagier is dan zou ik misschien een alternatieve route kiezen waarvan ik kan zien dat het wat meer passagiers heeft bijvoorbeeld.

Gevoel
Ik ben een vrouw en ik maak heel veel gebruik van het ov, en ik zit dus dan ook best vaak op latere tijden in de bus. Dus ja stel ik zit in zo'n autonome bus en het is dusdanig ontworpen dat ik hulp vragen toegankelijk is, dat alles zichtbaar is en wordt gefilmd, dat personeel een goede overview heeft van de ruimte, ja dan voel ik me daar waarschijnlijk echt veel veiliger. Eigenlijk ook al de kleuren vind ik er aangenamer en veiliger uitzien, dus warme kleuren, alles is goed belicht, geen donkere hoekjes. Ik vind dat echt belangrijk.

Scenario 3

Ja opzich is het wel belangrijk dat ik kan anticiperen op wat de bus doet als ik dat wil. Dus dat de bus naar rechts of links knippert met die breathing ceiling of de feedback voor remmen enzo ja ik vind dat wel handig. Ik denk dat dat een subtiele manier is om mij als passagier te laten weten dat de bus iets gaat doen en niet iets randoms aan het kiezen is. De beelden met eigenlijk dus die object identification, ja ik weet hoe dat werkt, dus voor mij zeker wel handig als ik zoals in de scenario zie dat er fiets aankomt en dat de bus dat ook opmerkt, maar ik vraag me wel af of bijvoorbeeld ouderen die niet weten wat die vierkantjes zijn of ze dan wel snappen wat de bus doet. Maar ja voor mij is dat wel handig.

Wat ik me wel afvraag is stel de bus remt heel hard af. Waarschijnlijk is er dan iets spontaans wat daartoe leidt. Zou het dan niet te kort zijn voor de passagier om te anticiperen, omdat de bus het plotseling doet? Op zich toch wel handig dat de bus alsnog tegelijkertijd feedback heeft want dan weet je weer dat het niet random is.

Gevoel
Ja ik denk dus dat als ik op een gegeven moment zo'n autonome bus vaak genoeg heb genomen dat ik het op een gegeven moment wel vertrouw net als bij een normale bus, dus dat ik dan gewoon rustig mijn boek ga lezen of op mijn telefoon. Dus in die zin wel fijn dat die bus daar subtiele signalen over geeft die ik ook zou kunnen negeren als ik dat wil. Maar vooral die eerste 10 ritten ofzo zou ik er echt actief op letten, om die vertrouwen op te bouwen omdat ik dan begrijp wat de bus doet en begrijp dát bus weet wat het doet.

PARTICIPANT 3, 72 YEAR OLD MAN

Scenario 1

De hulp ring is heel goed te zien en heel fijn dat je daar alle stops en informatie kunt vinden. ook het scherm met alle stops is veel fijner dan zon klein schermpje waar je bijna niks op kunt zien en steeds moet wachten tot er meer stops te zien zijn. Als ik in stap bij die normale bus zou ik wel ook door de onoverzichtelijkheid en drukke vormgeving moeite hebben met het direct herkennen van het kleine scherm tussen alle relingen.

Gevoel
Ik vraag me af: Is er ook voor alles ge;luid. ik zou het liefst niet in een volledig stille bus willen zitten. dit geeft mij een ongemakkelijk en naar gevoel als het muisstil zou zijn. Ik wil wel iets van een stem horen bijvoorbeeld wat me veel geruststellender zou laten voelen.

Scenario 2

Dat er personeel aanwezig is is sowieso super fijn savonds. En omdat de nieuwe bus zo overzichtelijk is is deze persoon ook veel beter te zien.
Een dingetje voor mij is dat de kleur van het knopje beter zichtbaar moet zijn misschien zodat je meteen herkent van hier zit een knopje. nu valt het misschien weg tegen de achtergrond.

Gevoel
Het geeft mij een zekerder gevoel als er iemand aanwezig is. En ik denk dat het savonds zeker nodig is. Je kan het niet echt op een andere manier oplossen.

Scenario 3

Duidelijk wat de bus aangeeft en niet te overdreven. Het is duidelijk en ik weet precies wat de bus gaat doen van te voren. Het is duidelijk wat de deuren doen en ook het ademende plafond geeft mij een geruststellend gevoel en ik vind het fijn om dat te kunnen zien. Ik vraag me af in welke richting de lampen zouden moeten bewegen in principe voor het accellereren van de bus. Gaan de lampen naar voren of naar achter bewegen?

Gevoel
Het geeft mij een kalmerend gevoel, de signalen van het plafond zijn rustig en niet te afleidend.

PARTICIPANT 4, 50 YEAR OLD WOMAN

Scenario 1

Ik begrijp het helemaal en ik zou dit scherm ook wel gebruiken als ik iets moet weten. De knop is ook fijn als ik met iemand wil praten.

Gevoel
Het geeft een fijn en geruststellend gevoel dat ik weet dat er opties zijn om vragen aan te stellen.

Scenario 2

camera's en spiegels helpen ook echt
Drukke bus, deze is veel rustiger en kan ik goed zien waar die man zit wat ik fijn vind.

Een extra persoon aan boord helpt enorm en daardoor zouden die silent alarms niet perse meer nodig zijn op dat moment maar overdag wel wanneer er geen personeel is.

Gevoel
Het geeft me een heel veilig gevoel omdat ik weet dat er hulp in de buurt is als het nodig is, de knoppen en het personeel die er zijn.

Scenario 3

Duidelijk. Het is fijn als ik weet wat de bus gaat doen zodat ik niet verrast word ineens.

Gevoel
Het geeft mij een zelfverzekerd gevoel. Ik kan mij voorbereiden op wat er komen gaat.