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Design for shared driverless vehicles of the future

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ABSTRACT

On-demand shared transportation is a major new mobility innovation and potentially the main mode of transport in coming decades. Studies show that driverless vehicles have potential to accelerate uptake of shared vehicles at scale. People perceive sharing positively but do not necessarily translate perception into action, with desire for personal space a major reason for unwillingness to share vehicles. Design research is a powerful tool when creating methods and processes to anticipate future possibilities by visualising detailed features of proposed products. We present a set of design research methods engaging end users in a variety of empathy activities and a design process to translate their needs into visual concepts for future shared driverless vehicles that are attractive and more likely to be adopted.

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Shared driverless vehicles, future of mobility, design research methods, visualising concepts

1. Introduction

The new field of the future of mobility provides researchers specialised in design, science and technology opportunities to explore new research areas and experiment with new ideas to address limitations of traditional transportation. This includes transportation systems evolving from developments in autonomous vehicles (AVs), electric vehicles and other new technologies (Wu 2020). In this paper we focus on AVs with potential to provide more convenient sharing services to a wide range of mobility users.

Governments are campaigning to make urban travel more sustainable – the Mayor of London's Transport Strategy says "at its heart is a bold aim for 80% of all trips in London to be made on foot, by cycle or using public transport by 2041" (Greater London Authority 2018); Paris's 15-minute city aims to help people travel easily between home, workplace, shops, and other

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places people visit every day (Gongadze and Maassen 2023). We investigated how best to achieve these targets, and what sustainable vehicles/services would facilitate urban dwellers' daily travel other than cycling or walking.

With increasing numbers of researchers and innovators exploring sustainable transport solutions, sharing has come to the forefront of vehicle services and urban transport systems. Encouraging vehicle sharing has been viewed as an effective solution, increasing average occupancy of privately owned vehicles and lowering vehicle numbers, thereby decreasing congestion and greenhouse emissions (Machado et al. 2018). Ownership to "usership" shifting is promoted as good citizenship by expressing positive sustainability attitudes, however little work is found actively creating shared vehicles appealing to individuals' other motivations for using shared services. There is an attitude-behaviour gap: people talk about/perceive sharing positively, without necessarily translating into action (Hamari, Sjöklint, and Ukkonen 2016).

Ride-sharing (e.g. Uber), car-sharing (e.g. Car2Go), and car rental (e.g. SIXT) extend existing public transport options or provide alternatives to privately owned cars/taxi services for individual travellers. These schemes mainly use existing models of vehicles to serve shared car users, and are either not attractive to private owners (with privacy, time sensitivity and value for money commonly cited as issues) or exclude people with special needs (e.g. vulnerable users, users in areas with poor connections). Commercial innovators (e.g. Carpool, DriveNow, Uber) have new business models, services and technology innovations enabling people to easily share these standard vehicles by combining digital platforms, personal devices, and in-vehicle sensors. However there appears to be little research into which vehicle properties (e.g. controls, layouts, materials) need to be reconsidered for sharing at scale.

Automobile manufacturers/entrepreneurs have started producing models/concepts dedicated for sharing while simultaneously preparing for future scalable shared AVs such as:

- Dedicated car models designed for sharing – VW's MOIA is designed for sharing by different users and groups (MOIA 2024) focusing on adapting to users' reasons for travelling and behaviours. MOIA carpooling service considers interior features for sharing including seats for individuals/groups, with individual passenger lighting, Wi-Fi and front luggage storage, and more rear compartment legroom.
- Shared fully AV concepts - Zoox's autonomous pods are designed for urban travel by individuals sharing (ZOOX 2024). Digital panels on seat sides, premium materials and spacious interior are features the company emphasises as benefits for a dedicated car design for sharing. Dromos (PriestmanGoode 2024a), an AV concept, focuses on sharing with features such as modular seat designs for passengers and freight, and easily

maintained materials. Flexible interior requirements accommodating passenger needs including luggage, bikes/sporting equipment, step-free access and wide doors were considered in the design. New Car for London (PriestmanGoode 2024b) also looks at flexible seating arrangements to suit differing passenger needs. Lighting, storage, personal device connection and city views are key features of designs. NExT's (NExT 2024) bus-like electric vehicle has modules that join and detach with others. Flexible seating, material choice and optimal space utilisation for different types of travel are key considerations for these concepts.

- AV road tests – Waymo, Google's self-driving car project, produced the Firefly (Waymo 2017) prototype, intended as an experimentation/learning platform in partnership with car manufacturers such as Jaguar, Mercedes-Benz and Volvo, testing self-driving technology on the road. Waymo mainly focuses on developing core self-driving technologies rather than vehicles, with one U.S. pilot a taxi/ride hailing service using existing car models. GACHA, an AV pilot project collaboration by Muji and Sensible 4, aims to develop all-weather self-driving shuttles for urban and suburban areas, currently focusing on safety/availability for populations in remote regions (Muji 2022).

Although commercial projects (e.g. PriestmanGoode) are starting to consider user's detailed needs, research into emotions, personal preferences and subtle needs during shared journeys to inform the design of dedicated shared driverless vehicles is missing. It is important to ensure that future transportation advancements are designed from the beginning to consider different users' needs (Department for Transport 2020).

Design research offers methods for gathering tacit knowledge such as tradition, inherited practices, implied values and prejudgments, as opposed to more easily articulated explicit knowledge (Linde 2001; Williams 2006; Polanyi 2009), about users and the environment they interact with. It is helpful creating narratives identifying user needs and translating their needs together with contextual information into concrete demonstrations. This study is designed to use design research methods such as empathy design and vehicle concept visualisation to anticipate and identify attractors for sharing with the aim of achieving vision-driven innovation (Kleinsmann, Valkenburg, and Sluijs 2017). By creating visualised concepts, we envisage fully shared driverless vehicles and usage scenarios for implementation by vehicle manufacturers and adoption by consumers.

2. Design driven innovation for future shared driverless vehicles

We defined shared vehicles (Dill and McNeil 2021; Machado et al. 2018) as on-demand ride services providing door-to-door seamless journeys, provided by private companies with agreements with local authorities or companies for integration into municipal transport systems or leasing businesses. On-demand

mobility (typically car-sharing, ride-sharing, ride-sourcing or e-hail services) occurs among peers or is enabled by businesses (Greenblatt and Shaheen 2015). Door-to-door services at affordable cost could transform lives of older people and those with disabilities, especially when living where public transport options are unavailable/unsuitable and deserve additional research (Pettigrew, Dana, and Norman 2019). In this project, we do not look at micro-mobility (e.g. bicycles/scooters) or commercial vehicles (e.g. vans/lorries). We do not investigate shared public transport (e.g. bus/train/underground), however we consider seamless journeys integrated into existing or future public transport systems.

We considered fully driverless vehicles as our ideation platform as they provide a broader design space for currently excluded shared vehicle users, and shared vehicles and fully AVs are seen as closely related in surveys of future mobility trends (Merfeld et al. 2019; Lavieri and Bhat 2019; Barbour et al. 2019; Taiebat and Xu 2019; The Economist 2018). We investigated possible trends (present to 2060) to predict transformations in shared interior designs and integrated services. The Future of Mobility (Government Office for Science 2019) hypothesises 80% of passenger miles will be in AVs in 2039, rural transport provision may struggle to meet ageing population demand, and that wider lifestyle choices need more attention. European Commission's Mobility Strategy (European Commission 2024) and UK Transport Vision 2050 (Innovate UK 2021) envision fully operational, multimodal, safe and resilient transport systems by 2050.

Research using design research methods (Forlizzi, Stolterman, and Zimmerman 2009; Frayling 1993; Zimmerman and Forlizzi 2008) to tackle questions and create concepts for future shared and driverless vehicles includes qualitative methods such as interviews, personas and quotes in the process of understanding passengers and drivers (including professional drivers, for example truck drivers' needs when using AVs) and for informing future innovation (Pink et al. 2020; Morton et al. 2019). Enactment workshop combined analysis is used to refine user expectations and suggest design directions (Pettersson 2017), addressing dimensions of comfort for journey experience for vehicle concept design (Wilson, Gyi, and Morris 2019), generating inclusive design areas, design framework and service apps for shared AVs and other future mobility vehicles aiming to serve wide ranges of users (Detjen et al. 2022; Martelaro et al. 2022; Schuß et al. 2022).

Most AV research focuses on technology development or people's needs when sharing driverless vehicles from social-psychological or anthropometric perspectives. These projects typically do not precisely define vehicle designs or features, or explain exactly how people use the suggested designs (Merat, Madigan, and Nordhoff 2017; Wedler and Vietor 2019).

Solving the problem that people do not wish to share for privacy and comfort reasons, particularly when AVs operate at scale, and how to make sharing more

comfortable for people when there is no driver or operator onboard are key. We reviewed research around shared vehicles and found four typical themes: business model analysis (Cohen and Kietzmann 2014), barriers and motivations for understanding the current environment for vehicle sharing (Merfeld et al. 2019; Sperling 2018), willingness to share using shared AVs (Barbour et al. 2019; Lavieri and Bhat 2019), and behavioural patterns (Alonso-Almeida 2022; Henderson, Cao, and Liu 2022; Kopp, Gerike, and Axhausen 2015). General assumptions, motivations and future predictions about trends provide insufficient information to help understand people's subtle concerns and therefore can hardly lead to detailed vehicle features that make sharing comfortable.

Our design research acquires detailed behavioural data presenting tangible actions with analysis about emotional changes such as how shared vehicle subscribers book, find and use vehicles, and whether they are happy or frustrated at each step.

This paper presents our journey from understanding people's needs and concerns for sharing (using survey and enactment workshops), to immersing designers into user experiences translating information about people's experience into visualised narratives (using scenario diagrams), and then exploring design directions around driverless vehicles (using vehicle design, storyboard and design metaphor).

3. Encouraging sharing

We started with a research question: are people willing to share? Research shows people are reluctant to share rides with strangers for privacy and comfort reasons (Barbour et al. 2019; Lavieri and Bhat 2019; Merfeld et al. 2019). Willingness to share changes with length of journey (grocery shopping journeys and short commutes are more likely to be shared) and value for money (two people travelling by car vs train) (Barbour et al. 2019; Lavieri and Bhat 2019). We found people's concerns using shared vehicle schemes are mostly about personal safety in two surveys we performed. More female passengers felt less secure than males when traveling at night using ride-sharing services. Physical security concerns are influenced by passenger's emotional feedback from the vehicle environment, the purpose of the journey and other passengers. The aim of the research is to design shared driverless vehicles that are more attractive and comfortable and more likely to be easily adopted by users and existing transport systems.

4. Methodology

4.1. Surveys and enactment workshops

We conducted two quantitative online surveys: a pretest ($N = 93$, age 25-64, 65% female) emailed (15K opted-in emails: 10K UK/5K rest-of-the-world) and

posted on social media (Twitter∼49K/LinkedIn∼93K) to our university's global graduate network; a SurveyMonkey UK audience panel ($N = 203$, age 18-74, 35% female). Both used SurveyMonkey online forms for data collection. Pretest responses were 97% age 25-34 so we used SurveyMonkey's audience panel service to survey a more general audience. The largest groups of pretest responses were UK nationals (48% UK; 5% USA; 47% rest of the world) and UK residents (84%), so we focussed on an UK audience. SurveyMonkey distributed the second survey only to UK participants spread evenly geographically, aged evenly between 18 and 80, with access to cars. SurveyMonkey automatically generated visual analysis and spreadsheets of participant responses (see supplementary materials).

Questions asked sought to identify: how willing respondents were to share different products, vehicles or other property they own; what respondents were willing to share with people they do/do not know; what motivates sharing; what concerns are considered when deciding whether or not to share; concerns held regarding vehicle sharing; under what circumstances respondents feel comfortable sharing a vehicle if other users are unknown to them; would they trust AVs, and more.

When designing the survey, we were particularly interested in contextual information from users' lives including motivations for sharing and sharing behaviours, such as sharing experiences other than sharing a car.

After gathering an initial understanding of general sharing behaviours and issues around sharing, we conducted enactment workshops to gather lived experiences using shared services, shared vehicles, renting and borrowing vehicles from friends. We were particularly interested in personal stories. This qualitative research provided details of individual users' subtle needs and typical usage scenarios later used in scenario diagrams and storyboards.

We ran three workshops with participants ($N = 15$, age 24-72) of mixed genders (eight female, seven male) and backgrounds. Participants owned and drove cars, shared their car with others, drove without owning a car, or did not drive but used bike, car rental and sharing services.

Workshops were conducted as 150-minute sessions including open discussion, individual completion of worksheets, and group role-play. Participants were guided to: share a story about sharing as a driver or passenger; talk about relationship distance when sharing between themselves and others; discuss a shared journey divided into five stages using journey mapping; enact the journey described with other participants to demonstrate what happened, their emotions, behaviours and reflections.

4.2. Scenario diagram

We analysed information (notes, completed worksheets, photographically documented role-play) collected at enactment workshops, combined with

survey results, and generated key themes that could lead to vehicle design innovations.

Our surveys showed people are more willing to share possessions, services or vehicles with people they know than strangers. Individuals indicated they trust vetted, regulated systems and those rated by other users, especially if systems are monitored. When sharing a vehicle with strangers, participants emphasised the need for adequate space between users, some felt screens/dividers could separate them and provide privacy, others wished to interact/socialise with others in the vehicle.

Stories told by participants covered scenarios such as sharing a vehicle as driver and passenger, and positive/negative experiences. Repeated stories used to extract typical scenarios include: 1) a lone journey to an unfamiliar destination, especially for young females considering sharing for cost reasons, highlighting safety consciousness in small shared spaces; 2) families travelling short and long distances, with disputes around children and difficulties sharing a journey with strangers because of children's needs, and desire for peaceful time with children on leisure journeys; 3) short distance commutes/work related journeys with friends, neighbours and co-workers with money saving, quiet time/being left alone important factors when considering sharing.

We generated scenario diagrams comprising design directions each presented by a scenario of travelling summarised from repeated stories (e.g. short distance urban travel, long distance inter-city travel, family daily commute and leisure travel, and business travel), a theme around the journey type (e.g. NANO - a small flexible shared space providing a sense of safety, MOSEY - a multimodal shared journey providing a sense of community, spareVROOM - a modular shared family vehicle, and ENROUTE - personalised shared vehicle providing convenience and comfort for work), modes of transport (e.g. on-demand vehicle, urban and inter-city combined transport, privately owned vehicle, and leased vehicle), potential personas (e.g. individual user, group users, family users and company users), and an image of vehicle type (outline sketch showing vehicle form). This helps us outline an expected journey for each individual user of the system, noting significant stages and detailing key requirements.

4.3. Storyboard, design metaphor and vehicle design

Having identified design directions, we started the concept design phase. Defining personas and storyboards helps designers empathise with end users' experiences, immersing themselves into persona's lives and creating concepts around them. Step-by-step journeys were defined including the travellers, type of journey, length, services and vehicle features required by

personas. Most storyboards were across a day, or a day and night, detailing shared driverless vehicle passengers' journeys through booking, waiting, onboarding, during the journey, arriving, egress and post-service experience. When creating journey-based storyboards we identified vehicle design outputs.

The vehicle design phase focused on interior design. The vehicle design process comprises identifying vehicle types (including exteriors to check vehicle architecture/packaging), optimising interior layout, seating, materials and interfaces, and considering how the vehicle can be used and embedded in wider transport systems. Vehicle concepts (sketches/renderings) were visualised in the context of vehicle use scenarios.

Design metaphor was used for one design direction to create a seating area for a sensitive persona. We investigated how other products are designed to create safe enclosed spaces for users. Sketches of methods used by existing products to create such spaces were generated to study vehicle seating design language.

5. From research findings to design concepts

5.1. Survey findings

We analysed survey data to identify vehicle sharing related concerns, focussing on 'What do you share?' (part 2, questions 10-12) and 'Sharing vehicles' (part 4, questions 16-20) (see supplementary materials). Part 2 captures what people like to share with people they know/do not know, and why they wish not to share, with answers reflecting basic preferences about sharing/not sharing which could affect choices about vehicle sharing. Part 4 focuses on concerns/opportunities around vehicle sharing.

We identified five key findings (Table 1) and linked them with potential vehicle design opportunities. We found most fell in three areas: vehicle interiors (users mostly interact with a vehicle's interior); vehicle types (size/personality/uses); and service (into which the vehicle will be integrated and users will first see when booking or looking for choices).

Table 1. Key survey findings.

Finding	Vehicle interior	Vehicle type	Service
Barriers to sharing include cleanness, personal safety and privacy (Q12)	X		X
Items people are unlikely to share with someone they do not know are more personal, higher value or harder to replace (Q11)		X	
People more likely to share a journey with people they know than with strangers (Q10-11)	X	X	X
Older people were more concerned about sharing a driverless vehicle with others (Q20)	X	X	X
People would trust a shared driverless vehicle more if the service provider supervises/monitors the journey, if users are part of a regulated scheme/vetted by the service and if the interior is configured to provide personal space and privacy for each passenger (Q17-20)	X		X

5.2 Enactment workshop findings

Participants most commonly shared a vehicle with others for short journeys, such as sharing commutes with neighbours or co-workers for economy. Participants also described less common longer trips shared with family, friends or co-workers for holidays or events.

Detailed user habits included two females who used shared taxi services explaining they sit on the curb side rear seat (i.e. not behind the driver) to be as far away from the driver as practical. Most participants said when sharing a car with people they know they would like to socialise except when commuting - two people said they barely talked during early morning commutes with peers (one a neighbour, the other a co-worker). Most said they would avoid talking to strangers when sharing a journey in a shared taxi.

Very few people would like to share with complete strangers. When participants were asked to list relationship distance when considering sharing items with others among family, friends, neighbours, co-workers and top-rated users (those highly regarded by the service/others but strangers), family members are the most trusted sharers, followed by friends, co-workers, and neighbours, with the least trusted being top-rated users. This shows consistency with the survey findings - survey 1: 55% participants chose 'very likely to share a journey with someone they know' compared to 18% 'very likely with someone they do not know'; survey 2: 17% chose 'very likely to share a journey with someone they know' compared to 3% 'very likely with someone they do not know'. Our design target is increasing willingness to share with complete strangers, ideally reaching the same level as with friends/co-workers. Interior space issues were repeatedly raised in surveys/workshops – people desire enough space between themselves and others, the ability to be able to sit where/how they prefer, but feel uncomfortable asserting themselves with strangers, especially those already in the vehicle. Some did not wish to feel obliged to communicate with others.

Some participants said they want privacy inside the vehicle - their own "bubble" or personal space without intrusion of others' preferences. Participants expressed desire to be in control, were uneasy without it, and concerned about personal safety. Shared taxi users felt less secure getting into a vehicle with strangers at night, but only females vocalised this. Depending on mood people wished to socialise or be private. Communication between passengers, driver and the system operating the service were important.

Consistently identified by online surveys and enactment workshops were requirements for better designed vehicles to accommodate strangers, families and lone individuals sharing.

5.3. Design concepts

Combining survey findings identified vehicle interior, vehicle type and service as key design opportunities with typical usage scenarios extracted from workshop participants' repeated stories. We defined four design directions in the scenario diagram – design for shared driverless vehicle space to enhance privacy and create a sense of safety (NANO); for group travellers to feel a sense of community (MOSEY); for family sharing (spareVROOM) and for bespoke personalised journeys (ENROUTE).

5.3.1. Persona and storyboard

Visualisation is an important design approach allowing designers to accurately envisage what design creation could achieve. Creating and including personas in storyboard sketches enables designers to emphasise persona's feelings and emotions and translate into tangible design features. Four personas emerged from workshop participants' stories and were summarised in scenario diagrams with brief descriptions of journey type, mode of transport, and vehicle type. We immersed ourselves in four design directions described in scenario diagrams with notes and pictures from workshops, and key cultural, social and economic trends. We distilled detailed information for each persona (Hannah, Nick&Sam, TomSusan&Jimmy and Mike) and formed storyboards around them.

Storyboards for NANO, MOSEY, spareVROOM and ENROUTE (Figures 1–4) present personas, journey steps and service information for each shared driverless vehicle design direction.

5.3.2. Vehicle design

We designed vehicle concepts encouraging people to share by increasing enjoyment and sense of safety.

Figure 1. NANO storyboard. Hannah is a shy introverted person with mild social anxiety who prefers interpersonal interactions when needed using services. She is travelling solo on holiday somewhere new. The scenario includes two shared vehicle service journeys: a daytime trip from the airport where she meets a friend, to accommodation chatting during the ride, and a late-night journey from accommodation to club where she feels unsafe and wishes to cocoon herself from other passengers.

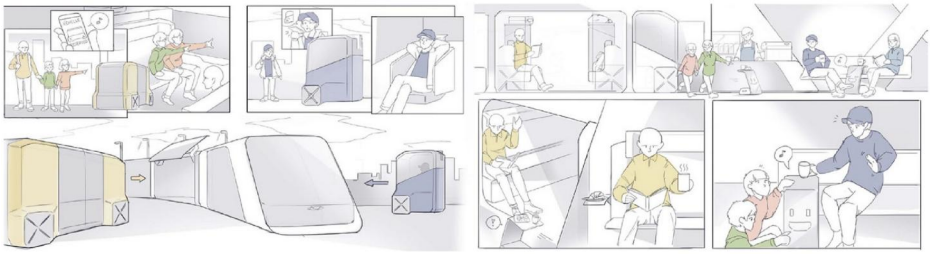

Figure 2. MOSEY storyboard. Nick travels ∼4 h returning two grandchildren after a month. He would like a door-to-door service to remove worry about transfers. The journey tires him. He prefers having a quiet space where grandchildren can be with him or safely walk around. His large suitcase needs storage easy to access without lifting. Sam is attending an event in a city ∼3 h away. He is excited, hopes to interact with people, and do something to kill time. Scenic views with drinks and interesting people would be ideal. The storyboard presents these personas journeys: boarding a door-to-door service vehicle to a high-speed train, and activities during the journey including staying alone in a private space and visiting a communal area.

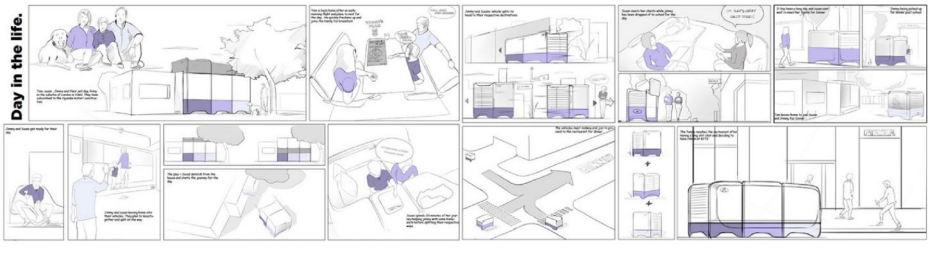

Figure 3. spareVROOM storyboard. Family of three Tom (professor), Susan (architect), and Jimmy (10-year-old son) live in a suburb. Tom and Susan have irregular schedules due to jobs, while Jimmy is active/curious with various after-school activities. They would like to share a car taking them to different locations which becomes a living room when docked with the house that Tom uses as work space, Susan a meeting room, Jimmy a playroom. The storyboard presents a day, each using the vehicle to go to work, school and as meeting room separately, and together to go to supper.

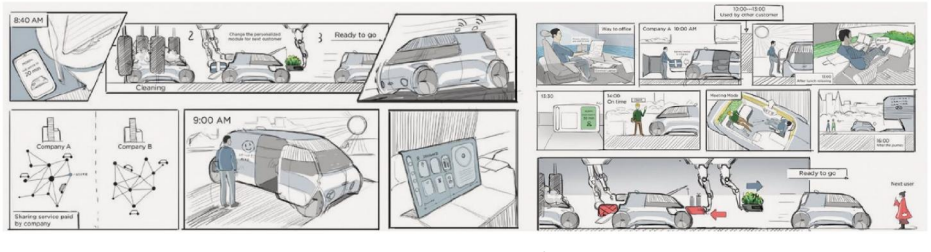

Figure 4. ENROUTE storyboard. Mike is a banker preferring sophisticated classic styling. His company books shared vehicles for short (<30 min) and long (30-120 min) trips to client/partner meetings. About to make a journey, Mike is notified his booked vehicle is arriving. The vehicle plans his day's agenda. En route he reviews confidential company material and meets a client. Afterwards he relaxes. The vehicle returns to base for cleaning.

NANO emphasises flexible seating layouts accommodating four passengers in a small driverless space. We collected design references to analyse existing car models, concept designs, user experience and interaction designs relevant to this design direction. Renault's EZ-GO (Renault 2018) and Qatar Airways Qsuite (Qatar Airways 2024) were inspirations - one providing extended seating areas for passengers, the other private comfortable space for solo travellers. We combined these features, providing a morphic seating area that automatically folds-up and expands as passengers' choose to be sociable or enclosed.

To explore seating design, specifically having seat material create an enclosed space, we conducted a Design Metaphor project focusing on how products create safe enclosed spaces for users such as telephone booths, chairs and clothes. Figure 5 shows a sketch of various methods existing products create privacy without closing the space to study possible vehicle seat design language, and concepts for different ways of opening/closing seats for passenger selected private and social modes.

"Feeling in control" and "personal space" were repeatedly mentioned in surveys and workshops. Seat textiles could solve these issues for seat configuration and surroundings. We proposed variably transparent textiles to avoid

Figure 5. Design metaphor ('create privacy without closing the space') to seating concept ('choose privacy or interaction').

dividing a small space into smaller rooms, creating semi-transparent barriers multiplying the effect of open yet private space.

MOSEY explored interior layouts creating sense of community while allowing passengers to sit peacefully. A challenge is creating a seamless travel experience for both user types according to persona. Seoul's Callbus (Kojects 2016) community service transporting passengers at night and Leap's (Hypebeast 2015) premium commuter bus providing communal space and amenities to entertain passengers, were innovation references. Callbus created efficient routes for all passengers and Leap's zones for working and social activities inspired our designs for door-to-door solutions, dividing our concept interior into individual and communal areas.

Three design challenges emerged: optimising journey stages as seamless experiences, spacious storage and quiet space for one, and communal area design. We designed a driverless pod (Figure 6) with a variable number of seats that takes passengers to a high-speed train-like vehicle, docks becoming a compartment, and undocks transferring passengers to their final destination. We designed the pod to provide ample convenient storage, easing passengers' journeys by helping them avoid lifting heavy luggage with under-seat storage in single and four-seater pods. We investigated interior design cues to guide passengers from pods to communal areas once docked with the train, selecting integrated continuous furniture linking the floor, a passenger window facing bench, and tables with seating towards the head of the train. This furniture links different zones in the communal area, providing a sense of connection while maximising views.

spareVROOM's design challenge is creating interior designs serving three family member's journeys, adapting to their reasons for travelling, switching between vehicle and living space serving home, work and social needs. Design reference Hyundai's Mobility Vision concept 2017 (Green Car Congress 2017), describes a vehicle that becomes part of a home's living space by docking with the house or transferring car seats to the home, and BMW's Mini Vision Urbanaut concept (Business Insider 2020) seats turn into a daybed. Flexible interior configurations catering for work, play and family time compatible with different family members' schedules are major design challenges.

The design concept presents a living space for family relaxation combining three reconfigurable vehicle spaces also used as an office, a meeting room and a playroom. (Figure 7).

ENROUTE's design challenge is creating personalised vehicle interiors that respect status, confidentiality and make users feel valued. Ensuring no interruptions and features customised according to travel purpose and work agenda are key. Volvo's 360c (Volvo 2024) and Icona's Nucleus (Icona 2024) design references provide premium journey experiences for travellers

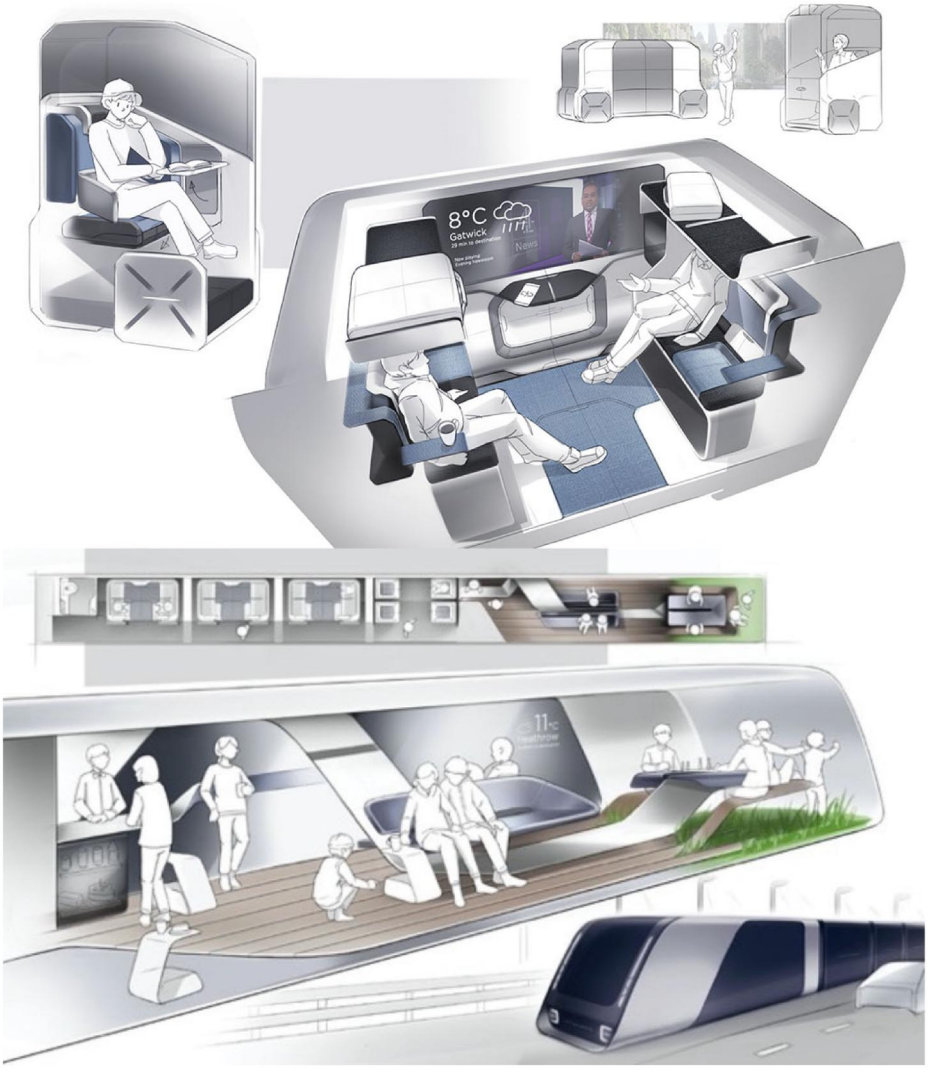

Figure 6. Single and four-seater driverless pod interior designs with continuous furniture guiding passengers from pod to communal area.

between meetings needing on-demand mobility for private workspaces, small group meetings and leisure.

Following the storyboard for journey mapping, we identified vehicle design features including an interior design accommodating work on-the-move with a desk, noise cancellation, privacy for confidential work and amenities including Wi-Fi. Figure 8 shows an adjustable interior based on customer's selected mode of working, meeting and relaxing using small adaptions to lighting and layout. Easily swapped bespoke u-shape amenities modules adapt the space to customer's preferences.

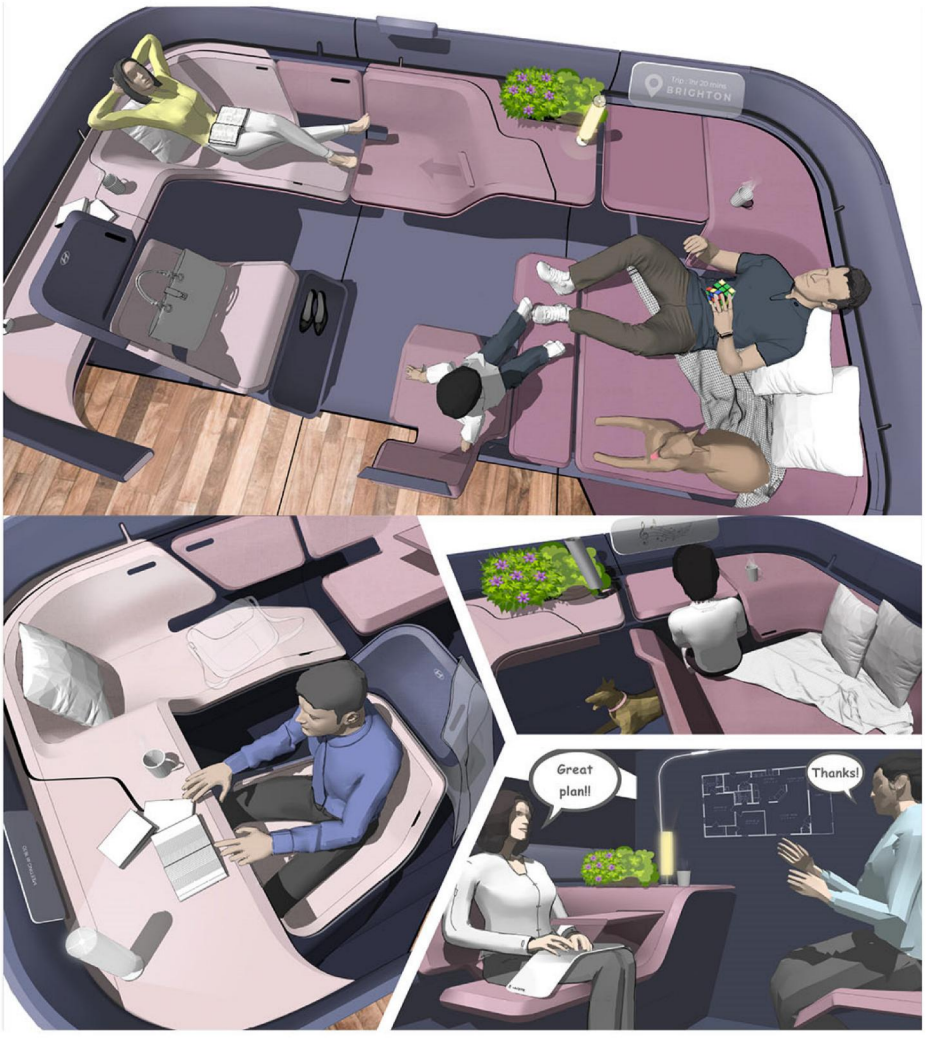

Figure 7. Combined living space for relaxation, with three vehicle spaces supporting family members' work/study.

6. Discussion and conclusion

This project undertook design research studying people's insights around their willingness to share vehicles with others. We developed initial vehicle concepts visualising potential innovations around driverless shared vehicles for attractive easily adopted solutions. Our surveys show people generally are not willing to share vehicles because of issues around "privacy" and perceptions of "safety".

Concepts were designed by four pairs of vehicle and service design MA students and validated in three phases (briefing, pathfinding, crystallisation). Students were selected by portfolio screening (ensuring ability to complete

Figure 8. Meeting mode (orange) with sofa rotated for face-to-face meetings and additional table for food/beverages, work (blue) and relaxation (green) modes.

design projects at design research level), interview (matching their aspirations with research team and customer aims), and scoring by tutors for design performance.

Survey and workshop outputs captured by four researchers were distilled into a service design guide by two service design students. This briefing for vehicle designers, contained detailed journey maps for four persona/journey scenarios, with timepoints indicating events and subtle emotional changes, service and vehicle design opportunities.

Vehicle and service design students were paired, pathfinding innovative vehicle design concepts for identified design opportunities. Pathfinding included

benchmarking design features in existing concept or production vehicles, reviewing requirements and sketching concepts overseen by the researchers.

Crystallisation involved vehicle design students finalising design concepts in detail with computer renderings and storyboards explaining vehicle use.

Each phase's outputs were reviewed by a panel of eight including four researchers, three tutors (vehicle design) and an industry designer/engineer (sponsor/customer) who helped evolve concepts until they addressed feasibility, desirability and business values.

We presented research and design processes around four themes: "NANO" addressing subtle feelings around privacy and safety concerns; "MOSEY" seeking innovations to simultaneously provide community and tranquillity; "spareVROOM" exploring family sharing and living space; "ENROUTE" investigating personalised vehicle work spaces and premium corporate sharing. Each theme dealt with flexible/adjustable interior layouts and seating, fulfilling different users' needs simultaneously and consecutively. Design concepts targeted future scenarios (within 40 years), but seat designs and interior layouts with adjustments could be used by current public transport and car sharing services.

This project shows shared vehicle space design is not a standalone process. It is a critical part of a user's entire journey experience and should be considered with elements such as multiple transport modes, trip monitoring, management tools and more.

Key recommendations when designing shared driverless vehicles include:

- Accommodate privacy and social interactions in one shared vehicle space
  People have different requirements during journeys – some are not at ease sharing rides with strangers, some want privacy and others prefer interacting with people. Vehicle and service designs that consider different needs, providing flexibility to let users rearrange their space are ideal. We advocate design research focussing on people's subtle feelings rather than basic physical needs when designing mobility futures. Further research into natural personal interfaces allowing individuals to contact service operators or report security issues, and seating allowing users to arrange space separation and interact or disconnect with other passengers is needed.
- Create integrated experiences throughout journeys (booking-to-arrival).
  Most participants mentioned convenience and cost as important motivations for using shared vehicles. Vehicle services that ease an individual's journey, linking other activities and transport modes before/during/after journeys are attractive. Detailed journey mapping with clearly defined personas and scenarios, immerses designers in step-by-step journey experiences, visualises where difficulties emerge, and potential design

solutions. However, timelines grow as we investigate detailed user physical and emotional feedback, design requirements and service providers' responses. Key is moving away from details once designers feel they understand users' needs, and start noting ideas. Storyboarding is a good way of linking journey stages and providing more concrete designs.

- Design customised/adaptable vehicle properties for different users
  People have different needs when travelling with different people for different purposes. For some, infotainment systems are important because they want music during journeys, others prioritise adjustable seats for group interactions. Cleanliness is frequently mentioned as important when choosing to use shared vehicles. Easy to maintain, or materials that look fresh even after colours fade, are viable design strategies. Choices of materials, data connection/disconnection, and modular vehicle components allowing customers to rearrange vehicles according to journey type or mood should be considered. Further research on requirements of family groups, the elderly and people with special needs is required.
- Consider users' emotional needs
  Multiple studies, including this, show concerns people have using shared vehicles are mostly about personal safety (Alonso-Almeida 2022; Barbour et al. 2019; Merfeld et al. 2019). Physical security concerns can be influenced by emotional feedback. How people perceive their safety depends on vehicle environment and other passengers. We found users' emotions require more attention when a vehicle is used by multiple people simultaneously to ensure positive experiences for every user. Emotional feelings were our primary area of focus, from surveys to workshops we asked questions regarding feelings when sharing products. We considered persona's lifestyle and personality, added emotional points to journey mapping and followed emotional timelines in the storyboard. Proposals for seats and layouts focus on managing users' emotional state.

We presented research ranging from understanding potential shared vehicle users' concerns to immersing designers into detailed user experiences and generating vehicle concepts. Further research and design are needed to progress vehicle demos with refined functions, materials, space designs and user-vehicle interactions. Outputs only went as far as digital visualisations, full-sized vehicle models would help further concepts. Innovative ideas about how doors should operate, seat placement, and adjusting vehicles for different groups of users should be explored in more detail. Expanding prototyping methods would accelerate the evaluation and feedback process, particularly using different modes (computer simulation, rapid prototyping, hi-fidelity prototyping), materials (paper, foam, metal, fabrics) and virtual/augmented reality technologies.

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