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Navigating the future of mobility user experience: Eliciting user values

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ABSTRACT

Creating successful future mobility products and services requires a deep understanding of user values and requirements. Past research studies are limited in that they have predominantly focused on a single mobility context, such as private car use, leaving areas like shared mobility services and air travel insufficiently explored. The lack of comprehensive understanding of how user values and requirements vary and interrelate across different mobility contexts creates a significant knowledge gap. This gap impedes not only the design of context-specific user experiences but also the cohesive integration of various mobility forms at a systemic level. Addressing this, this study delved into the user values and functional requirements across four distinct mobility contexts: private cars, shared mobility services, airplanes, and public transportation. Through expert interviews, unique user values with corresponding functional requirements were identified for each mobility context. The study findings would inform the user experience design for future mobility systems.

1. Introduction

Digital technologies, such as IoT, AI/ML, cloud computing, robotics, etc., are providing new opportunities for the UX design in the domain of mobility products and services. Some examples of new technologically enabled mobility experiences include the vehicular integration of various mobile applications, such as Google Maps, Wave and Spotify, and, the current autonomous ride-hailing services, such as Alphabet's Waymo and General Motors' Cruise. New technologies, whilst enabling new product/service functions, may also be utilized to create novel interfaces to innovate human-vehicle interaction.

It should be emphasized that for any product/service domain, the ultimate goal of the UX design is to address user needs and thereby support realizing user values. New technologies and creative design are the means to this goal. Thus, identifying user needs and values has a fundamental importance in the UX design research (Boztepe, 2007; Park and Han, 2013). According to the Merriam-Webster dictionary, the term 'need' refers to 'a lack of something requisite, desirable or useful' and the term 'value,' 'something desirable or valuable.' Since user needs and

user values are very similar and closely related concepts, the term "user value" will be used in this study to refer to both.

Given the importance, numerous studies have investigated user values. Some of them were concerned with basic user values relevant to a wide variety of products and services (Laugwitz et al., 2008; Brooke, 1996; Kirakowski and Corbett, 1993; Thielsch and Moshagen, 2011; Minge et al., 2017; Gediga et al., 1999). Others, user values specific to a particular product/service domain (Maslov et al., 2021; Ike et al., 2021; Park and Han, 2013; Park et al., 2013). Some of the domain-specific studies attempted to determine the user values for future mobilities (Lee et al., 2020; Lee et al., 2022; Wolf et al., 2018; Hildén et al., 2016; Pfleging et al., 2016). Lee et al. (2022) examined the user values for future autonomous vehicles and identified increasing demands for continuity, personalization, and social activity. Wolf et al. (2018) investigated far-future mobility-related customer needs by analyzing short stories gathered from creative writing workshops. Hildén et al. (2016) explored the domain of future public transportation, reporting that user values for future public buses encompass informative and entertaining bus stops, a relaxing atmosphere, subtle opportunities for

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social interaction, a sense of luxury, and ecological sustainability. [Pfleger et al. \(2016\)](#) investigated the non-driving-related activities that drivers/occupants wish to engage in while inside highly or fully automated vehicles. These activities included daydreaming, writing text messages, eating and drinking, browsing the internet, and making calls, as well as traditional activities such as talking to passengers and listening to music.

Despite previous research, gaps remain in understanding user values for future mobility. One notable gap is the limited examination of different mobility contexts in assessing these values. Most studies, including those by [Lee et al. \(2022\)](#), [Hildén et al. \(2016\)](#), and [Pfleger et al. \(2016\)](#), focus on a single context, leaving areas such as shared mobility services and air travel insufficiently explored. Additionally, the similarities and differences in user values across various mobility contexts, as well as their interrelations, are not well understood. This knowledge gap is problematic, hindering not only the design of user experiences for individual contexts ([Axsen and Sovacool, 2019](#)) but also the integration of different mobilities at the system level ([Ceder, 2021](#)).

To address the research gap outlined above, this study is guided by the following three research questions:

RQ1. What user values are associated with future mobility experiences across four distinct contexts (private car, shared mobility services, airplane, and public transportation)?

RQ2. Which user values are commonly important across all mobility contexts, and which user values are particularly salient in specific contexts?

RQ3. What functional requirements are associated with these user values in each mobility context to inform future mobility user experience design?

To answer the abovementioned research questions, experts proficient in both user values and technical aspects of mobility products were interviewed. They were asked about the types of products, systems, and services they would prefer to experience in the future within each mobility context.

2. Methods

A set of basic user values was prepared as a reference for the subsequent user value identification process – this user value set (hereafter, the reference user value set) was to help the researchers label and organize the user values from the interview script data.

The reference user value set was primarily developed based on the UX aspects of the UEQ + framework ([Schrepp and Thomaschewski, 2019](#)). The UEQ + framework offers a comprehensive catalog of general UX aspects, totaling 16 in number, many of which align with user values. The 16 UX aspects were: attractiveness, efficiency, perspicuity, dependability, stimulation, novelty, trust, aesthetics, adaptability, functionality, intuitive use, value, trustworthiness of content, quality of content, acoustics, and haptics. As for the UX aspect ‘value,’ [Schrepp and Thomaschewski \(2019\)](#) used the term to refer to craftsmanship (‘of high quality and professional design’).

The UEQ+ was created through an analysis of research papers and the UX evaluation scales of the existing UX questionnaires ([Schrepp and Thomaschewski, 2019](#)). Only the aspects that align with user values were included, leading to the exclusion of haptics and acoustics. Also, three new user values (comfort, safety, and maintainability) were added because they represent some fundamental user values for mobility and transportation. The modifications were based on an expert discussion – three UX experts participated. As a result, the reference user value set was constructed with a total of seventeen user values, which were: attractiveness, efficiency, perspicuity, dependability, stimulation, novelty, trust, aesthetics, adaptability, functionality, intuitive use, value (craftsmanship), trustworthiness of content, quality of content, comfort, safety, and maintainability.

2.1. Interviewees

A total of ten interviewees, with an average of 5 years (Min: 2 years, Max: 18 years) of professional experience in the mobility industry participated in the study. They were from four different countries: the Netherlands, Sweden, South Korea, and the United States. The participants’ working experience in the mobility industry and their roles at the time of the interview are described in [Table 1](#).

This study intentionally employed expert interviews rather than end-user interviews to explore user values associated with *future* mobility experiences. The participating experts were selected based on their extensive professional experience, enabling them to reason beyond current practices and consider emerging technological and systemic conditions.

2.2. Interview procedure

In each interview, after collecting basic information (work experience, occupational background, and job description) about the interviewees, detailed descriptions of the four different mobility contexts (private car, shared mobility services, airplane, and public transportation) were first presented to them. An identical starter question was utilized for all of the four mobility contexts, and, follow-up questions were determined using the laddering technique. The starter question was as follows: “Let’s imagine that you are living in a world where all the IoT devices are connected with mobilities so that all kinds of information are accessible while moving around. Wherever you are you can always get the information or the services that you want. In this connected mobility world, what kinds of products, systems, and services would you like to experience? Please think of the situation where you are on (a mobility context).” The order of the four contexts presented to each interviewee was randomized. Each interview took approximately 1 h.

All the interviews were conducted using a video conference call platform. For subsequent data processing and analysis, the entire round of interviews was recorded by a Voice Recorder application, with the participant’s agreement. The interview protocol was approved by the institutional Human Research Ethics Committee (HREC).

2.3. Data collection and analysis

All the recorded interview content was transcribed. Then, each interviewee’s interview script was segmented and coded into minimum meaningful topics and relevant user values using Atlas.ti. Five experienced coders independently reviewed each interview script and made notes about the topic of each text segment. During this phase, coders annotated each segment with (1) a short descriptive topic label capturing the main theme of the segment and (2) one or more candidate user values that the segment reflected. In cases of disagreement, the coders jointly reviewed and discussed the issues to reach agreements. After several offline workshops, all disagreements were resolved.

Table 1
Detailed information of interviewees.

Interviewee code	Working experience (years) in the mobility industry	Roles
1	2.5 years	UX lead
2	3.5 years	Senior research engineer
3	18 years	UX/UI manager
4	2.5 years	System safety engineer
5	10 years	Strategy manager
6	2 years	Interaction engineer
7	2.5 years	Product designer
8	3.5 years	Product designer
9	4 years	Product manager
10	5 years	UX designer

Based on the analysis results, the reference user value set was iteratively refined based on the coding results. First, user values from the reference set that were not mentioned by any interviewee (i.e., attractiveness and aesthetics) were removed. Second, when interviewees' expressions consistently reflected a value conceptually aligned with an existing one but expressed using slightly different language, the corresponding value labels were revised through careful discussion among the coders. Specifically, the user values of stimulation, intuitive use, trustworthiness of content, and quality of content were renamed as immersiveness, intuitiveness, transparency, and informativeness, respectively, to improve consistency across value labels and to convey more specific and precise meanings. Third, when interviewees repeatedly raised themes that could not be adequately mapped onto any existing value in the reference set, new user values were added. Through this process, three user values (continuity, human connection, and anthropomorphism) were identified and incorporated into the final user value set.

The interview scripts were carefully re-reviewed with respect to each of the four mobility contexts. For each context, a user value was considered relevant if an interviewee explicitly mentioned or implicitly expressed that value while discussing experiences or expectations specific to that context. The relevance of each user value was quantified through frequency analysis by counting the number of interviewees who referenced the value within each mobility context. In parallel, functional requirements were extracted from context-specific interview segments that described desired system capabilities, features, or behaviors. Each functional requirement was subsequently mapped to one or more user values based on the underlying need or concern expressed in the segment from which it was derived. These functional requirements define the design problems to be addressed, delineating what a mobility system must accomplish in future UX design endeavors.

3. Findings and insights

3.1. User value set for future mobility design

A total of nineteen user values were identified as the user value set for future mobility. They were: adaptability, anthropomorphism, assistance, comfort, human connection, continuity, controllability, efficiency, immersiveness, informativeness, intelligence, intuitiveness, maintainability, novelty, pleasure, privacy, safety, alert/warning, and functionality. Descriptions of the nineteen user values are provided in Table 2. Note that each user value in the set was mentioned by at least one expert for at least one of the four mobility contexts.

For each user value, the expert response frequencies for the four mobility contexts are presented in Fig. 1. Whilst some user values were relevant to multiple mobility contexts, others were not (Fig. 1). Consequently, the four mobility contexts differed substantially in the expert response frequency distribution for the 19 user values, and, also, in the set of relevant user values (the user values with expert response frequency greater than 0) (Fig. 1). Private car was associated with 18 out of the 19 user values. Airplane, shared mobility services, and public transportation, 13, 11 and 10, respectively.

The nineteen user values cover a diverse range of human values. This is thought to reflect that mobility is now more than simply moving from one place to another and the range of things that the users want to accomplish and experience through in-vehicle interactions is continually expanding.

The frequency analysis highlights both commonalities across all mobility contexts and salient differences specific to individual contexts, thereby providing important implications regarding which user values require greater design attention. In terms of similarities, among the 19 user values, adaptability, efficiency, informativeness, and continuity were the ones that were relevant to all four mobility contexts and at the same time had a relatively larger magnitude of overall relevance than the other user values. These user values in combination seem to indicate

Table 2

User value set of future mobility.

User value	Description
Adaptability	Providing personalized experience mainly by adapting system features to a user's characteristics
Anthropomorphism	Users having an impression that they are interacting with human-like agents
Assistance	Assisting users with physical/cognitive impairments to perform tasks by providing useful functions
Comfort	Providing emotionally comforting and physically relaxing experiences
Human connection	Users having an impression that they are being socially connected to an external community
Continuity	Providing seamless user experience across different vehicles, devices and places
Controllability	Users feeling that they have some proper level of control over mobility functions
Efficiency	Saving time and cost in achieving a user goal
Immersiveness	Providing immersive and interactive experience
Informativeness	Providing useful information in real-time
Intelligence	Providing the most apposite assistance and information to users
Intuitiveness	Allowing simple, intuitive, and user-centered interactions
Maintainability	Providing proper notifications about the mobility's maintenance status
Novelty	Providing novel and original experience
Pleasure	Providing hedonic and interesting experience
Privacy	Users feeling that their personal data are being carefully managed and protected
Safety	Keeping a user's safety and security
Alert/warning	Giving an alert/warning when drivers become distracted, drowsy, or if an unexpected event occurs
Functionality	Providing useful mobility functions

that providing optimal services based on contextual details (personal and situational information) is becoming more important. The user value 'continuity' is conceptually the same as the 'continuity' concept in the domain of multi-device experiences (Levin, 2014; Sørensen et al., 2014; Brudy et al., 2019). The result on 'continuity' (Fig. 1) seems to emphasize that the design of a mobility/transportation system (how to physically move people around) cannot be separated from that of an information system (how to virtually move information and knowledge around) in the present-day world. Specifically, in the mobility domain, continuity influences design by highlighting the need for seamless experiences across different transportation modes as well as across temporal phases of mobility, including before, during, and after travel. For example, users often move across multiple mobility modes within a single journey, and disruptions in information access, interaction flow, or task state during these transitions can increase cognitive burden and reduce overall experience quality. In addition, users increasingly expect to continue ongoing activities such as working and communicating throughout the mobility process, rather than treating travel as a disconnected interruption. The prominence of continuity across all mobility contexts, therefore, suggests that effective mobility design must integrate physical transportation systems with digital information systems, ensuring that information, services, and user activities persist seamlessly across modes, devices, and contexts.

It is interesting that the user value 'safety,' which is a central concept in transportation, had a relatively low overall relevance level (Fig. 1). This does not necessarily indicate that safety is considered unimportant. Rather, it may reflect experts' tendency to treat safety as a baseline or assumed prerequisite for future mobility systems. Given the future-oriented focus of the interviews, experts may have held an optimistic view that future mobility systems would, in general, be safer than current systems in terms of transportation accidents. For example, autonomous vehicles are considered to be a safer means of ground transportation than traditional vehicles (Robert, 2019). Kalra and Paddock (2016) estimated that introducing autonomous vehicles sooner could save more than half a million lives over the next 20 years.

The differences between the four mobility contexts in the expert

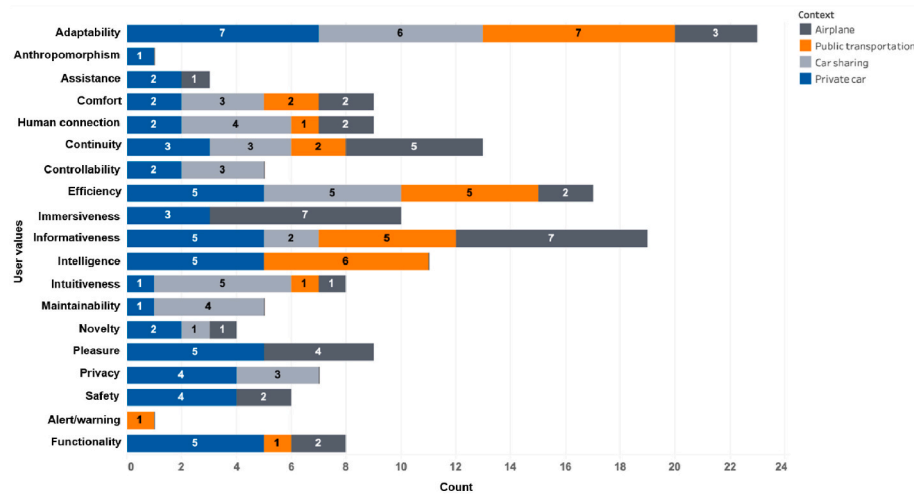


Fig. 1. Frequency analysis result.

response frequency distribution for the 19 user values (Fig. 1) could be attributed to the fact that the four mobility contexts differ in terms of the user goals and tasks, and, usage situations. Specifically, immersiveness and informativeness were more strongly emphasized in the ‘airplane’ context, reflecting the increasing importance of in-flight content and entertainment experiences. In the ‘public transportation’ context, adaptability and intelligence were more salient. This is likely due to growing user expectations for more user-aware and adaptive mobility experiences enabled by advancements in IoT technologies that minimize cognitive and physical workload during public travel. For ‘shared mobility services’, maintainability emerged as particularly important, as it directly influences the safety and efficiency of shared service use given the operational characteristics of such systems. In addition, intuitiveness was highly valued because intuitive service design directly reduces user effort in using shared mobility contexts. Interestingly, the ‘private car’ context was associated with more user values than the other three contexts (Fig. 1). In fact, almost all of the user values (18 out of the 19) were found to be relevant to the context. This can be attributed to the broad range of activities and use cases supported by private cars, which span commuting, leisure, caregiving, and work-related tasks, thereby eliciting diverse functional needs. In addition, unlike other mobility contexts, the private car is typically owned by the user, resulting in long-term and repeated interactions. This ownership-based relationship likely lead to stronger expectations for personalization, control, and system adaptation over time, allowing a wider spectrum of user values to become salient. Relatedly, anthropomorphism was found to have an association only with the private car context (Fig. 1). This is thought to reflect the distinct user-vehicle relationship in the private car context. A detailed discussion of why these user values are salient in each context and how they can be operationalized through concrete functional requirements is provided in Section 3.2.

Among the nineteen user values for future mobility, seven were from the reference user value set based on the UEQ+ (adaptability, comfort, efficiency, maintainability, novelty, safety, and functionality), nine were modifications of some user values in the reference set (assistance, controllability, informativeness, intuitiveness, immersiveness, intelligence, pleasure, privacy, and alert/warning), and three were newly added ones (anthropomorphism, continuity, and human connection).

As described above, the user value set for future mobility was substantially different from the reference user value set based on the UEQ+ (Schrepp and Thomaschewski, 2019). The difference was expected, as different product/service domains would be associated with different sets of user values. Relatedly, Schrepp and Thomaschewski (2019) stated that the UEQ+ does not cover all UX concepts (UX values) and it should be viewed as an incomplete framework. The UEQ+, however, is

highly useful as a starting point for constructing a domain-specific user value set. Indeed, multiple studies have derived domain-specific user value sets utilizing the UEQ+ (Setiaji, 2020; Meiners et al., 2021; Klein et al., 2020) and other domain-non-specific user value sets, such as AttrakDiff2 and meCUE (Hassenzahl, 2004; Minge et al., 2017).

3.2. User values for each mobility context

Figs. 2–5 each present the expert response frequency distributions for the four mobility contexts, in the order of airplane, public transportation, shared mobility services, and private car. Tables 3–6 present the sets of relevant user values for the four mobility contexts. In each table, for each of the relevant user values, major functional requirements, and representative user quotations identified from the interview data are presented. For each mobility context, some notable observations are discussed in what follows.

3.2.1. Context 1) Airplane

As for the context of airplane, the user values with the highest expert response frequency were immersiveness and informativeness – 7 out of the 10 experts mentioned the two user values. The user value ‘immersiveness’ pertained to the use of in-flight virtual reality (VR). Two functional requirements were identified: providing real-time/near-real-time location-based VR services (e.g., providing a 3-D flight map and a virtual tour of a place/country when flying over it) and enabling VR-based in-flight work collaboration (e.g., a virtual meeting with others far away). The user value ‘informativeness’ was related to two types of information: flight information (including in-flight environment information) and information about the destination.

Immersiveness seems relatable to some characteristics (UX problems) of current air travel: 1) airplane journeys tend to be for longer durations than travel by other transportation modes, 2) both physically and digitally, passengers are more disconnected from the outside world when inside an airplane than other vehicles. For example, most airline passengers cannot see outside easily during a flight, and, internet connection is typically unavailable, and 3) as passengers do not take part in the driving/operation of the vehicle, they are left in a confined space without much to do. For these reasons, different forms of in-flight entertainment have been developed to improve the in-flight experience (World Health Organization, 2005; Liu, 2007). VR seems to offer new possibilities for overcoming the problems of current air travel, especially the problem of disconnection, and, improving the in-flight experience.

The functional requirement of real-time/near-real-time location-based VR services (e.g., providing a 3-D flight map and a virtual tour of

Context 1) Airplane

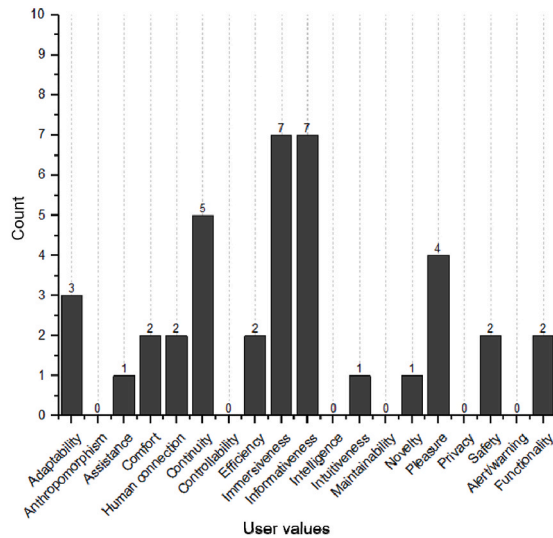


Fig. 2. Frequency analysis result for the context of the airplane.

China when flying over China”) is interesting. This expert prediction suggests that airline passengers would want to be continually updated with the positional change during a flight and also would want to enjoy experiences similar to the physical (mainly visual) experiences gained from looking out through a window while traveling in a car or a train. This functional requirement seems to represent the desire to restore the physical connection with the external world, which is not well supported in the current airplane journeys.

The functional requirement of VR-based in-flight work collaboration

(e.g., a virtual meeting) suggests that in addition to the physical connections with the physical world, maintaining and even increasing the social connections with the rest of the world would be an important human desire/need, and, technology and design need to be best utilized to address the current state of social disconnection during air travel.

It should be further noted that entering a virtual place (e.g., entering a virtual meeting) using VR technology is conceptually very similar to physically moving to a place using a mode of corporeal mobility. Relatedly, Kellerman (2011) has claimed that three categories of mobility, that is, terrestrial (moving people), aerial (moving people) and virtual (moving information) mobilities, are not separate entities but should be viewed as categories of a single more general entity (mobility at large) as they share a basic model of mobility cycles and are all IT-based or IT-dependent. It seems likely that future passengers would want to visit many virtual destinations to maintain social connections while physically moving to a destination via an airplane (which itself is in many cases socially motivated). How to manage all the concurrent and successive, and, corporeal and virtual trips and activities at different real and virtual places would become an important issue to many airplane passengers and thus UX designers.

Regarding the practicality of providing real-time, location-based VR services in the airplane context, it is important to note that such experiences are becoming increasingly feasible given recent technological advances. In-flight internet connectivity has already been widely deployed on many airlines and routes, with improving bandwidth and stability enabling real-time data transmission. In addition, VR hardware has rapidly evolved from bulky head-mounted displays to lightweight, glasses-like form factors, which are more compatible with in-flight safety requirements and passenger comfort. While fully immersive, high-bandwidth VR experiences may still face technical constraints, hybrid approaches offer a practical solution under current conditions. For example, locally cached VR content (e.g., virtual flyover views,

Table 3

User values and functional requirements for the context of the airplane.

User values	Functional requirement	Representative quotation
Adaptability	Customization	"I would prefer the content and information to be more curated and tailored to individual passengers."
Assistance	Head-mounted device for improving concentration and work performance	"It would be great if passengers can concentrate more on their work with virtual reality head-mounted display."
Comfort	Meditation tutorial using a VR headset	"A lot of people also get anxious sitting in a confined space. So maybe there could be meditation tutorials or something that would help them relax. A VR headset would be necessary for such meditation."
Human connection	In-flight social network platform	"You can go sit in the first-class seat. So maybe you can use, like, some platform to connect with people on the same flight. So, if there is somebody who is experiencing some physical or medical issues, and someone in the first-class seat doesn't mind letting somebody else borrow the seat for one or 2 h, a match can be made through the in-flight social networking system."
Continuity	Seamless connection of mobilities before and after flight Seamless boarding experience	"If you are going outside and want to take Uber, it would be great if you don't get confused on how and where to take it. The connection between different mobilities would be highly important." "Currently, you have to show your passport and boarding pass to different people and you don't really know where to go and who wants to see the passport or the boarding pass. This inconvenience should be rather fixed"
Efficiency	Guiding passengers for improving boarding experience	"So it calculates your own boarding time. Yeah. Yo. Always it's like maybe boarding begins at 5pm. Yeah, but it takes 20 min. So you may arrive 30 min before the boarding is closed. Getting the optimal boarding time and the process would be helpful."
Immersiveness	Unique flight experience through virtual reality Working while traveling using virtual reality	"I think I can see like a 3-D map of where I'm at right now. For instance, when we are flying around China, having virtual tours of China would be great." "If you have meetings during the journey, I want to still attend the meeting while in flight. Using VR technology, for example, I would be able to take part in the virtual meeting."
Informativeness	Information about flight environment Information about destination	"I would like some information about my flight including flight hours left and weather condition." "I wonder if the weather of the flight destination isn't going to be too cold. And then before I arrive at the airport, I would like to get informed about any important local news."
Intuitiveness	Intuitive touchscreen interface for in-flight services	"It would be nice if we could order in-flight meals through the touchscreen."
Novelty	Automatic security check system	"The entire process of security check usually takes so long. It would be better to make the security check system smarter and improve efficiency by utilizing IoT technologies."
Pleasure	Diverse entertainment content	"I want to get some more entertainment, like watching movies or reading interesting news."
Safety	Information about possible flight-related safety concerns	"I just want to know the risk of turbulence during the flight."
Alert/warning	Providing transparently and openly information that a user needs	"I want to know about the unexpected situation in advance. For example, If the alarm goes off 10 min before getting off the subway, I think it'll help a lot."
Functionality	Wi-Fi service	"Having a high-speed WiFi service during flight would be awesome."

contextual destination previews, or location-based entertainment) can be dynamically updated at specific designated times and locations.

The user value “informativeness” was mostly concerned with information about multiple locations/places that a passenger must deal with, such as the current location of the airplane, the cabin and the flight destination. The user information needs related to locations and places would likely increase in the future as future passengers are expected to visit multiple virtual locations/places in addition to physical ones. Electronically extending the self for more experiences and connections is beneficial but would accompany an increase in the information processing load.

Continuity was the user value with the third highest expert response frequency (5 out of the 10 experts). It calls for seamless connection of mobilities before and after flight and seamless boarding experience. For example, pre-flight activities such as itinerary planning, seat selection, entertainment preferences, or work-related tasks can be synchronized across personal devices and airline systems through cloud-based user profiles. During the flight, these states can be maintained and extended via in-flight connectivity and entertainment systems. This would also allow passengers to continue ongoing activities, such as working on documents, consuming personalized content, or accessing contextual information, without disruption. After landing, continuity can be further supported by leveraging passengers' in-flight activities to enable personalized post-flight tasks. It can also ensure seamless coordination with ground transportation and navigation systems. Furthermore, if disruptions such as in-flight delays or changes in a passenger's health and mental condition occur, these factors can be reflected in subsequent services, such as adjusting travel plans or recommending alternative transportation options. The user value ‘continuity’ in the context of airplane seems to be closely related to the observation that “‘aero-mobilities’ are related in several different and distinctive ways to other forms of mobility, sometimes as rings in a chain of intermodal transportation systems” (Cwerner, 2009). Indeed, before and after flight, passengers perform various related work tasks (e.g., making a flight reservation and calling an Uber) using virtual mobilities and move a lot by terrestrial mobility modes, including walking (e.g., first and last mile transportation) (Kellerman, 2011). Optimizing the flows of work tasks and physical movements occurring in multiple digital and physical spaces is thought to be crucial to reducing the physical and cognitive workloads of the passengers, improving work productivity and efficiency, and, enhancing the overall passenger experience. Given the prediction that various VR destinations will be added to the passengers' list of places to visit, the importance of continuity is expected to increase even more. Continuity would greatly affect the ability to make connections and extend self.

Adaptability (3 experts) and pleasure (4 experts) were also found to be relevant to the airplane mobility context. The functional requirement for adaptability was to curate and tailor entertainment and information according to the needs of each individual passenger. The functional requirement for pleasure was to provide a wide variety of entertainment and information. These two user values are related to the importance of in-flight entertainment. Different passengers have different tastes and preferences. Thus, the availability of many entertainment options and the ability to tailor them according to individual preferences would help increase user satisfaction.

It is interesting that the user value ‘comfort’ was associated with a functional requirement of providing VR-based meditation tutorials. Traditionally, physical elements, such as legroom, personal space, seat dimensions, noise, climate, and hygiene, have been considered important factors of in-flight comfort, along with the quality of airline crew services (Vink et al., 2012). In addition to these factors, dimensions of psychological comfort should also be considered to improve the passenger experience. As mentioned earlier, VR seems to offer different possibilities, including the provision of relaxing experiences.

3.2.2. Context 2) Public transportation

Four user values were found to be the major ones for the context of public transportation. They were adaptability (7 experts), intelligence (6 experts), informativeness (5 experts), and efficiency (5 experts).

Adaptability was concerned with helping the users optimally use the public transportation system by supplying relevant information. Informativeness was very similar to adaptability. The experts seem to suggest that different users may choose different objectives (e.g., minimizing travel time or maximize personal space) according to their personal preference or the context. Intelligence and efficiency pertained to the reduction of cognitive and physical efforts of users during the use of a public transportation system.

The expert responses concerning the user values ‘adaptability’ and ‘informativeness’ have similarities with some of the core characteristics of the ‘mobility-as-a-service (MaaS)’ concept (Hietanen, 2014; Jittrapirom et al., 2017). Hietanen (2014) describes MaaS as a mobility distribution model that delivers users' transport needs through a single interface of a service provider. MaaS combines different transport modes to offer a tailored mobility package, like a monthly mobile phone contract. The core characteristics of MaaS include integration of transport modes, tariff option, one platform, multiple actors, use of technologies, demand orientation (user-centric), registration requirement, personalization and customization (Jittrapirom et al., 2017). Future public transportation systems may be in the form of a MaaS service or would share some similarities with it.

It is quite interesting that ‘personal space’ was suggested as a potential factor that could affect a user's choice among different public transportation options (“It is possible to consider how many people are in the bus or the subway when choosing the means of transportation”). Factors affecting user-decision making and inter-individual differences in decision-making need to be investigated to inform the design of future public transportation systems. User segmentation and user modeling (Fischer, 2001) will be important research topics. Additionally, research studies are needed to understand how context affects user decision-making.

The user values ‘intelligence’ and ‘efficiency’ emphasize the importance of reducing cognitive and physical efforts associated with the use of a public transportation system. UX design techniques, such as contextual inquiry and analysis and design ideation, and, design knowledge from human factors and ergonomics would be important for the realization of effortless interaction.

Related to intelligence, a design idea involving the use of a

Context 2) Public transportation

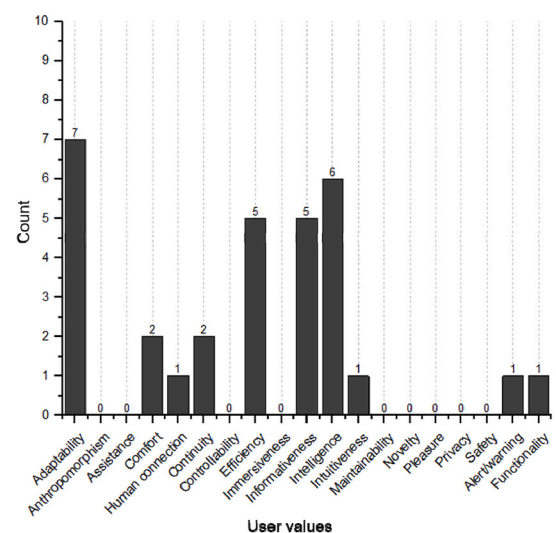


Fig. 3. Frequency analysis result for the context of public transportation.

Table 4

User values and functional requirements for the context of public transportation.

User values	Functional requirement	Representative quotation
Adaptability	Adaptive time scheduling	"The app suggests that you should leave 5 or 10 min later or earlier. So your way to the gym and afterwards to home will be optimized "
	Recommendation on optimal means of transportation	"It is possible to consider how many people are in the bus or the subway when choosing the means of transportation. And you are also able to choose a more preferred route or the most efficient way in the navigation system."
Comfort	Comfortable ride experience	"The app may also include in the plan not taking the tram because it is really crowded, but may include taking the bus because it is not crowded"
Human connection	Network connection with local communities	"The app should be connected with the surrounding social communities before and after boarding."
Continuity	Seamless connection of multiple means of transportation	"If passengers use more than one means of transportation, it is important how seamless the transfer is."
Efficiency	Getting in and out of a vehicle without tagging a physical card	"For example, you have to pull out the physical card for tagging in and out, but it seems completely redundant"
Informativeness	Information about optimal path	"If I need to go from point A to point B, the system should tell me the most efficient way."
Intelligence	Alarm when arriving at a place to get off	"An alarm like vibration on the seat wakes you up when you're at your stop."
Intuitiveness	Intuitive information delivery	"I want to know easily which bus arrives next through the smartphone app."
Alert/warning	Detailed information about traffic situation	"It would be best if public transportation was operated according to the set schedule, but in case of an unusual event, I would like to be notified in advance."
Functionality	Reduced waiting time	"It would be good to use public transportation with minimal waiting time"

vibrotactile alarm was suggested. The design of effective yet socially acceptable (Väänänen-Vainio-Mattila et al., 2013; Koelle et al., 2020) and privacy-preserving alarm displays would be an important issue for future public transportation systems.

3.2.3. Context 3) Shared mobility services

The user values with relatively higher expert response frequencies were adaptability (6 experts), efficiency (5 experts), and intuitiveness (5 experts). Also, human connection and maintainability had responses from 4 experts, and, comfort, continuity, controllability, and privacy, from 3 experts.

Regarding adaptability, two functional requirements were identified: 1) getting access to personal accounts and services while riding a shared car, and, 2) automatically adjusting in-vehicle settings based on the personal profile of the user.

Efficiency was concerned with minimizing the movements (providing optimal departure and destination points) and the time (minimizing the time for car searching and waiting) associated with the use of shared mobility services. Intuitiveness pertained to reducing user efforts while interacting with the system interfaces. Continuity ("seamless pick-up service"), similar to efficiency and intuitiveness, reflects the user's need for minimizing the movements, time, and efforts. The three user values are similar in that they are all related to the reduction of user costs while using shared mobility services.

Human connection had two different aspects: connecting with the other passengers in the same physical space ("passenger matching system based on personality") and connecting virtually with people in distant places.

Maintainability was concerned with providing the users with the vehicle state information of a shared car, such as fuel level, tire pressure, etc., to help better maintain the vehicle. Informativeness (2 experts) also touches on the user needs for vehicle state information.

Comfort involved implementing a driver/passenger matching system that considers users' emotions or characteristics when using shared mobility services. Controllability focused on allowing users to freely select their preferred drivers. Privacy entailed carefully managing the use of personal information. Specifically, users' private information, such as their current location, should only be accessed with their explicit consent.

The two functional requirements identified for the user value 'adaptability' were concerned with personalization – providing personalized mobile app services and automatically configuring the adjustable vehicle components (seat, steering wheel, pedals, and mirrors) according to an individual driver's preferred setting. In addition to

these two, another potentially useful vehicle function may be to provide personalized human-vehicle interfaces (displays and controls) based on a user model or user data. Such an interface personalization capability, if realized, would greatly benefit driving safety and driver experience, especially for those who must drive an unfamiliar vehicle in the context of shared mobility services. Reconfigurable displays (Corsi and Sattler, 1989; Knoll, 2017) would be the enabling technology in realizing interface personalization.

As in the other mobility contexts, the expert responses concerning efficiency, intuitiveness and continuity indicate that minimizing the system use costs (physical movements, time, and user cognitive/physical efforts) should be an important goal for the design of future shared mobility services. The importance of cost minimization becomes more evident when considering that shared mobility services are to compete against private vehicles, which are generally superior to shared mobility services in terms of the aforementioned cost elements at this time. Widespread adoption of shared mobility services may be contingent upon how well the cost minimization can be done. The vehicle functions based on personalization mentioned earlier could contribute to the reduction of user physical and cognitive efforts during the use of shared mobility services.

The functional requirement "passenger matching based on personality" of the user value "human connection" seems to be related to the fact that ridesharing requires one to share long journeys with complete strangers in close confines. The uncertainties involved in such interactions can become a barrier to the adoption of ridesharing services (Chan and Shaheen, 2012; ITS America, 2015). Passenger matching may be an effective way for reducing uncertainties. Personality may be only one of many dimensions in which passenger matching could be performed. Various personal variables, including physical variables, may be considered as possible dimensions for passenger matching. More studies are warranted in order to identify relevant dimensions, determine passenger types, and, develop effective passenger matching algorithms.

The user values "maintainability" and "informativeness" seem to reflect the need for reducing the uncertainties about the vehicle provided during a carsharing or ridesharing transaction. Providing sufficient, accurate and reliable vehicle information in a timely manner would greatly impact the level of user trust and the service acceptance.

Similar to the concepts of 'passenger matching,' 'maintainability,' and 'informativeness,' controllability emphasizes the importance of reducing uncertainties associated with shared mobility services. Specifically, controllability involves enabling users to freely choose their preferred drivers in the context of ride-hailing or ride-sharing, addressing concerns about the driver's driving style and other service characteristics.

Context 3) Shared mobility services

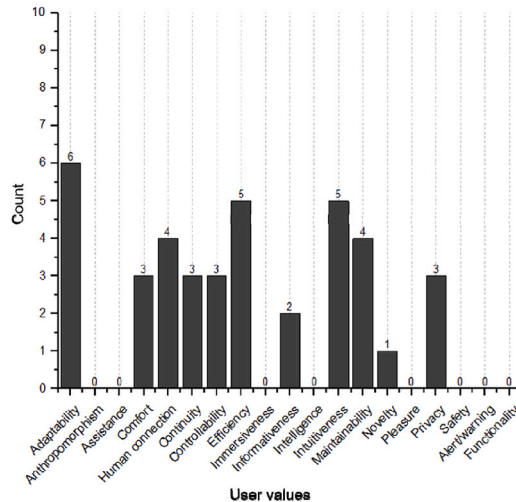


Fig. 4. Frequency analysis result for the context of shared mobility services.

We authors concur with the notion that driving style is an important UX factor affecting the level of user satisfaction. Developing an effective driver recommendation system (or an effective driver-passenger matching system) would require research studies on how to represent different driving styles objectively and quantitatively, how to identify and represent a user's preferred driver driving style, and how to quantify the goodness of match between a driver's actual driving style and a customer's preference.

It is interesting to note that the user value 'human connection' has a virtual mobility (Kellerman, 2011) component ("in-vehicle social networking service") similarly to the user value 'immersiveness' ('working while traveling using virtual reality') in the context of airplane, although it does not involve the use of highly immersive VR. Indeed, long-distance ridesharing appears to have some commonalities with travel by air. The UX issues and design solutions found in one mode of transportation may serve as useful references for solving problems and improving the UX in the other.

3.2.4. Context 4) Private car

Again, the 'private car' context was associated with more user values than the other three contexts (Fig. 1). In fact, almost all of the user values (18 out of the 19) were found to be relevant to the context. This is likely because a wider variety of user activities occur in the private car context than in the others. Also, the private car context differs from the others in the user-vehicle relationship in that in the context, the user owns the vehicle. Relatedly, anthropomorphism was found to have an association only with the private car context (Fig. 1). This is thought to reflect the distinct user-vehicle relationship in the private car context.

The user value with the highest expert response frequency was adaptability (7 experts). Efficiency, informativeness, intelligence, pleasure, and functionality also had 5 expert responses.

Similarly to the other mobility contexts, minimizing the user costs in terms of movements, time, and cognitive/physical efforts was identified as an important UX design goal for the private car context. The related user values were efficiency ("determining optimal route"), intelligence ("home secretary system"), intuitiveness ("one touch automated parking system"), and functionality ("vehicle payment system").

The user values 'human connection' and 'continuity' again reflect the human desire to extend self and make connections ("driver-to-community communication"), and, emphasize the notion that the design of a mobility/transportation system (how to physically move people around) cannot be separated from that of an information system (how to virtually move information and knowledge around). Recent approaches to solving the "driver-to-pedestrian (vehicle-to-pedestrian) communication" problem (a functional requirement identified for the user value 'human connection') also show how the utilization of information technologies is becoming important in addressing this old problem (Anaya et al., 2014; Praticò et al., 2021).

Many of the user values in Table 6 collectively express a view that future private cars would function as both an intelligent autonomous agent and a versatile physical robot. These cars would perform a variety of tasks for owners, including economic activities. The user values are adaptability ("music recommendation system"), anthropomorphism, assistance, comfort, intelligence ("home secretary system"), intuitiveness, maintainability ("automated fuel charging"), and functionality ("delivery service through automated driving"). The "agent/robot" analogy may be useful for stimulating ideation for various new car usage scenarios. Also, it is thought that reviewing the current developments in the fields of robotics and human-robot interaction may help understand possibilities for future private cars. The notion that a privately-owned

Table 5
User values and functional requirements for the context of shared mobility services.

UX value	Functional requirement	Representative quotation
Adaptability	Getting access to personal accounts and services while riding a shared car	"When I ride Uber, I want my Uber account and Spotify account to be linked, so that I can control Spotify in the car. Even if it's not my car, I want the car to be my personal space with the help of technology."
Comfort	Automatically adjusting in-vehicle settings based on personal profile	"You have a digital profile of the position of your seat, steering wheel, etc. And the car would load the personal profile and automatically adjust the mirrors and seat to fit you."
Human connection	Passenger matching system based on personality	"Like, you know matching you with people who are as talkative as you are."
Continuity	In-vehicle social networking service	"I would like some social services so that I can keep in touch with people there that I'm heading to"
Controllability	Seamless pick-up service	"I want to experience a more easy-to-use and convenient pickup service."
Efficiency	Enabling users to freely choose preferred drivers	"Yeah, so it means you can freely choose the riders that you prefer."
	Providing optimal departure and destination points	The mobility service recommends the best place to pick up and get off the vehicle considering my route."
	Efficient car matching	"You don't have to waste so much time like searching and waiting for the car"
Informativeness	Detailed and accurate car status information	"I just want to know, for example, how much gas I have to put on. Also, I want to know if there is anything that I have to consider like the tire pressure or some other maintenance issues"
Intuitiveness	Intuitive application user interface design	"In order for the overall experience of the ride to be good, application interface should be intuitive and easy to use."
	Simple interaction design for shared mobility services	"The idea is that you just have a simple button, you just press on it and the app says the car is available for sharing."
Maintainability	Detailed and precise car status information	"Before renting a car, I would like to know all the details of any damage, such as scratches, and any odors present in shared cars."
Novelty	Vehicle-to-vehicle communication and social networking	"If it is possible for people in one vehicle to communicate with others in other vehicles using the IoT technology, it is likely to be used in the future."
Privacy	Privacy report and permissions	"It should be possible to check if my location is being tracked and choose whether to allow it or not."

Context 4) Private car

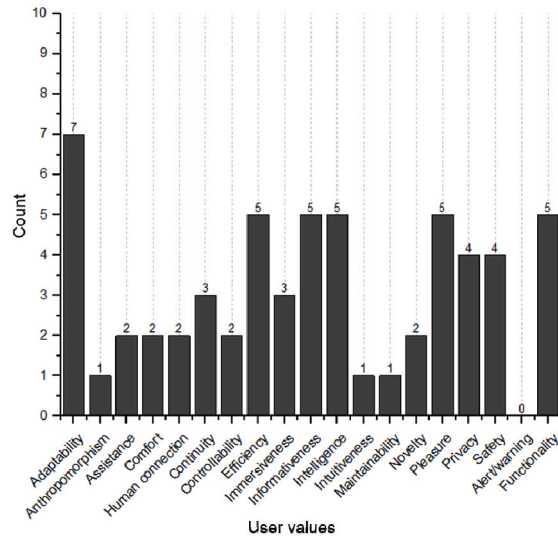


Fig. 5. Frequency analysis result for the context of private car.

vehicle is a resource for economic activities seems to set this particular mobility type apart from the others. Indeed, it may become a reason some individuals would want to own private vehicles in the future despite the current trend toward sharing economy – such individuals and the services they provide may account for a significant portion of future shared mobility services.

The functional requirement “parcel receiving system” of the user value “novelty” reflects the unique characteristic of a private car that it can serve as a storage space - the other mobility types do not seem capable of providing this function. The parcel-receiving function, if successfully implemented, may greatly improve the user experience with product delivery and also could contribute to enhancing the efficiency of future supply chains.

Many of the functional requirements described in Table 6 may be relevant to the other mobility contexts. For example, although providing driving assistance based on driver state monitoring (the user values ‘assistance’ and ‘comfort’) was mentioned only for the private car context, such functionality could be made available to those who drive unfamiliar vehicles via shared mobility services. Anthropomorphism may also be useful for shared car users. The availability of the driver’s own voice agent in a shared car may greatly help the driver deal with the unfamiliar vehicle. This could be understood as one aspect of personalization in shared mobility services. Healthcare monitoring (the user

Table 6

User values and functional requirements for the context of private car.

User values	Functional requirement	Representative quotation
Adaptability	Allowing personalization/customization	"If it is a personalized car, basically the owner has the flexibility to set the settings or define what the car should do in any way that he wants."
	Music recommendation system	"I want my car to recommend music according to my mood. And it will be great if the car adjusts the seat or the light of the car considering my mood."
Anthropomorphism	Human-like in-vehicle voice user interface	"If the vehicle is equipped with a human-like voice agent like Siri, it will be more user-friendly."
Assistance	Suggestion/recommendation based on driver state monitoring	"When I lose the focus of driving, I want my car to tell me to take a rest."
Comfort	Driver state monitoring and automatic adjustments of in-vehicle settings	"The car monitors the driver's condition and adapts the internal lighting system. For example, if the monitoring results indicate that driver is nervous or stressed, the internal lighting system can be warmed to help him/her relax."
Human connection	Driver-to-community communication	"I want to get more in touch with the community or the social context around the car."
	Driver-to-pedestrian communication	"I think there is a lack of communication between drivers and pedestrians. There should be a better way of sending signals than honking when pedestrians interfere with the vehicle."
Continuity	Continuous use of external services inside a car	"In my car, I just want to continue to enjoy the movie that I was watching in the living room. Whether it is listening to music or anything, I want to enjoy the activities that I was doing in my place."
Controllability	Direct vehicle control	"I usually prefer driving myself because I like the feeling of accelerating and braking. Even if autonomous driving becomes available, manual driving would make me feel like controlling everything on my own."
Efficiency	Determining optimal route	"The vehicle can optimize travel routes based on traffic patterns or things like that"
Immersiveness	Immersive driving experience through augmented reality	"If I can get driving-related information while looking at the road ahead through augmented reality technology, I will be able to fully immerse myself in driving."
Informativeness	Information about road conditions	"On the road I'm going to drive, accidents, such as a big tree falling on the road, can occur. If I could receive such information in advance, I would be able to avoid a possible accident."
	Local information about destination	"It would be good if you can get information about restaurants or stores around your destination."
Intelligence	Home-connected digital assistant	"It is necessary for the car to give you a warning so that you don't forget what food ingredients are insufficient in the refrigerator and what to do today."
	Driving-related information support	"If you get information, such as how long you have to wait for the traffic light to change, you will be better prepared for driving."
Intuitiveness	One-touch automated parking system	"Whenever I'd have to pull my car outside the garage or I have to park my car, I would just let my car do it itself by just pressing a button. I think that will be really awesome."
Maintainability	Automated fuel charging system	"When I'm sleeping at home, I think it'd be nice if the car goes to the gas station by self-driving, gets refueled, and, then, comes back before I even know"
Novelty	Parcel receiving system	"People can deliver the packages to your car that acts as a kind of storage."
Pleasure	Diverse entertainment content	"While moving there is much content that I can watch such as Netflix, and YouTube. I think I will be spending much of my time doing that."
Privacy	One-time permission system	"One-time permission is required for someone other than me to open the trunk of my car. The person can be authenticated with the person's cell phone. This is for delivery storage."
	Privacy protection of in-vehicle conversation	"The car will listen to what people are talking about inside or outside the car. And how do you keep that privacy?"
Safety	Healthcare monitoring system	"It will be possible to check the health conditions of a seated person through monitoring bio-signals. Medical feedback can be provided"
Functionality	Vehicle payment system	"When I go to get food from takeout or something, I don't have to pull up my credit card. They just can get the payment by tapping the car that remembers my credit card information. I don't have to pull anything out."
	Delivery service through autonomous driving	"I can program my vehicle to go to the restaurant or grocery store and bring food for me. It will be basically like a robot that I own that can just go places and do things for me, right?"

value of 'safety') could also be considered in airplanes, public transportation, and shared mobility services in addition to private cars. These extensions, however, require collecting and/or accessing individuals' personal data from outside a driver's private vehicle; thus, privacy protection and data security are prerequisites for such extensions.

4. Concluding remarks

In this study, expert interviews were conducted to identify the user values and functional requirements relevant to the UX design of future mobilities. Four different mobility contexts were considered: airplane, public transportation, shared mobility services, and private car. Overall, a total of 19 user values were identified from the four mobility contexts. The four mobility contexts had some commonalities but differed substantially in the set of relevant user values and the expert response frequency distribution.

Some key points from the analyses of the expert interviews are as follows: The experts predict that future mobility users will want to make physical and social connections across multiple real and virtual places and extend their presence, and, in doing so, they will be simultaneously utilizing physical and virtual mobilities. Individuals would have to manage many concurrent and successive, and, corporeal and virtual trips and activities. Thus, the amount of human information processing would greatly increase, most likely in the form of multitasking and task switching, and, obtaining situation awareness would become very challenging. It is thought that interaction and interface design based on sound human factors design principles will become even more important in the future.

Many of the future scenarios that the experts presented, especially those related to the user values of 'human connection' and 'continuity,' suggest that the design of a mobility/transportation system (how to physically move people around) cannot be separated from that of an information system (how to virtually move information and knowledge around). More research is warranted to develop design methods that facilitate the integration of the two design aspects.

Despite the new trends of shared mobility services and MaaS, private cars would continue to be important in the future. Compared with other mobility modes, privately owned vehicles offer a wider range of functions (for example, receiving and storing delivery goods). Also, considering the current developments in the AI and robotics fields, future private cars would likely function as intelligent autonomous agents and also versatile physical robots; such agent/robot cars are expected to help the owners with various tasks and even perform economic activities for them. Indeed, for this reason, private cars can be regarded as a component of shared economy/mobility. There seem to be many innovation opportunities in this aspect.

Providing personalized user experiences was emphasized across the four mobility contexts. Such personalization requires understanding individual users' unique preferences and personal characteristics, including both physical and psychological. Human factors and ergonomics, which traditionally dealt with individual differences in the context of design, is expected to play an important role. Also, further research on user modeling and user segmentation is warranted for each mobility context.

Across all four mobility contexts, the expert responses highlighted that the mobility system design must strive to minimize user costs in terms of movements, time, and cognitive/physical efforts. Cost minimization is thought to be especially important in the shared mobility service context; widespread adoption of shared mobility services may be contingent upon how well the cost minimization can be done. Cost minimization would require the application of methods and knowledge from the fields of industrial engineering and human factors and ergonomics.

Through expert interviews, the current research study explored the user values and functional requirements related to future mobilities for each of four different mobility contexts (private car, shared mobility

services, airplane, and public transportation). The study results helped identify key user values for each mobility context and understand how one context relates to another. The study findings and the insights derived from them would help the UX design for future mobilities.

The user value set for future mobility and the functional requirements provided in this study is by no means complete or comprehensive. Whilst these findings represent valuable information for the UX design of future mobilities, they only represent the viewpoints of industry experts. In particular, the perspectives presented here may not fully capture the lived experiences, emotional responses, or contextual nuances of actual travelers. While experts can anticipate user needs and values based on domain knowledge and prior evidence, their perspectives may differ from those of end users in everyday mobility situations. Future research should therefore complement expert insights with empirical studies involving diverse traveler populations. Also, while the interviewees of the study consisted of professionals from four different countries (the Netherlands, Sweden, South Korea, and the United States), this study did not examine possible regional differences in perspectives, mainly because the sample size did not allow such analyses. Future studies may focus on each regional/cultural context so as to provide more context-specific design information. In addition, there are various types of mobility such as urban air mobilities and maritime mobilities which were not covered in this study. Since novel types of mobility continue to emerge, future research should examine them as well.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the author(s) used ChatGPT (version GPT-5, OpenAI) solely for language editing to improve clarity, grammar, and readability. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

CRediT authorship contribution statement

Hyesun Chung: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft, Writing – review & editing. **Wookjae Lee:** Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Woojin Park:** Data curation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Eunjung Choi:** Conceptualization, Data curation, Formal analysis, Investigation, Project administration, Writing – original draft, Writing – review & editing. **Jiwon Jung:** Conceptualization, Data curation, Formal analysis, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

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Data availability

Data will be made available on request.

References

- Anaya, J.J., Merdrignac, P., Shagdar, O., Nashashibi, F., Naranjo, J.E., 2014. Vehicle to pedestrian communications for protection of vulnerable road users. In: 2014 IEEE Intelligent Vehicles Symposium Proceedings. IEEE, pp. 1037–1042.
- Axsen, J., Sovacool, B.K., 2019. The roles of users in electric, shared and automated mobility transitions. *Transport. Res. Transport Environ.* 71, 1–21.
- Boztepe, S., 2007. User value: competing theories and models. *Int. J. Des.* 1 (2).
- Brooke, J., 1996. SUS-A quick and dirty usability scale. *Usability evaluation in industry* 189 (194), 4–7.
- Brudy, F., Holz, C., Rädle, R., Wu, C.J., Houben, S., Klokmose, C.N., Marquardt, N., 2019. Cross-device taxonomy: survey, opportunities and challenges of interactions spanning across multiple devices. In: *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, pp. 1–28.
- Ceder, A., 2021. Urban mobility and public transport: future perspectives and review. *Int. J. Unity Sci.* 25 (4), 455–479.
- Chan, N.D., Shaheen, S., 2012. Ridesharing in North America: past, present, and future. *Transp. Rev.: A Transnational Transdisciplinary Journal* 32 (1), 93–112. <https://doi.org/10.1080/01441647.2011.621557>.
- Corsi, K.M., Sattler, W.J., 1989. Reconfigurable displays used as primary automotive instrumentation. *SAE Trans.* 345–350.
- Cwerner, S., 2009. Introducing aeromobilities. In: *Aeromobilities*. Routledge, pp. 13–34.
- Fischer, G., 2001. User modeling in human–computer interaction. *User modeling and user-adapted interaction*, 11 (1), 65–86.
- Gediga, G., Hamborg, K.C., Düntsch, I., 1999. The IsoMetrics usability inventory: an operationalization of ISO 9241-10 supporting summative and formative evaluation of software systems. *Behav. Inf. Technol.* 18 (3), 151–164.
- Hassenzahl, M., 2004. The interplay of beauty, goodness, and usability in interactive products. *Hum. Comput. Interact.* 19 (4), 319–349. https://doi.org/10.1207/s15327051hci1904_2.
- Hietanen, S., 2014. Mobility as a service. *the new transport model* 12 (2), 2–4.
- Hildén, E., Ojala, J., Väänänen, K., 2016. User needs and expectations for future traveling services in buses. In: *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, pp. 1–6.
- Ike, T.C., Hoe, T.W., Kim, J.L.E., Y'ng, N.Y., 2021. Exploring user experience from an emotional context when designing immersive games for education. *Journal of ICT in Education* 8 (1), 10–25.
- ITS America, 2015. Rise of the real-time traveler: an exploration of trends and innovation in urban mobility. <http://www.trb.org/Main/Blurbs/173251.aspx>.
- Jittrapirom, P., Caiati, V., Feneri, A.-M., Ebrahimigharehbaghi, S., González, M.J.A., et al., 2017. Mobility as a service: a critical review of definitions, assessments of schemes, and key challenges. *Urban Plan.* 2 (2), 13–25. <https://doi.org/10.17645/up.v2i2.931>. <https://www.cogitatiopress.com/urbanplanning/article/view/931>. (Accessed 29 June 2017).
- Kalra, N., Paddock, S.M., 2016. Driving to safety: how many miles of driving would it take to demonstrate autonomous vehicle reliability? *Transport. Res. Pol. Pract.* 94, 182–193.
- Kellerman, A., 2011. Mobility or mobilities: terrestrial, virtual and aerial categories or entities? *J. Transport Geogr.* 19 (4), 729–737.
- Kirakowski, J., Corbett, M., 1993. SUMI: the software usability measurement inventory. *Br. J. Educ. Technol.* 24 (3), 210–212.
- Klein, A.M., Hinderks, A., Schrepp, M., Thomaschewski, J., 2020. Construction of UEQ+ scales for voice quality: measuring user experience quality of voice interaction. In: *Proceedings of the Conference on Mensch Und Computer*, pp. 1–5.
- Knoll, P.M., 2017. Some pictures of the history of automotive instrumentation. *J. Soc. Inf. Disp.* 25 (1), 44–52.
- Koelle, M., Ananthanarayan, S., Boll, S., 2020. Social acceptability in HCI: a survey of methods, measures, and design strategies. In: *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, pp. 1–19.
- Laugwitz, B., Held, T., Schrepp, M., 2008. Construction and evaluation of a user experience questionnaire. In: *Symposium of the Austrian HCI and Usability Engineering Group*. Springer, Berlin, Heidelberg, pp. 63–76.
- Lee, S.C., Nadri, C., Sanghavi, H., Jeon, M., 2020. Exploring user needs and design requirements in fully automated vehicles. In: *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, pp. 1–9.
- Lee, S.C., Nadri, C., Sanghavi, H., Jeon, M., 2022. Eliciting user needs and design requirements for user experience in fully automated vehicles. *Int. J. Hum. Comput. Interact.* 38 (3), 227–239.
- Levin, M., 2014. *Designing multi-device Experiences: an Ecosystem Approach to User Experiences Across Devices*. O'Reilly Media, Inc.
- Liu, H., 2007. In-flight entertainment system: state of the art and research directions. In: *Second International Workshop on Semantic Media Adaptation and Personalization (SMAP 2007)*. IEEE, pp. 241–244.
- Maslov, I., Nikou, S., Hansen, P., 2021. Exploring user experience of learning management system. *The International Journal of Information and Learning Technology* 38 (4), 344–363.
- Meiners, A.L., Kollmorgen, J., Schrepp, M., Thomaschewski, J., 2021. Which UX aspects are important for a software product? Importance ratings of UX aspects for software products for measurement with the UEQ+. In: *Mensch Und Computer 2021*, pp. 136–139.
- Minge, M., Thüring, M., Wagner, I., Kuhr, C.V., 2017. The mCUE questionnaire: a modular tool for measuring user experience. In: *Advances in Ergonomics Modeling, Usability & Special Populations*. Springer, Cham, pp. 115–128.
- Park, J., Han, S.H., Kim, H.K., Cho, Y., Park, W., 2013. Developing elements of user experience for mobile phones and services: survey, interview, and observation approaches. *Hum. Factors Ergon. Manuf. Serv. Ind.* 23 (4), 279–293.
- Park, J., Han, S.H., 2013. Defining user value: a case study of a smartphone. *Int. J. Ind. Ergon.* 43 (4), 274–282.
- Pfleging, B., Rang, M., Broy, N., 2016. Investigating user needs for non-driving-related activities during automated driving. In: *Proceedings of the 15th International Conference on Mobile and Ubiquitous Multimedia*, pp. 91–99.
- Prattico, F.G., Lamberti, F., Cannavò, A., Morra, L., Montuschi, P., 2021. Comparing state-of-the-art and emerging augmented reality interfaces for autonomous vehicle-to-pedestrian communication. *IEEE Trans. Veh. Technol.* 70 (2), 1157–1168.
- Robert, L.P., 2019. Are automated vehicles safer than manually driven cars? *AI Soc.* 34 (3), 687–688.
- Schrepp, M., Thomaschewski, J., 2019. Design and validation of a framework for the creation of user experience questionnaires. *International Journal of Interactive Multimedia & Artificial Intelligence* 5 (7).
- Setiaji, B., Hayaty, M., Setyanto, A., Santoso, H.B., 2020. Assessing user experience of a secure Mobile exam application using UEQ+. In: *2020 3rd International Conference on Information and Communications Technology (ICOLACT)*. IEEE, pp. 246–251.
- Sørensen, H., Raptis, D., Kjeldskov, J., Skov, M.B., 2014. The 4C framework: principles of interaction in digital ecosystems. In: *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, pp. 87–97.
- Thielsch, M.T., Moshagen, M., 2011. *Erfassung Visueller Ästhetik Mit Dem Visawi. Tagungsband UP11*.
- Vink, P., Bazley, C., Kamp, I., Blok, M., 2012. Possibilities to improve the aircraft interior comfort experience. *Appl. Ergon.* 43 (2), 354.
- Väänänen-Vainio-Mattila, K., Häkkinen, J., Cassinelli, A., Müller, J., Rukzio, E., Schmidt, A., 2013. Experiencing interactivity in public spaces (eips). In: *CHI'13 Extended Abstracts on Human Factors in Computing Systems*, pp. 3275–3278.
- Wolf, P., Klotz, U., Baumann, S., 2018. What can we do for you? Far-future mobility-related customer needs. In: *19th International Cinet Conference: Continuous Innovation: Spinning out and Spinning in*, pp. 447–456.
- World Health Organization, 2005. Travel by air: health considerations. *Weekly Epidemiological Record= Relevé épidémiologique hebdomadaire* 80 (21), 181–191.