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# Systemic Design Strategies for Shaping the Future of Automated Shuttle Buses

**Ming Yan[1], Peng Lu [1], Venanzio Arquilla [1], Fausto Brevi [1], Lucia Rampino [1] and Giandomenico Caruso [2,*]**

[1] Department of Design, Politecnico di Milano, 20158 Milan, Italy; ming.yan@polimi.it (M.Y.); peng.lu@polimi.it (P.L.); venanzio.arquilla@polimi.it (V.A.); fausto.brevi@polimi.it (F.B.); lucia.rampino@polimi.it (L.R.)

[2] Department of Mechanical Engineering, Politecnico di Milano, 20156 Milan, Italy

* Correspondence: giandomenico.caruso@polimi.it

**Abstract:** Automated shuttle buses entail adopting new technologies and modifying users' practices, cultural and symbolic meanings, policies, and markets. This results in a paradigmatic transition for a typical sociotechnical system: the transport system. However, the focus of the extant literature often lacks an overall vision, addressing a single technology, supply chain, or societal dimension. Although systemic design can manage multiple-level and long-term transitions, the literature does not discuss how systemic design tools can support implementation. This paper takes the four strategies proposed by Pereno and Barbero in 2020 as the theoretical framework to fill this literature gap, discussing the specific systemic design methods applicable to the design of automated shuttle bus systems. A six-week workshop to facilitate the exploration of future autonomous public transportation is taken as a case study. The systemic design approach was applied to enrich the Human–Machine Interaction (HMI) and functional architecture of automated shuttle buses.

**Keywords:** automated shuttle buses; sociotechnical system; systemic design; speculative design



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## 1. Introduction

With the advent of emerging vehicular technologies such as automated driving, connected cars, and electric vehicles, as well as the concept of Mobility as a Service (MaaS) [1], public transport systems are undergoing a profound transformation. A new type of mobility based on autonomous, connected, electric, and shared vehicles [2] is coming into being. As such, expectations are rising for those vehicular technologies to be applied in public transportation, putting Shared Autonomous Vehicles (SAV) in the spotlight. SAV is an umbrella term for shared public buses and logistics vehicles, also known as robot taxis or shuttle buses. Some vehicle companies have already explored these new markets, putting their automated shuttles into commercial use. Based on their primary functions, these automated shuttles can be roughly divided into delivering goods and transporting human passengers [3,4]. Examples include the robotic delivery vehicles from Nuro and Udelv in the United States; the autonomous shuttle "Olli" from the (recently shut down) American Local Motors Company; the autonomous shuttle Arma from the French company Navya; and the driverless taxi "Apolong" by the Chinese company Baidu [5].

Such a transformation of the public transport system suggests adopting a macro and systemic perspective. The city transport system has long been considered a sociotechnical system [6–8]. The term was initially coined by Emery and Trist (1960) to describe systems that involve a complex interaction between humans, machines, and the environment [9]. Any significant technical development implies "the formation of novel sociotechnical systems" [10]. The transition to the SAV is undoubtedly disruptive for current transport sociotechnical systems, which rely on manual-driving private cars.

Furthermore, the “technization of society and the socialization of technology” is emphasized for a sociotechnical system [10], and changes induced in a sociotechnical system imply “many complex interactions between societal groups, different actors as well as the alignment of specific factors” [11]. However, the current focus of AV research in the design discipline is mainly on technology developments, usability testing, interaction modes in user experience, etc. These separate investigations ignore the system’s macro environment and fail to address the complex linkages between the different influencing factors in this system.

Self-driving vehicles would disrupt the mode of transportation in future cities, opening a challenging design space that should be addressed systematically, considering the impacts on the entire sociotechnical system. The current design research on autonomous vehicles is guided mainly by service design through subjective data collection methods (such as observation and interviews) [12], as well as on prototype outputs and iterations of HMIs in interaction design [13], which implies a lack of a systemic design perspective.

As an interdisciplinary design field underpinning systems thinking and design thinking [14], systemic design is considered to effectively inform human-centered design for complex sociotechnical systems [15] and catalyze social systems changes [16]. As such, adopting a systemic design to speculate the sociotechnical system innovations triggered by the future diffusion of automated shuttle buses is promising.

In this research, we report a workshop with senior undergraduate students from China who utilized systemic design to propose a future vision of automated shuttle buses. We took the systemic design strategies presented by Pereno and Barbero (2020) [17] as the theoretical framework to organize the process and methods of the workshop. After the workshop, we conducted a series of semi-structured interviews with five participating students to collect their feedback on the usability of the systemic design approach. Given the significance of systemic design and sociotechnical system theory for this research, we will first introduce those two fields. The paper’s organization is as follows. Section 2 discusses the current research status of related work and explains their application for sociotechnical systems innovation from two aspects: system design and automated shuttle buses. Section 3 suggests leveraging systemic design methodologies as a source of inspiration for tackling the obstacles associated with the future dissemination of automated shuttle buses, which conducts a specific analysis by utilizing a creative workshop as a case study. Section 4 discusses the innovative design method explicitly proposed for the autonomous shuttle bus system, including an analysis of the advantages and limitations of the creative workshop. Section 5 concludes this paper, summarizes the specific work done in this paper, and provides suggestions for future work.

## 2. Related Works

### *2.1. Systemic Design*

As envisioned by Buchanan in his well-known Orders of Design Model [18,19], the design field has been gradually extended to address large-scale societal changes. Design research is increasingly recognized to contribute to a complex sociotechnical sense of changes in society [20,21], and designers are “increasingly working with activities that mostly have societal implications” [22]. The urgent need for sustainable development in human society is also pushing design practitioners to take responsibility to engage in a sociotechnical system level of changes [21,23–25]. Specifically in the area of public transportation development, which has societal implications, recent studies have also pointed to the importance of drawing on the discipline of design [26].

Recently, systemic design has been defined as “an evolving interdisciplinary field to effect anticipatory change in complex social, sociotechnical, and social systems” [15]. Adopting automated shuttle buses can be recognized as a sociotechnical system innovation. Therefore, applying systemic design to speculate about future mobility with the diffusion of automated shuttle bus systems appears appropriate.

Compared to other design concepts, such as interaction design and experience design, systemic design is distinguished in terms of “scale, social complexity, and integration” and “its concern for long-term contemporary challenges” [15].

Since it was proposed, systemic design has thrived as a pluralistic field with different perspectives from different scholarships. Three main trends of knowledge production have been recognized, as suggested on the SYSTEMIC DESIGN ASSOCIATION [27]:

1. Systems Oriented Design, mainly by Birger Sevaldson and colleagues from the Oslo School of Architecture and Design, implies the relations between scales and looks at “vast fields of relations and patterns of interactions” among various categorically separated items [28,29]. One typical design visualization tool for this trend is GIGA-mapping [30].
2. Systemic Design by Chiara Battistoni and Silvia Barbero from Politecnico di Torino aims to model production and energy systems for circular economies with a deeply connected with the local territory [31].
3. Systemic Design by Peter Jones from OCAD University emphasizes the design of complex social and sociotechnical systems [15,32].

Although there are different emphases, the essential design aspects they all include in their specific design methodologies are:

1. System Diagnosis: to identify and visualize all the components and stakeholders and their relations to each other.
2. System Ideation: to create a system based on recognized relations and/or conflicts among stakeholders and/or actors.
3. Proposal Evaluation: to preliminarily evaluate the proposed new system, including the internal relations, and identify possible interventions.
4. Proposal Implementation: to realize the design proposal and foster the system transitions.

By integrating systems thinking, the systemic design adapts design competencies to “describe, map, propose and reconfigure complex services and systems” [32]. Therefore, systemic design can be simplistically defined as applying systems approaches to inform human-centered design for complex sociotechnical systems [15], aiming to “help the participants to collectively make sense of the challenge and provide them with plans of action they can carry out in the systems they are ordinarily entangled in” [15].

Applying Systemic Design for Sociotechnical Systems Innovation

In the original sociotechnical theory, the Multi-Level Perspective (MLP) [33–36] is recognized as “a framework for understanding sustainability transitions that provide an overall view of the multi-dimensional complexity of changes in sociotechnical systems” [34]. The MLP distinguishes three analytical levels: niches, sociotechnical regimes, and an exogenous sociotechnical landscape [34]. The interactions within and between those levels are proposed as the source of sociotechnical transitions [34,37].

Based on the MLP model, Pereno and Barbero identify four main strategies for sociotechnical innovation for systemic design (2020):

1. Establishing learning processes: learning about new technologies, behaviors, and social models.
2. Building multi-stakeholder networks: involving established stakeholders, frontrunners, and outsiders who could play a vital role in radical system innovation.
3. Sharing foresight visions: developing and translating the shared, articulate, inspiring, and promising long-term vision to short-term actions.
4. Enhancing green niche innovations: ensuring the scale-up of niche innovation that drives the transition to a new sustainable regime.

To explore how systemic design can contribute to adopting automated shuttle buses, we took the four systemic design strategies of Pereno and Barbero described above as a starting point.

### 2.2. Adopting Automated Shuttle Bus as a Sociotechnical System Innovation

Providing adequate mobility services to residents and visitors is a complex sociotechnical task for urban public transport systems. The mobility of people and goods is at the core of urban transport planning and decision-making. Autonomous shuttle buses can move quickly in the narrow streets of a city to rapidly transport humans and goods. Moreover, they are also conducive to promoting the development of the urban transportation system in a low-carbon and sustainable direction. Over the past few years, several cities have expressed interest in using automated shuttle buses for "last mile" transportation services.

However, transitioning to a transportation system based on an automated shuttle bus is never easy. As a complex sociotechnical system, a transportation system includes many elements, such as user practices, cultural and symbolic meanings, infrastructure, maintenance networks, industry structure, and vehicle technologies [6,33,38]. According to MLP, each sociotechnical system can be distinguished into three analytical levels [33–36], which consist of many subsystems. Changes in one subsystem trigger changes in its constituent elements and other subsystems.

In general, the introduction of AV technology has been met with various obstacles, including fragmented infrastructure, the lack of common laws and regulations, and consumer unacceptance and distrust [39,40]. These can be seen as various aspects of the complex transport sociotechnical system. Some scholars employed a sociotechnical transition perspective to study the facets of the modern transportation system (e.g., [41,42]). For instance, by utilizing the MLP approach to examine the complexities and uncertainties of the interrelationships between various social groups, complex processes, and multiple sociotechnical dimensions, Canitez (2021) provides insights into assessing the user acceptance of autonomous driving technologies in the future from a theoretical basis [43].

Few scholars are beginning to adopt a sociotechnical transition perspective regarding the diffusion of automated shuttle buses in cities. For example, Bucchiarone et al. (2021) proposed the concept of Autonomous Shuttles-as-a-Service (ASaaS) as a critical pillar to achieve innovative and sustainable near-distance mobility to arrange the most suitable transportation solutions for users [44].

However, several design challenges exist for the diffusion of automated shuttle buses, such as the specific mode of delivery, visitor experience of prescribed routes, and shared and integrated mobility. Considering automated shuttles as pillars of innovative and sustainable near-distance mobility in intelligent transportation systems requires systematic design, i.e., integrating systems thinking with design thinking. As suggested in [45], future research directions for applying automated shuttle bus technologies should include: a. integrating automated shuttles with extant public transportation systems; b. building more sustainable mobility ecosystems via a comprehensive approach; and c. increasing end-users' engagement and encouraging them to change their user behavior. A systemic design approach that combines design thinking with systems thinking seems to have a positive effect on the three research directions mentioned above. The following sections will focus on applying systemic design in this field.

## 3. Systemic Design for Speculating on Automated Shuttle Bus

As a sociotechnical transition with a high degree of automation, the operation of an automated shuttle bus involves many aspects of HMI and Systems Engineering (SE) [17]. This section proposes drawing inspiration from the tools of systemic design to address the complex challenges in the future diffusion of the automated shuttle bus, meeting the needs of interactive system designers.

### 3.1. Systemic Design Tools for Automated Shuttle Buses Innovation

In this study, we have chosen to adopt the four systemic design strategies for sociotechnical innovation proposed by Pereno and Barbero (2020) as a logic for classifying extant and often-used systemic design tools adopted in this research, which could be used in the back-and-forth spiral process (Figure 1).

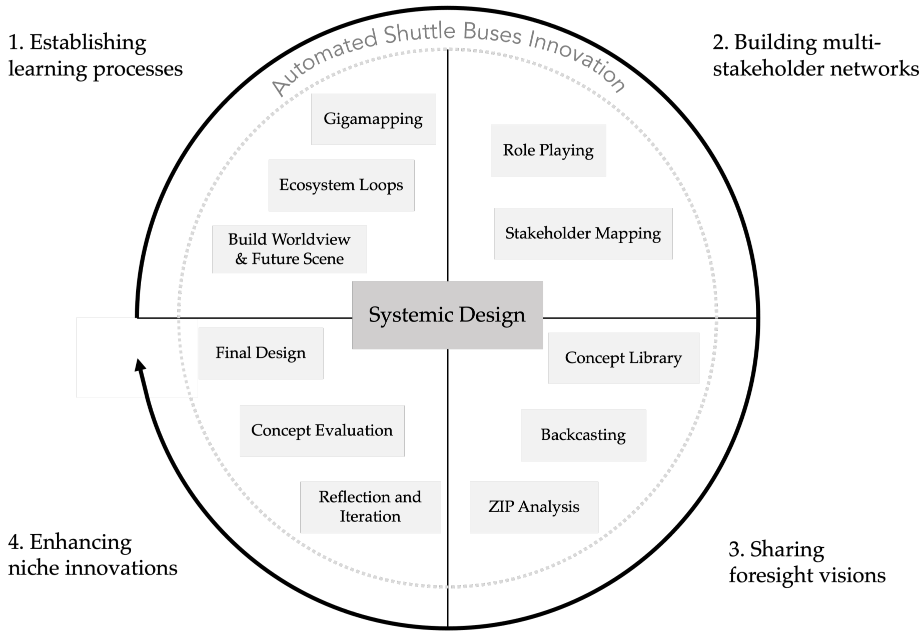


**Figure 1.** Diagram of systemic design tools related to automated shuttle buses innovation strategies.

1. Establishing learning processes: designing for the automated shuttle should consider not only the AV technology, but also the changes in user behavior caused by this new technology and its new social models. The aim is to draw an overarching picture that gives back the identity of the SAV, building a comprehensive basis for developing new strategies. However, it is difficult for designers to grasp the demand for automated shuttle buses from the perspectives of all the actors involved in the transition process. Under the guidance of this strategy, those actors (such as the government, advertising agencies, management departments, service partners or suppliers, etc.) require a learning process in which they need to understand relevant information and knowledge to mobilize their roles. This learning process enables policymakers to provide economic and strategic support for projects and initiatives and service providers to support and assist new behavioral and social patterns emerging in the project process. Those different roles, with their respective understanding and knowledge, can promote the adoption and diffusion of the referred technology thanks to the learning process.
   The design tools for framing the system innovation usually utilize the designer's visualization capability, which graphically presents the complexity of the addressed problem. We first sorted out the relationship between different stakeholder roles based on the anticipated user group classification and technology expansion through Gigamapping. Then, we built connections between the divergence of related trends of potentially relevant technologies for automated shuttle bus innovation. Secondly, we used ecosystem loops to visualize the complexity of the entire system to define the different aggregation levels, ranging from the stakeholders to the transportation environment. Finally, we built the worldwide usage scenario of automated shuttle buses.
2. Building multi-stakeholder networks: The partnership of multiple actors generated through the flow of knowledge triggered by the learning process described above expands the range of established stakeholders that would otherwise be ignored in the existing system. The stakeholders of automated shuttle buses are anticipated to exist among a broad spectrum, including shared transportation service providers, ordinary passengers, passengers with travel impairments, people waiting for the bus, drivers of other motor and non-motor vehicles, pedestrians, etc. This requires comprehensively understanding their interrelationships and different needs through diverse levels and perspectives.
   Under the second strategy's guidance, role-playing could balance the variety of disciplines, perspectives, authorities, diversity, and interests among stakeholders. It

requires the designers to empathize with them, explore their demands, and construct meaningful service concepts. In addition, we propose that stakeholder mapping could be adopted to get a visual representation of all the entities that can impact sociotechnical innovation and how they are connected. It is the visualization process of laying out all the stakeholders of a product, project, or idea on one map.

3. Sharing foresight visions: Guided by the two previous strategies, designers have established a vision and worldview for the field's future development. The next step is translating the long-term vision into concrete short-term design actions. At first, envisioning processes are needed to identify problems collectively, build alternative visions, and establish the strategies to implement them. The persona generated after the definition will help the designers gradually enrich their ideas and produce their concept library, which is conducive to selecting and deepening the later scheme. Next, backcasting is a valuable approach to re-framing the present and future, which asks designers to play stakeholders' roles to visually map the problems in the present by reflecting on the future; identify the relations and dynamics between actors; and envision long-term, lifestyle-based futures that solve the problems. It could help determine the expectations designers want to achieve and the issues they must avoid. Finally, ZIP analysis helps analyze the areas or points on the Gigamap that are worthy of further study to clarify the design scope and direction. The innovation points among the design scope for appropriate interventions are selected to generate ideas addressing potential problems and pain points.
4. Enhancing green niche innovations: For public driving, it is essential to consider green and sustainable innovation in the early development period. Indeed, under the guidance of the fourth strategy, policy- and decision-makers can support the creation and diffusion of strengthening niche innovation development and scale-up through public subsidies, road traffic regulations, and infrastructure investments. Above all, we propose to track the application of the new sustainable regime in our design scheme to support the monitoring and evaluation of sociotechnical experiments through reflection and iteration, specifically through alternating phases of observation and improvement. During this process, the generated design concepts need to be evaluated. Although it is proving completive to compare radically different ideas [46], we are still required to assess the system's boundaries and reach a consensus on them before evaluating each concept. The analysis of specific challenges needs to be conducted with the analyzed experts and institutions based on public transport characteristics and requirements. A green, sustainable, and innovative design scheme is selected for the final deepening through concept evaluation, thus forming the final design. The final design phase elaborates on future visions and develops plausible trajectories to implement the envisioned desirable and optimistic future, involving a network of relevant stakeholders and entities.

Given the characteristics of openness, purpose, and complex integrity of a sociotechnical system, participatory design or co-design is commonly used in this field [4,47,48]. The main objective of our work is to explore how automated shuttle buses can work in conjunction with the surrounding stakeholders in the public transport system in a future scenario.

Hereafter, we present the results of a workshop with a representative test group for the bus station.

### 3.2. Creative Workshop

Drawing upon the examination of the theoretical framework in Section 3.1, our objective is to enhance readers' comprehension of the practical application of different design tools and methodologies within this theoretical framework, which will be achieved through the implementation of a tangible activity. Prior academic studies have included methodologies such as workshops, focus groups, and expert interviews to apply and validate the proposed theoretical design strategies or framework. The creative workshop method has gained significant traction in the domain of automated shuttle buses. A study was under-taken by Andreas Riener et al. (2021) [49] that focused on design research pertaining to external communication and interior design. The study employed two creative workshops to enhance the user experience of individuals utilizing automatic shuttle buses in public transit. In addition, Jaemyung Lee et al. [50] investigated the design complexities associated with autonomous vehicles by means of scenario exploration through an immersive design workshop in 2022. Scholars in the aforementioned design disciplines are endeavoring to validate their theoretical framework by means of workshops. Consequently, we delivered a six-week workshop that employs thinking, methods, and tools from the systemic design mentioned before to facilitate the exploration of insights into future autonomous public transportation. This workshop with ($n$ = 28) different people (19 female and 9 male) aged between 18 and 22 years (mean age = 21.63) was conducted with Chinese undergraduate design students who are in their last academic year to equip them with systemic and speculative thinking by speculating the complex transport systems and reflecting on alternative futures. The participants were divided into two groups to explore the future development scenarios of the station in 5–10 years or 50 years later.

#### 3.2.1. Procedure and Structure

Initially, students selected several representative user groups, including waiting passengers, online service providers, offline service providers, passers-by, pets, etc., for the interaction scene of the bus station for the role-playing, in which the team members conducted a preliminary exploration of the different users' views. To find connections between their roles, each team plotted Gigamapping regarding trends in autonomous driving and various forms of HMI technology. Subsequently, each group brainstormed the possible future development of technology and the possibility of HMI to create future scenarios with visual presentations. Moreover, the two teams defined the research questions and design challenges that might be faced in the future, reflecting on the previously created scenarios. Furthermore, the two groups formed their concept library based on the difficulties defined, in which they produced many preliminary design concepts by brainstorming. After that, they selected three ideas worth further extension through ZIP analysis and visually displayed them. The two groups shared and mutually gave feedback and conducted design reflection and iteration. Eventually, the content of the final design output was presented through prototypes, videos, and in-depth design schemes, including background sorting, ecosystem loop diagram drawing (including stakeholders), future scene construction, etc.

#### 3.2.2. Results and Impact

We organized two groups with different focuses on future scenes, respectively forecasting in the next 5–10 years and speculating in 50 years. The forecasting group is called Group A, and Group B is the speculating group. Over time, the future's predictability decreases dramatically, whereas their uncertainty increases. Therefore, the two groups showed significant differences in their future worldviews.

Group A believes that due to the rapid development of various driving-related technologies, including fixed-speed cruise, intelligent blind lane, display and inputs units, communication interfaces, data storage, etc. (see Figure 2). In the next 5–10 years, the transportation system will be more prosperous, and the concept of the Internet of Everything will be further developed. More specifically, people will pay more attention to diversified feelings according to the different experiences, scenes, and ways of interacting. As illustrated in Figure 2, the future scene focuses more on the diversification of station themes and the enhancement of the user's immersive experience via interactive scenes. Using the themes "history and culture", "green travel", and "animal protection" as examples, they proposed three future station concepts for distinct themes and employed story-telling techniques related to the themes to enhance their imagination of future scenes.

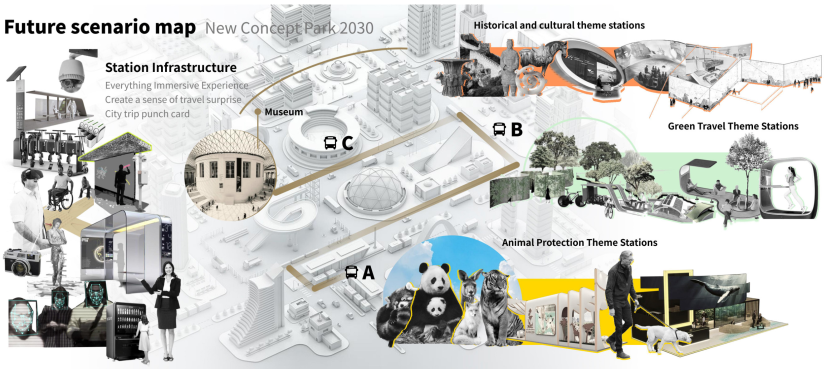


**Figure 2.** Future scene and worldview constructed from Group A.

In comparison, Group B has a more negative attitude toward the future. Specifically, they believe the temperature will rise significantly while the living area of humans will decrease due to the greenhouse effect. As a result, the competition for resources will be severe, and the transportation system will be used for inter-community travel due to the closed community model. This group's constructed future scenario is depicted in Figure 3. At the same time, the interaction between humans and technologies will be more entirely managed by Artificial Intelligence (AI), and the Brain–Computer Interface (BCI) concept will be incorporated into subsequent designs. Future scenarios involving human travel will rely on pipeline transportation networks to facilitate community communication. For medium- and long-distance journeys, public transportation will be the primary mode of transportation at this time.

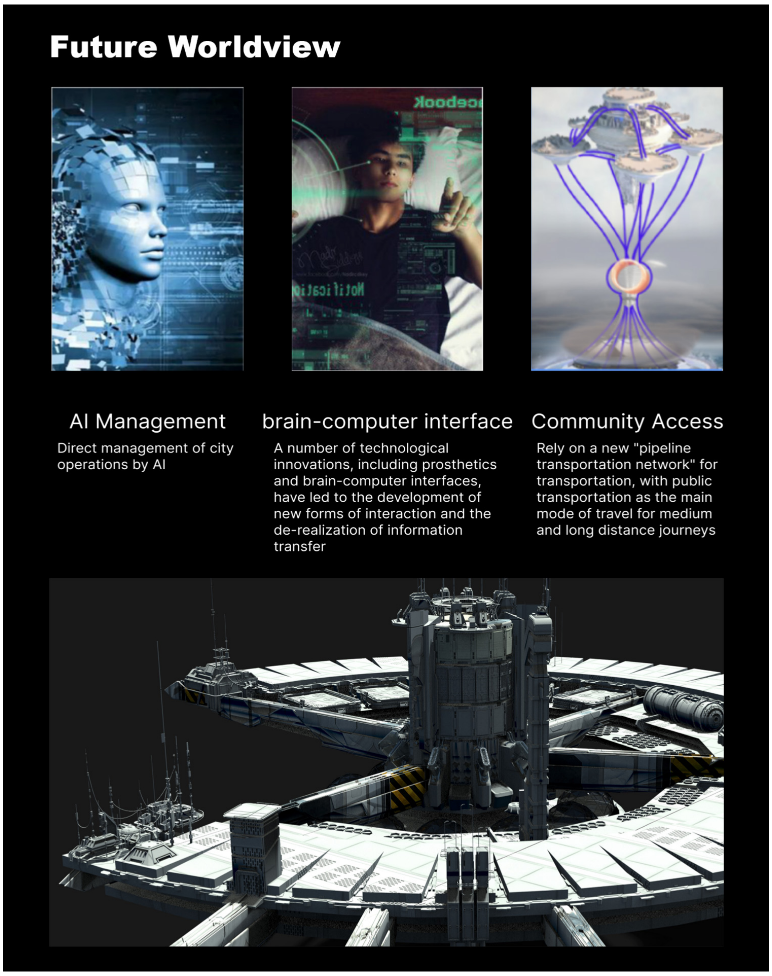


**Figure 3.** Future scene and worldview constructed from Group B.

Because of the divergence in how future scenes are envisioned , there is a significant contrast in the design concepts between Groups A and B. However, they both build ecosystem loops (see Figures 4 and 5) on a Gigamapping basis, considering the stakeholders associated with their respective systems. On the one hand, Group A creates different themes for the station, including historical culture, green travelling, animal protection, etc. As shown in Figure 4, the group's ecosystem loops prioritize the provision of services. These themes can be adjusted according to the location, and they require consideration of the relationships between stakeholders such as government, community management departments, advertising and insurance companies, equipment suppliers, etc. On the other hand, since Group B is confident about technology development, it is essential to sort out the information flow in the stakeholder map (see Figure 5). They paid particular attention to the relationship between the station operation department, the service suppliers, the database management, and the users (including intelligent service providers, passengers, pedestrians, electric and/or natural pets, etc.). The final design output of those two groups is described hereafter.

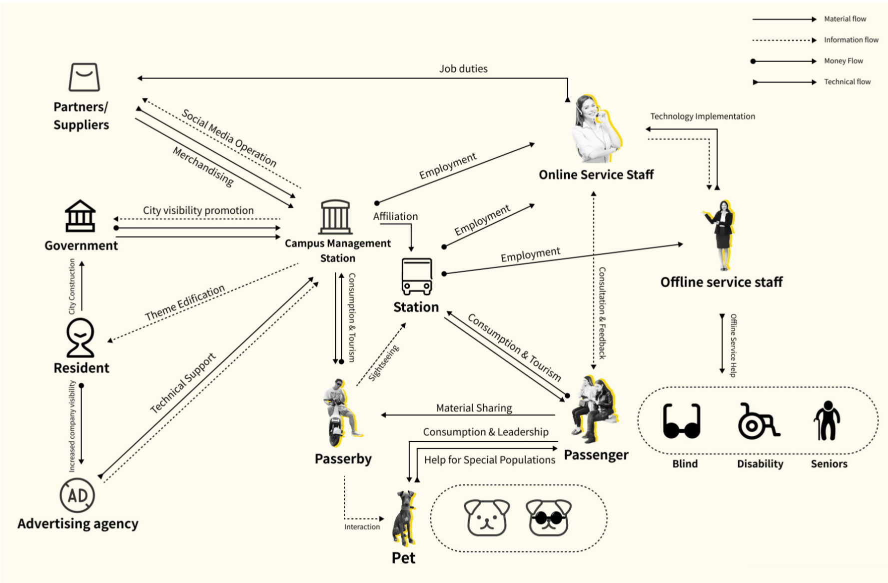


Figure 4. Ecosystem loops based on Gigamapping from Group A.

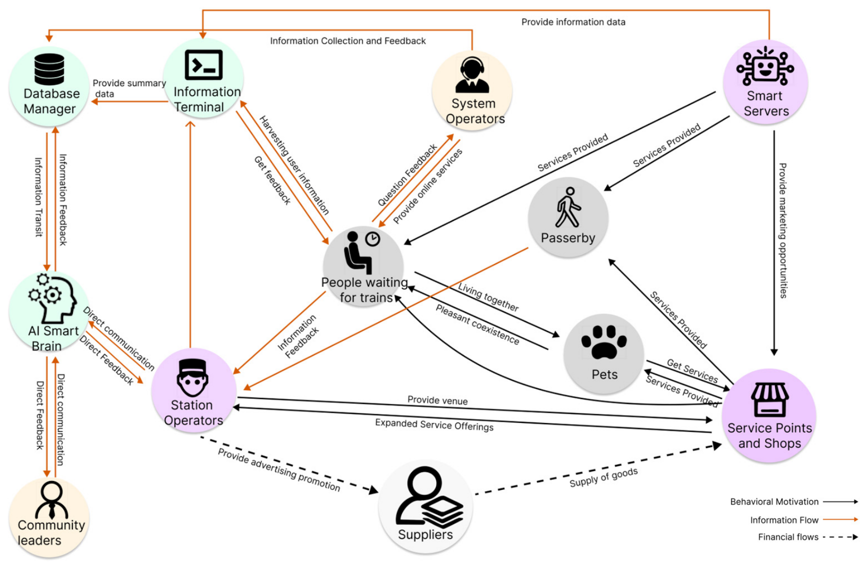


Figure 5. Ecosystem loops based on Gigamapping from Group B.

Group A replanned the layout of the current shuttle bus stations and divided the whole station into two areas, A and B. Area A is dedicated as the waiting area, including seats for resting, blind lanes for guiding visually impaired groups, and progress bars for displaying information on the ground to indicate the arrival time, etc. Area B is used for other services and interactive functions, such as telling wildlife-related stories to pedestrians through projections and using motion-capture technology to interact with animal images on interactive screens. In addition, when users purchase souvenirs and products through the vending machine, a portion of their spending is expected to be donated to animal protection organizations. Figure 6 shows the final concept in detail. In the topmost portion of the image, the concept station's layout is depicted. The station's central location on the road necessitates that passengers board and exit from both sides. The right side provides a detailed illustration of the layout of the A and B areas. Various conceptual looks for the site (left) and renderings and three perspectives of the final version are depicted in the lower half of the image.

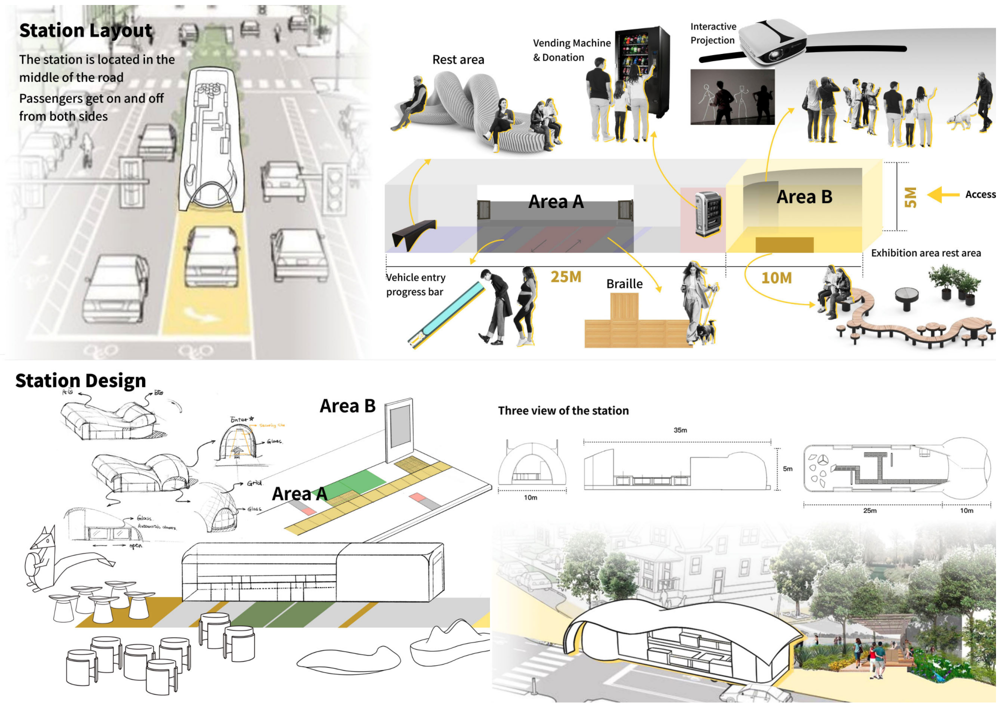


**Figure 6.** Station layout and design scheme of the final output from Group A.

Group B provided a visual representation of how the site might offer the services in a storyboard (see Figure 7). First, the target station is found under the guidance of Augmented Reality (AR) navigation through the prescribed security check channel in the station. Secondly, the station system then prompts the user to board the bus in a timely manner, and the user engages in video call communication with the consumer while on the bus. Thirdly, upon prompting by the station system, the user exits the bus promptly and then locates the customer's location in order to negotiate. Fourthly, users can interact with the interactive devices on the platform within the station's viewing area and use the voice assistant to comprehend the specific content of the interactive video. Furthermore, rapid lanes offer charging services. Next, users communicate with the system in real-time through the BCI. Moreover, the station provides pet storage services to meet the various needs of different users.

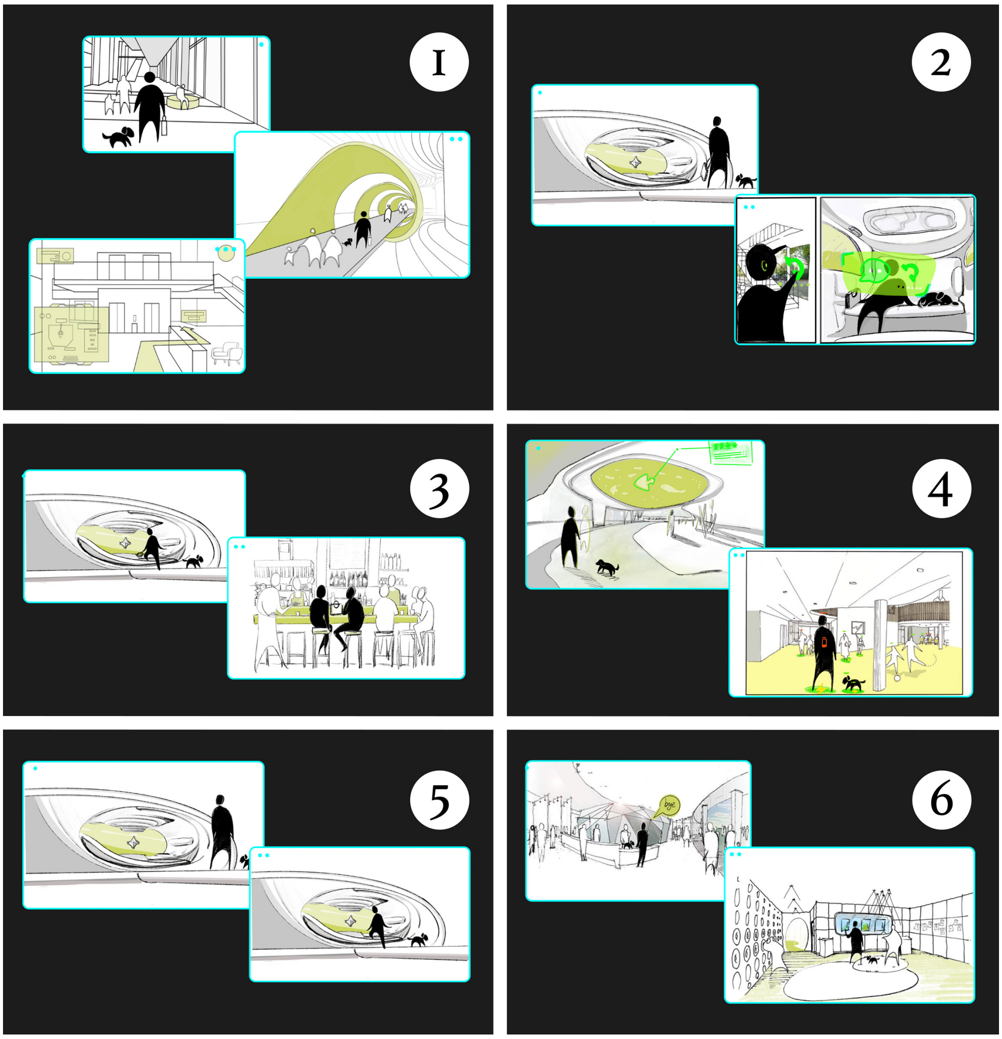


**Figure 7.** A storyboard representing the final design output of Group B.

## 4. Discussion

The perspective of sociotechnical innovation design proposed by Pereno and Barbero outlines an iterative process based on learning processes and building multi-stakeholder networks. It means imagining new ways of co-creating value for facilitating the adoption of AV technology by redefining connections, integrating resources, and enabling the capabilities of multiple user groups and organizations. In other words, the holistic, collaborative, and human-centered approach to systemic design can support the creation of speculating on future development trajectories through the observation and understanding of users' behaviors and needs and the links between the actors involved.

Semi-structured interviews were conducted with five participants (three female and two male) after presenting the workshop output to find out the opinion of the actual feedback debating the advantages and disadvantages of adopting the systemic design approach in speculating on automated shuttle buses.

All interviewees affirmed the significant role of systematic design approaches in this area. They felt that considering the needs of different user groups contributes to improving user experience. Three participants found the role-playing process innovative, which could help them to substitute the role from a first-person perspective to think from the user's point of view, which is out of the designer's perspective. In addition, applying Gigamap makes the design solution more comprehensive and complete. By systematically exploring automated shuttle buses, the design steps can be planned more comprehensively from multiple perspectives, and the design process can be more rigorous and logical.

Despite its numerous benefits, this workshop's systemic design process has certain limitations. First, backcasting to re-framing the present and future is confusing for participants, which is more difficult for Chinese students who do not emphasize critical thinking to some extent. Second, fieldwork and experience are also necessary for building multi-stakeholder networks. However, due to the specificity and limitations of automated shuttle buses, there are difficulties in field research, which is also the direction of future research. Finally, systematic design in this area requires a rich knowledge base of different disciplines, which can be difficult for undergraduate students. Experts, developers, and experienced customers should also be included.

Significant changes are occurring in the implementation of autonomous driving technology in public transportation systems. As a future highly automated sociotechnical system, automated shuttles necessitate paradigm and sociotechnical changes, which necessitate modifications to new technologies and markets, user practices, policies, and cultural meanings, according to the findings of this study. In response to this shift in sociotechnical systems, this paper validates the capacity of system design and speculative design to engage critically with system complexity and to account for future uncertainties.

Currently, the majority of automobile manufacturers in various nations are investigating and developing this field and implementing their autonomous shuttles in commercial applications. Current research in this field is primarily concerned with technological advancements, usability testing, innovation in user experience interaction models, and other related topics. However, these isolated studies of this technology fail to address the intricate interconnections between various fields and disregard the field's macroenvironment. In future research, autonomous driving technology development companies, car enterprise service providers, government institutional planning departments, and public transportation systems should all participate and form a more systematic service system, in addition to interactive system designers in this field who must pay attention to such design processes and methods.

## 5. Conclusions

This study explores how to integrate systemic perspectives into the application of automated shuttle buses in future urban contexts in the design field, which underscores the need for a systemic design approach. The findings contribute to the debate on systemic design, highlighting the synergy among different sub-disciplines.

Concretely, this paper conducted a literature review to understand the current state, gaps, and consequent possible opportunities of systemic approaches embedded in speculating on the automated shuttle bus to adopt it as a sociotechnical system innovation. Then, this paper elaborates on how the four design strategies for sociotechnical innovation proposed by Pereno and Barbero (2020) can be adapted to embed systemic perspectives into public transportation in smart cities for designers by analyzing relevant systemic design methods for automated shuttle bus system innovation.

According to the process of the workshop, the following capabilities for the designers have been highlighted: the ability to analyze, define, and visualize the existing system and challenges; the ability to envisage creative and desirable future scenarios that solve existing problems; the ability to build co-creation processes involving multiple stakeholders and sectors. Finally, this research meets the needs of interactive system designers in this field by offering them systemic design methods intervening and enriching the HMI and functional architecture of the automated shuttle bus.

However, this article contributes to the above implications based on a workshop process without participating in an actual project about implementing the automated shuttle bus in real settings, which is undoubtedly a relevant limitation. However, we still expect this exploratory article will trigger more research and exploration about integrating systemic design into real-world scenarios, such as the automated shuttle bus innovation.

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## References

1. Heikkilä, S. Mobility as a Service-A Proposal for Action for the Public Administration, Case Helsinki. Master's Thesis, Aalto University, Espoo, Finland, 2014.
2. Zhu, L.; Wang, J.; Garikapati, V.; Young, S. Decision support tool for planning neighborhood-scale deployment of low-speed shared automated shuttles. *Transp. Res. Rec.* **2020**, *2674*, 1–14. [CrossRef]
3. Hu, J.; Bhowmick, P.; Arvin, F.; Lanzon, A.; Lennox, B. Cooperative control of heterogeneous connected vehicle platoons: An adaptive leader-following approach. *IEEE Robot. Autom. Lett.* **2020**, *5*, 977–984. [CrossRef]
4. Simonsen, J.; Robertson, T. *Routledge International Handbook of Participatory Design*; Routledge: Oxford, UK, 2012.
5. Hamid, U.Z.A.; Al-Turjman, F. Introductory Chapter: A Brief Overview of Autonomous, Connected, Electric and Shared (ACES) Vehicles as the Future of Mobility. In *Towards Connected and Autonomous Vehicle Highways*; Springer: Cham, Switzerland, 2021; pp. 3–8.
6. Geels, F.W. The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). *Technol. Anal. Strateg. Manag.* **2005**, *17*, 445–476. [CrossRef]
7. Cascetta, E.; Cartenì, A.; Pagliara, F.; Montanino, M. A new look at planning and designing transportation systems: A decision-making model based on cognitive rationality, stakeholder engagement and quantitative methods. *Transp. Policy* **2015**, *38*, 27–39. [CrossRef]
8. Kanger, L.; Geels, F.W.; Sovacool, B.; Schot, J. Technological diffusion as a process of societal embedding: Lessons from historical automobile transitions for future electric mobility. *Transp. Res. Part Transp. Environ.* **2019**, *71*, 47–66. [CrossRef]
9. Baxter, G.; Sommerville, I. Socio-technical systems: From design methods to systems engineering. *Interact. Comput.* **2011**, *23*, 4–17. [CrossRef]
10. Ropohl, G. Philosophy of socio-technical systems. *Soc. Philos. Technol. Q. Electron. J.* **1999**, *4*, 186–194. [CrossRef]
11. Fraedrich, E.; Beiker, S.; Lenz, B. Transition pathways to fully automated driving and its implications for the sociotechnical system of automobility. *Eur. J. Futur. Res.* **2015**, *3*, 11. [CrossRef]
12. Van Ael, K.; Jones, P. Design for Services in Complex System Contexts: Introducing the Systemic Design Toolkit. *Touchpoint-J. Serv.* **2021**, *12*, 1–8.
13. Saffer, D. *Designing for Interaction: Creating Innovative Applications and Devices*; New Riders: Indianapolis, IN, USA, 2010.
14. Ryan, A. A framework for systemic design. *FORMakademisk* **2014**, *7*. [CrossRef]
15. Jones, P. Systemic design: Design for complex, social, and sociotechnical systems. In *Handbook of Systems Sciences*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 787–811.
16. Vink, J.; Wetter-Edman, K.; Koskela-Huotari, K. Designerly approaches for catalyzing change in social systems: A social structures approach. *She Ji J. Des. Econ. Innov.* **2021**, *7*, 242–261. [CrossRef]
17. Pereno, A.; Barbero, S. Systemic design for territorial enhancement: An overview on design tools supporting sociotechnical system innovation. *Strateg. Des. Res. J.* **2020**, *13*, 113–136. [CrossRef]
18. Buchanan, R. Branzi's dilemma: Design in contemporary culture. *Des. Issues* **1998**, *14*, 3–20. [CrossRef]
19. Buchanan, R. Design research and the new learning. *Des. Issues* **2001**, *17*, 3–23. [CrossRef]
20. Dorst, K. Design beyond design. *She Ji J. Des. Econ. Innov.* **2019**, *5*, 117–127. [CrossRef]
21. Norman, D.A.; Stappers, P.J. DesignX: Complex sociotechnical systems. *She Ji J. Des. Econ. Innov.* **2015**, *1*, 83–106. [CrossRef]

22. Westerlund, B.; Wetter-Edman, K. Dealing with wicked problems, in messy contexts, through prototyping. *Des. J.* **2017**, *20*, S886–S899. [CrossRef]
23. Ceschin, F.; Gaziulusoy, I. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Des. Stud.* **2016**, *47*, 118–163. [CrossRef]
24. Irwin, T. Transition design: A proposal for a new area of design practice, study, and research. *Des. Cult.* **2015**, *7*, 229–246. [CrossRef]
25. Manzini, E. *When Everybody Designs: An Introduction to Design for Social Innovation*; The MIT Press: Cambridge, MA, USA, 2015.
26. Kuys, J.; Melles, G.; Al Mahmud, A.; Thompson-Whiteside, S.; Kuys, B. Human Centred Design Considerations for the Development of Sustainable Public Transportation in Malaysia. *Appl. Sci.* **2022**, *12*, 12493. [CrossRef]
27. SDARESEARCH. Available online: https://systemic-design.org/research/ (accessed on 10 November 2022).
28. Sevaldson, B. Systems Oriented Design: The emergence and development of a designerly approach to address complexity. In Proceedings of the DRS//Cumulus: Design Learning for Tomorrow, Oslo, Norway, 14–17 May 2013.
29. Sevaldson, B. Systems-oriented design for the built environment. In *Design Innovation for the Built Environment*; Routledge: Oxford, UK, 2013; pp. 107–120.
30. Sevaldson, B. GIGA-Mapping: Visualisation for complexity and systems thinking in design. *Nordes* **2011**, *4*, 1–20.
31. Battistoni, C.; Barbero, S. Systemic Design, from the content to the structure of education: New educational model. *Des. J.* **2017**, *20*, S1336–S1354. [CrossRef]
32. Jones, P.H. Systemic design principles for complex social systems. In *Social Systems and Design*; Springer: Tokyo, Japan, 2014; pp. 91–128.
33. Geels, F.W. Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Res. Policy* **2002**, *31*, 1257–1274. [CrossRef]
34. Geels, F.W. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Res. Policy* **2010**, *39*, 495–510. [CrossRef]
35. Geels, F.W.; Schot, J. Typology of sociotechnical transition pathways. *Res. Policy* **2007**, *36*, 399–417. [CrossRef]
36. Rip, A.; Kemp, R. Technological change. *Hum. Choice Clim. Chang.* **1998**, *2*, 327–399.
37. Raven, R.; Schot, J.; Berkhout, F. Space and scale in socio-technical transitions. *Environ. Innov. Soc. Transit.* **2012**, *4*, 63–78. [CrossRef]
38. Jones, P. Design research methods for systemic design: Perspectives from design education and practice. In Proceedings of the 58th Annual Meeting of the ISSS-2014 United States, Washington, DC, USA, 27 July–1 August 2014.
39. Steinhilber, S.; Wells, P.; Thankappan, S. Socio-technical inertia: Understanding the barriers to electric vehicles. *Energy Policy* **2013**, *60*, 531–539. [CrossRef]
40. Guo, J.; Susilo, Y.; Antoniou, C.; Pernestål Brenden, A. Influence of Individual Perceptions on the Decision to Adopt Automated Bus Services. *Sustainability* **2020**, *12*, 6484. [CrossRef]
41. Cohen, M.J. The future of automobile society: A socio-technical transitions perspective. *Technol. Anal. Strateg. Manag.* **2012**, *24*, 377–390. [CrossRef]
42. Lee, J.; Kim, J.; Kim, H.; Hwang, J. Sustainability of ride-hailing services in China's mobility market: A simulation model of socio-technical system transition. *Telemat. Inform.* **2020**, *53*, 101435. [CrossRef]
43. Canıtez, F. Transition to Autonomous Vehicles: A Socio-Technical Transition Perspective. *Alphanumeric J.* **2021**, *9*, 143–162. [CrossRef]
44. Bucchiarone, A.; Battisti, S.; Marconi, A.; Maldacea, R.; Ponce, D.C. Autonomous shuttle-as-a-service (ASaaS): Challenges, opportunities, and social implications. *IEEE Trans. Intell. Transp. Syst.* **2020**, *22*, 3790–3799. [CrossRef]
45. Chaalal, E.; Guerlain, C.; Pardo, E.; Faye, S. Integrating Connected and Automated Shuttles with Other Mobility Systems: Challenges and Future Directions. *IEEE Access* **2023**, *11*, 83081–83106. [CrossRef]
46. Hart, S.L.; Sharma, S. Engaging fringe stakeholders for competitive imagination. *Acad. Manag. Perspect.* **2004**, *18*, 7–18. [CrossRef]
47. Bannon, L.J.; Ehn, P. Design matters in participatory design. *Routledge Int. Handb. Particip. Des.* **2012**, *711*, 37–63.
48. Barbier, R.; Yahia, S.B.; Le Masson, P.; Weil, B. Co-Design for Novelty Anchoring Into Multiple Socio-Technical Systems in Transitions: The Case of Earth Observation Data. *IEEE Trans. Eng. Manag.* **2022**, 1–22. [CrossRef]
49. Riener, A.; Schlackl, D.; Malsam, J.; Huber, J.; Homm, B.; Kaczmar, M.; Kleitsch, I.; Megos, A.; Park, E.; Sanverdi, G.; et al. Improving the UX for users of automated shuttle buses in public transport: Investigating aspects of exterior communication and interior design. *Multimodal Technol. Interact.* **2021**, *5*, 61. [CrossRef]
50. Lee, J.; Park, W.; Lee, S. Discovering the Design Challenges of Autonomous Vehicles through Exploring Scenarios via an Immersive Design Workshop. In Proceedings of the Designing Interactive Systems Conference 2021, Virtual, 28 June–2 July 2021; pp. 322–338.