Automated Shuttle Buses

Subjects: Transportation

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Shared Autonomous Vehicles (SAV) is an umbrella term for shared public buses and logistics vehicles, also known as robot taxis or shuttle buses. 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.

Keywords: automated shuttle buses ; sociotechnical system ; systemic design ; public transport system ; innovation

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][7][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.

2. Systemic Design

As envisioned by Buchanan in his well-known Orders of Design Model [17][18], 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 [19][20], and designers are "increasingly working with activities that mostly have societal implications" [21]. 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 [20][22][23][24]. 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 [25].

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 [26]:

- 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 [27][28]. One typical design visualization tool for this trend is GIGA-mapping [29].

- 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 [30].

- Systemic Design by Peter Jones from OCAD University emphasizes the design of complex social and sociotechnical systems [15][31].

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

- System Diagnosis: to identify and visualize all the components and stakeholders and their relations to each other.

- System Ideation: to create a system based on recognized relations and/or conflicts among stakeholders and/or actors.

- Proposal Evaluation: to preliminarily evaluate the proposed new system, including the internal relations, and identify possible interventions.

- 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" [31]. 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) [32][33][34][35] is recognized as "a framework for understanding sustainability transitions that provide an overall view of the multi-dimensional complexity of changes in sociotechnical systems" [33]. The MLP distinguishes three analytical levels: niches, sociotechnical regimes, and an exogenous sociotechnical landscape [33]. The interactions within and between those levels are proposed as the source of sociotechnical transitions [33][36].

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

- Establishing learning processes: learning about new technologies, behaviors, and social models.
- Building multi-stakeholder networks: involving established stakeholders, frontrunners, and outsiders who could play a vital role in radical system innovation.
- Sharing foresight visions: developing and translating the shared, articulate, inspiring, and promising long-term vision to short-term actions.
- 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, the four systemic design strategies of Pereno and Barbero described above were taken as a starting point.

3. 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][32][37]. According to MLP, each sociotechnical system can be distinguished into three analytical levels [32][33][34][35], 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 [38][39]. 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., [40][41]). 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 [42].

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 [43].

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 [44], 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.

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