A foresight study on urban mobility: Singapore in 2040

Seyed Mehdi Zahraei, Jude Herijadi Kurniawan and Lynette Cheah

Abstract

Purpose – *The transportation system in any city is complex and evolving, shaped by various driving forces and uncertainties in the social, economic, technological, political and environmental situations. Its development and demands upon it cannot be projected by simply extrapolating past and current trends. This paper aims to present a foresight study examining the future of urban mobility, focusing on the dense Asian city-state of Singapore. The objective is to develop scenarios for the future of urban mobility, to facilitate future policy implementation by highlighting long term challenges and opportunities for transportation planning in cities.*

Design/methodology/approach – *To create future scenarios, the authors first sought to identify key drivers of change through environmental scanning, expert interviews, focus group discussions and technology scanning. These drivers of change were subsequently used in a scenario planning workshop, organized to co-create alternative future visions for urban mobility 2040 with experts and local stakeholders.*

Findings – *Two scenarios emerged, called the Shared World and the Virtual World. For each scenario, the authors described the key features in terms of dominant transport modes for the movements of passengers and freight. Subsequently, the authors discussed possible implications of each scenario to the individual, society, industry and government.*

Originality/value – *As cities grow and develop, city and transport planners should not only address daily operational issues but also develop a well-informed, long-term understanding of the evolving mobility system to address challenges that lie beyond the five- or even ten-year horizon. By using scenario planning approach, the authors hope to prepare stakeholders for the uncertain futures that are continuously shaped by the decisions today.*

Keywords *Transportation planning, Transport policy, Scenario analysis*

Paper type *Case study*

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1. Introduction

As cities grow and develop, having long-term land use and transportation plans become an inevitable requirement for city planners. The need to pre-empt and plan for the future means that planners should not only address daily operational issues but also develop a well-informed long-term understanding for the evolving mobility system to address challenges that lie beyond the five- or even ten-year horizon (Inayatullah, 2003; Auvinen *et al.*, 2012). What would future mobility be like in the city? How would technologies disrupt urban travel experience? How could we plan for changing social behavior and norms that would affect travel demand and preferred travel modes? These questions cannot be reliably addressed by simply extrapolating past and current trends. Further, mobility itself is a complex system that evolves and is continuously shaped by various driving forces and prospective uncertainties prevalent in our social, economic, technological, political and environmental situations in the future.

In this paper, we described a foresight study to envision the future of urban mobility in Singapore in 2040. Singapore's urban transportation system has evolved and developed

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rapidly over the past few decades. Private transport demand is well-managed through heavy ownership taxation and electronic congestion road pricing. As for public transport, the bus network is extensive and the country's mass rapid transit (MRT) system has been in operation since 1987. Over the years, long term land-use and transportation master plans have been published by the government, which define the vision and contributed to the quality of the current transportation services in Singapore. There are, however, two key challenges that policymakers must consider when carrying out long-range planning. First, the focus on policy solutions based on static assumptions makes it difficult for planners to prepare for uncertainties. Second studies informing policies tend to be prescriptive, undermining the potential influence of driving forces and global trends on policy outcomes.

Singapore is a fast-growing high-density Asian city and our study usefully highlights challenges and opportunities in transportation planning for cities with similar characteristics. A foresight study focuses on developing multiple future scenarios to cover the spread of different possibilities that can occur as a result of today's decisions (Hejazi, 2011). The intention of this study is to facilitate future policy implementation by highlighting future challenges and opportunities for transportation planning in cities. The study scope covers the land transport domain in Singapore, addressing both passenger and freight transport.

The rest of the paper is organized as follows. In Section 2, we discuss our foresight methodology used to identify key drivers of change. In Section 3, we briefly describe the scenario planning workshop process. In Section 4, we present a summary of future scenarios including the narratives and implications. Finally, we wrap up with a short discussion and conclusion in Section 5.

2. Study methodology

We conducted a foresight study to develop scenarios for the future of urban mobility in Singapore. Foresight studies assume that the future is not an extrapolation of a set of predetermined trends and innovations. Instead, it builds on the principle of an uncertain future that can be shaped by today's actions. The intention of foresight studies is not to predict the future correctly. Rather, these studies using participatory approaches can help stakeholders overcome surprising and challenging futures. Moreover, the participatory approach can cultivate "scenario thinking," exposing the stakeholders to a variety of policy decisions, efforts, and the potential outcomes of those decisions (Rickards *et al.*, 2014).

Typically, a foresight study uses a combination of different methods at different stages. By evaluating more than 800 foresight studies, Popper (2009) showed that, on average, five to six methods have been adopted for each foresight study. The author further classified foresight methods into four attributes based on their ability to gather or process information, namely, *creativity*, *expertise*, *interaction* and *evidence*.

After reviewing existing literature, we selected foresight methods by considering the time horizon of the project and Singapore's context, as well as the above-mentioned fundamental attributes of the foresight methods. The selected methods are summarized as follows: *Environmental Scanning* (evidence attribute) helps to understand the nature and the pace of change in the environment and to identify important economic, social, environmental, technological and political trends. *Expert Interviews* (expertise and evidence attributes) are structured conversations used to gather insights from individuals who are specialists in their respective fields. *Focus Group Discussions* (interaction attributes) provide insights into how people think. *Technology Scanning* (expertise attribute) helps to identify critical technologies under development that can have game-changing effects on the system. The process of scanning helps to chart the course of these technologies and how they fit into future scenarios. *Scenarios Planning Workshop* (creativity and interaction attributes) helps to identify various plausible future scenarios and prepares stakeholders to

tackle uncertainties. For more detailed discussion on foresight methods and the selection process for this study see Popper (2009) and Zahraei *et al.* (2016).

In this study, we used a detailed process of first identifying key *drivers of change* through using several foresight methods, namely, environmental scanning, expert interviews, technology scanning, and focus group discussions. We define influential drivers of change as strong forces that might effectively shape the future mobility landscape in Singapore, such as trends, challenges and technologies. These drivers of change were subsequently incorporated into a scenario planning workshop to create alternative future visions of urban mobility in 2040. An overview of this process is illustrated in Figure 1 and discussed in more detail in the following sections.

2.1 Environmental scanning

We began by conducting a comprehensive review of urban transport scenario studies. We particularly focused on foresight studies, which were found to be pertinent to the urban theme. These studies covered time-periods up to 2100, with the bulk of studies looking toward 2040 (Table I). Moreover, these studies have been conducted by diverse interest groups such as consulting firms, academic institutions and governmental agencies, bearing in mind how different organizations may cultivate different types of scenarios.

Through this process, we identified drivers of change that are emerging in urban studies. These include vehicle automation, virtual travel, robotics and intelligent transportation system integration, on-demand mobility services, the uncertainty of energy mix and prices, climate change and environmental sustainability.

To supplement insights from our review of foresight studies, we also compiled regional and local factors that are potentially influential. Particularly, the threat of terrorism targeting public infrastructure such as transport systems in major cities. Another factor is Singapore's *smart nation* vision (including the trend of smart mobility services tapping on the use of internet of things (IoT) and sensor technologies), which charts the direction for Singapore to develop greater innovative capacity, and encourage companies to place engineering at the core of their businesses to harness technology to the fullest. Finally, Singapore has expressed the intention to reduce the greenhouse gas intensity by 36 per cent from 2005 levels by 2030 (National Climate Change Secretariat, 2016). This pledge at the COP21 climate talks in Paris in 2015 is likely to impact the transportation sector, which is a substantial contributor to greenhouse gas emissions in Singapore.

2.2 Expert interviews

We conducted structured interviews with more than 50 experts working on the various aspects of urban mobility to gather insights about leading trends and challenges in their respective fields. These expert participants are from governmental agencies, academia and

Figure 1 Overview of the foresight methodology

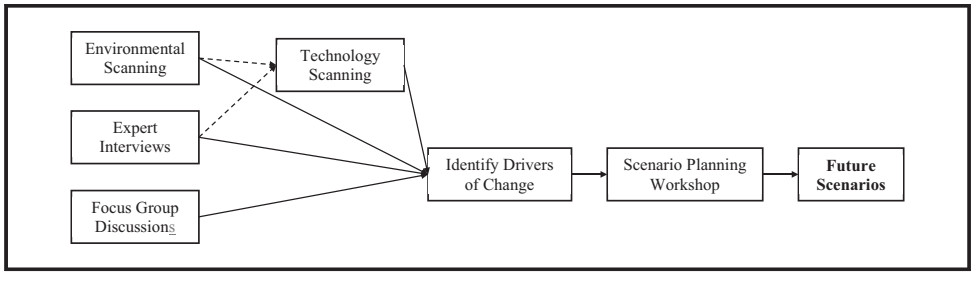


Table I Summary of 12 foresight studies on urban mobility

Foresight study	*Foresight year*	*Cities/region*	*Key drivers of the future*
Townsend (2014)	2030	US megacities	Energy mix and price, vehicle automation, global trade of technology, economic instability, virtual travel and individualism
van Voorst tot Voorst and Hoogerwerf (2014)	2040	Dutch urban centers	Individualism and globalization
Office of Science and Technology (2006)	2056	UK urban centers	Environmental sustainability and public acceptance of intelligent infrastructure
DHL (2012)	2050	Megacities	Energy price, climate change, political stability, global trade, income distribution, ICT and robotics, changing consumer needs, urban development, scarcity of resources, legislations and material technologies
Martins *et al.* (2012)	2018	Brazil urban centers	Investment in infrastructure, the efficiency of legislation and quality control
Auvinen *et al.* (2012)	2100	Finland urban centers	Energy mix, climate change, legislations, urbanization, virtual travel and ITS integration
Zhao *et al.* (2012)	2030	Jinan and China	Urbanization and environmental sustainability
Lyons *et al.* (2014)	2042	New Zealand urban centers	Cost of energy and virtual travel
Gazibara *et al.* (2010)	2040	Megacities	Energy mix and supply and demand, governance model
Zmud *et al.* (2013)	2030	US megacities	Price of oil (energy), climate change and investment in infrastructure
Fishman (2013)	2020	Megacities	Vehicle automation, virtual travel, ITS integration, mobility-on-demand, real-time information and dynamic pricing
Ecola *et al.*, 2015)	2030	Chinese megacities	Pace of economic growth, constraints on driving and vehicle ownership and environmental conditions

industries. Most experts interviewed reside in Singapore. Additionally, we also invited participants from foreign universities who are working on future urban mobility projects.

During these interviews, experts shared their views on what they believe to be the top trends, challenges and technologies for the future of transport. In addition, they discussed specific issues within their realm of expertise, sharing insights about the underlying forces influencing their fields.

2.3 Technology scanning

Based on the insights gathered through environmental scanning and expert interviews, possible game-changing technologies in urban mobility were identified. For each identified disruptive technology, we examined its role in Singapore's mobility system, documenting the current state of development, and detailing challenges to their development and application. The assessments of these technologies could help transport planners to consider the development and/or investment in appropriate technologies.

Nine groups of technologies were identified, including autonomous vehicles, electric and alternative fuel vehicles, connected vehicles (V2X) and IoT, data analytics, personal mobility devices (PMDs) such as bicycles and electric scooters, artificial reality (including virtual and augmented reality technologies), drones and freight robotics, mobile technology (including applications for shared mobility) and shared city cars. Each technology has the potential to address major challenges in the Singapore mobility landscape. For instance, autonomous vehicles could provide mobility for the elderly and disabled, PMDs could complement feeder bus services for first and last-mile travel, and V2X technologies together with data analytics could reduce traffic congestion by routing vehicles through the city more efficiently.

2.4 Focus group discussions

The main objective of conducting focus group discussions in this study is to understand commuters' behavior, concerns and ideals regarding moving around the city in the future and any current challenges they are experiencing in regard to mobility services.

The study team conducted discussions with two groups of commuters in early 2016. One group comprises tertiary students between 16-24 years of age, and the other group comprises Singapore residents between 24-40 years of age. Through purposive sampling, we ensured that the group make-up would compose of individuals of different ethnicities, age, gender, occupation, and primary mode of transport, to the best possible. The key themes that emanated from the focus group discussions are:

- participants' preferences for one travel mode over another;
- their experiences with the travel modes currently available to them;
- their behaviors in response to past or current travel experiences (e.g. coping or accommodating strategies); and
- their expectations and aspirations with regards to future mobility services in Singapore. For an in-depth discussion of the focus group discussions conducted, see Kurniawan *et al.* (2018)

2.5 Drivers of change

Environmental scanning, expert interviews, focus group discussions and technology scanning help to identify key drivers of change. We collected 54 factors with a direct or indirect impact on shaping mobility landscape of the future. After clustering them for consistency and dependency, we categorized them into 19 key drivers of change, which were sorted into five influencing areas: demographics and urban form, evolving travel behavior, transportation technologies, macro factors and global drivers. The identified key drivers are summarized in Table II. Subsequently, these drivers were used in scenario development.

3. Scenario planning workshop

Scenario planning techniques have demonstrated the capability to systematically explore the complex interplay among various key drivers of change to provide insight into the uncertainties of the future. Events and trends affecting the future can have cascading effects. Such effects are hard to be understood intuitively, let alone forecasted (Schultz, 2015). Yet, forecasting techniques remain dominant in transportation planning and travel demand management to support policy decisions. Policymakers and stakeholders have to deal with deep uncertainty in exercising judgment when they plan for the future. Over the past few decades, scenario planning has emerged as an important tool for decision-making under such circumstances (Bishop *et al.*, 2007). Accordingly, we used a scenario planning process to inform our long-range mobility foresight study.

A one-day scenario planning workshop was held in March 2016 with a total of 22 participants from public, private and academic sectors. In the workshop, participants were first briefed on the significance and the potential impacts of the key drivers of change; they were asked to internalize the nature of uncertainty of these drivers. Then, the participants were asked to rate the drivers based on their inherent uncertainty and impact on the future of urban mobility in Singapore. After this exercise, five drivers of change were chosen that reflected a collective opinion of workshop participants. The five drivers, according to participants, are both highly uncertain and highly impactful:

1. local innovative capacity;
2. PMDs;

Table II Key drivers of change that will influence the future of urban mobility in Singapore

Areas	*Key drivers*	*Description*
Demographics and urban form	Ageing population	Evolving mobility needs because of the increasing number of senior citizens
	Population size	Increasing population density resulting in congestion within city centers. Competition between using the land for roads, housing, public spaces, etc
	Socioeconomic status	Evolving socioeconomic status – changing educational attainment and income per capita – and social expectations, influencing vehicle ownership and preferred travel modes
	Multi-zone districts	The promoting of mixed land uses within the urban form, which influences travel patterns, such as travel destinations, trip distances and trip purposes
Evolving Travel Behavior	Multi-modal transport	The provision of multi-modal transport services to help commuters travel from point-to-point, along with shifting commuter behavior to adopt the use of these modes
	Shared mobility	Adopting and commercializing of shared mobility systems such as car sharing, carpooling, ride-sharing, and mobility-on-demand services such as Uber and Grab. This applies to both commuters and businesses and passenger and freight transport
	Active mobility	Growing interest in cycling and walking modes, especially for the first- and last-mile travel
	Virtual travel	Trends toward telecommuting and teleworking reduce travel demand
	E-commerce	E-commerce activity such as online shopping for goods and services, resulting in travel behavioral change
Transportation Technologies	V2X infrastructure and communications	Communication between vehicles and road infrastructure, with capabilities that include dynamic traffic routing, increased safety as vehicles communicate their intentions to each other, and improved congestion management with platooning
	Autonomous vehicles	Self-driving vehicles for private and public passenger transport, as well as for freight
	Real-time information	The use of real-time information, big data and IoT, mobile apps and intelligent transport systems
	PMDs	PMDs such as bicycles, scooters, electric scooters, e-bikes, etc.
Macro Factors	Government policies	Regulations and policy initiatives that drive or limit transportation demand and supply, including their impact on commercial investments and innovations
	Environmental awareness	Greater environmental awareness, resulting in public and commercial interest in alternative fuel vehicles or other sustainable travel modes. Also, increasing the awareness of the impacts of transportation systems and infrastructure development on the environment
	Commitment to greenhouse gas reduction	Influence on transportation policies due to Singapore's intention to reduce greenhouse gas emissions intensity by 36 per cent from 2005 levels by 2030
	Innovative capacity	Singapore's capacity to innovate is ranked behind several developed countries. There is an increased drive to foster home-grown innovations rather than importing ready-made solutions
Global drivers	Cost of energy	Fluctuations in global oil prices influencing innovations and developments in the transportation sector
	Global terrorism	Greater concern about transportation system security and resilience

3. virtual travel;
4. multi-zone districts; and
5. e-commerce (Figure A1 in Appendix shows the voting results).

Smaller groups can foster better engagement among participants, allowing individuals to actively contribute to the ideas of the future. Accordingly, participants were divided into three breakout sessions to explore possible end-states for each driver of change with 2040 as the target year. These end-states are short narratives for how each driver might pan out in the future. The participants were guided to articulate end-states that were mutually exclusive, meaning that two or more end-states should not have overlapping ideas or one end-state should not be a subset of another.

To explore end-states and develop future scenarios, we adopted a method akin to *morphological analysis*. Morphological analysis is a method for investigating relationships of a non-quantifiable, qualitative description of variables (Ritchey, 1998). For each driver, a range of variables (i.e. end-states) is assigned, and all variables are then arranged in a

matrix, thus, producing a configuration space or a morphological field (Glenn and Gordon, 2009). Each configuration contains one value from each of these end-states. Some configurations may be judged as plausible because all end-states for that particular configuration are consistent (i.e. no contradiction between end-states).

Storylines (or narratives) were then developed around the selected configuration using a backcasting technique (Robinson *et al.*, 2011; Tuominen *et al.*, 2014). The idea of building narratives is to build details around the scenario – how such a vision can be achieved (not just a description of the end-state). Thus, narratives should capture the chronological events and the pathways for arriving at a particular future. Finally, a sense-making check was conducted to help build awareness on a given situation in each selected scenario.

Through this process, each group developed two to three internally consistent scenarios first, which were then discussed in a planery session. Through collective discussions and clustering for similarities and dependencies of scenarios, the workshop concluded with the selection and discussion on implications for three future scenarios for Singapore's urban mobility in 2040 that were deemed most plausible, interesting, and internally consistent by the participants. For expediency, we describe two scenarios here – the *Shared World* and the *Virtual World*.

4. Urban mobility scenarios for Singapore in 2040

The scenarios discussed in this section are a glimpse of alternate futures of 2040. There are some key trends common in these scenarios that we call "common projections." These are traits that, according to workshop participants, will highly likely happen and influence the future greatly. The degree of influence might vary in each scenario, but they are nonetheless expected to play a significant part in shaping the future of urban mobility.

4.1 Common projections

Demographics. The total fertility rate in Singapore has been below the replacement rate of 2.1 for more than three decades (NPTD, 2013). Consequently, elderly residents will account for about a quarter of Singapore's population in 2030. In addition, Singapore's total population will continue to grow because of a steady influx of non-residents and migrants. By 2030, the Singapore population is projected to be between 6.5 and 6.9 million compared to 5.54 million as of June 2015 (NPTD, 2013). Thus, we assumed that planning for the future of urban transport will incorporate provisions for addressing travel and work needs of both the aging and growing population.

Technological advancement. The second common thread that the two scenarios have the general advancement of technology across multiple fields, ranging from transportation technologies, mobility modes, and mobile devices to infrastructural developments. However, the pace of technological advancement in each scenario differs.

Increase in environmental awareness. The last projection is a steady shift toward adopting a greener lifestyle and reducing the carbon footprint of Singapore. As part of government's intention to reduce greenhouse gas emissions, there may be large-scale initiatives in favor of cleaner transportation. On a societal level, people are generally becoming more environmentally conscious because of worldwide media campaigns and the promotion of environmentalism over social networks. Over time, this could lead to an increase in the adoption of greener mobility modes and the preference to be more sustainable.

4.2 Scenario 1: Shared World

The first scenario depicts a radical shift toward a shared-living lifestyle. In the *Shared World*, people have embraced community living and shared-resources lifestyle featuring two key aspects: shared mobility and multi-zone districts. Shared mobility is an innovative

transportation strategy that enables users to gain short-term access to transportation modes on an as-needed basis. Examples of shared mobility include various forms of car sharing, bicycle sharing and ridesharing. Multi-zone districts are an overhaul of the current land-use plan that fundamentally change travel patterns, reducing cross-island travel for city dwellers. For such an urban form, each district spans approximately 3-4 square km and is organized in clusters of self-sustaining zones, complete with residential blocks around the circumference of each zone and commercial activity hubs, shopping centers, educational institutes, healthcare, MRT stations and other facilities at the center of each zone. Key features in this scenario are:

Government policies. The government has taken up the dominant role in shaping the mobility landscape and designing a new urban form with a focus on developing shared mobility systems. Policies are geared towards providing grants and other support measures to start-ups related to shared mobility, which has been promoted in a nationwide campaign since the 2020s. In 2040, shared mobility systems have the highest share of a modal split among all vehicle miles traveled in Singapore. The number of shared mobility services has grown in part because of the government's initiatives to re-invent the education system, which emphasizes innovation and creativity, and to promoting entrepreneuship and cultivating more risk-taking behavior among young Singaporeans. By 2030, reforms in the education system have borne fruit as Singapore is among the top 10 countries in the world for innovative capacity. As a result, Singapore is benefiting from harvesting home-grown innovation in all sectors, including mobility.

Mobility modes. The primary modes of transport within the shared world districts are autonomous shuttle buses, shared PMDs and vibrant culture of active mobility. Infrastructure, like bicycle pathway networks, built in the early 2020s makes walking and cycling more conducive, comfortable and efficient for traveling short distances. By 2030, in favor of making "car-lite" zones, cars have restricted access to roads within districts. By 2040, each district has an efficient autonomous bus network. Apart from autonomous shuttle buses, people also rely heavily on active mobility and shared PMDs for traveling within districts. First introduced in late 2010s, shared PMDs are extensively used for intra-districts trips, as well as first- and last-mile trips to/from MRT stations as "park-and-ride" and "shared stops" facilities at stations provide convenience for commuters to park their PMD and transfer to a train. By 2030, a specially designed PMD for seniors has also been adopted by the elderly population. For cross-island travel, the expanded MRT network, which was completed by 2030, forms the backbone. It is further complemented by car sharing and ride sharing facilities. This represents a radical shift in users' travel behavior as compared to present-day, where car ownership is preferred.

Life and work style. In an attempt to reduce cross-city travel for a daily trip purpose, both urban planners and companies are constantly developing innovative ways to provide people with commonly accessed services, amenities and facilities within each district. This new urban form has allowed residents including the elderly and the physically challenged to pursue many activities without traveling long distances. By 2030, another form of commercial centers emerged that can act as shared workspaces for several companies. In this new era of work culture, people go to commercial centers in their districts, find a hot desk, connect with a virtual reality headset, and immediately, they find themselves in their office premises, interacting with colleagues who are also tuned in through virtual reality headsets from different districts. By 2035, the retirement age has increased to 80 as people are living longer and healthier lives. Having workspaces co-located with residential blocks and recreational parks within the district has enabled the elderly population to work at their convenience. Multi-zone districts have resulted in a very different urban environment. With the co-location of work centers, schools, leisure and recreational activity hubs, district centers can operate round the clock. People adopt flexible working hours, rather than a

fixed work schedule. In essence, mobility modes also evolve to satisfy the demand of 24-h communities serviced by autonomous buses operating throughout night and day.

Urban freight. In this scenario, e-commerce has grown significantly, but still accounts for less than two-thirds of total retail. Most people still enjoy shopping at brick-and-mortar stores given its social dimension. However, they no longer need to carry their purchases with them because of a new form of delivery service within the districts. A web of underground tunnels connects each residential cluster to shopping centers and supermarkets. Purchases are tagged with the recipient's address and deposited at delivery centers located inside the shopping malls. By the time the buyers reach home, their goods are waiting at the goods receiving center at or near their residential complex. Moreover, together with the sophistication of shared mobility systems, the significant rise of e-commerce has led to the emergence of courier network services (CNS) who provide for-hire delivery services using an online application or platform to connect couriers with freight (Shaheen *et al.*, 2015). By 2040, most e-commerce and intra-district deliveries are fulfilled by CNS, while traditional freight companies (such as FedEx and SingPost) focus more on cross-island freight and transnational bulk shipments.

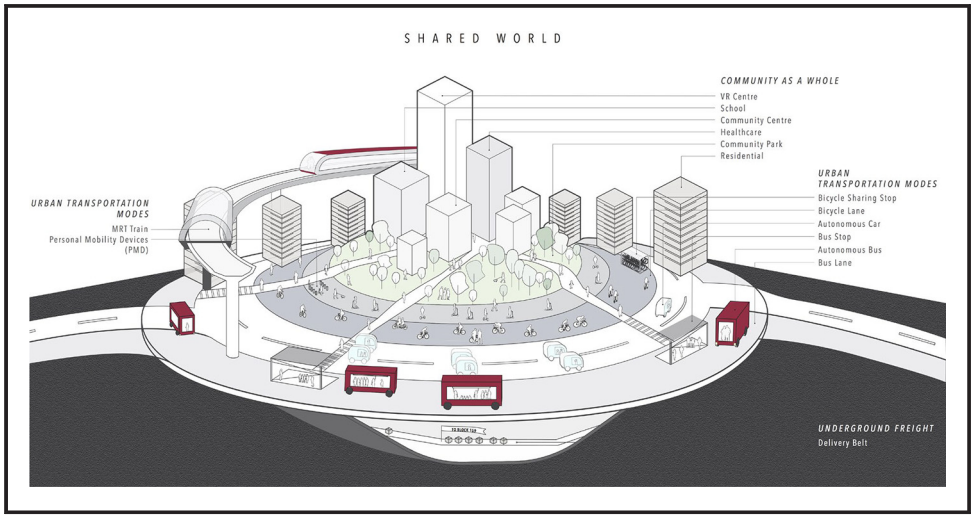
In this scenario, people live healthier lifestyles because of a vibrant culture of active mobility. Communities are tightly knit and everyone enjoys the benefits of state-run transportation, community living and shared mobility systems. Figure 2 shows an illustration of the key aspects of the *Shared World* scenario.

4.2.1 Shared world scenario implications.

Individual. A shared world is likely to be a favorable scenario for individuals. The new public transport chain, comprising autonomous buses and MRT, will become more efficient, as autonomous buses will solve issues of bus bunching and erratic schedules, and PMDs will provide first- and last-mile transport for commuters to access the MRT. Individuals will no longer feel the need or the desire to buy a car as shared mobility systems become affordable and more efficient. Moreover, having good schools within each district and on-campus residences in higher learning institutes will reduce the need for students to travel long distances. Residents of each district will likely experience a greater sense of belonging that can, in turn, encourage them to contribute actively to the betterment of their districts and the welfare of the residents.

Society. On the societal level, this scenario will have largely positive implications as well. With greater utilization per vehicle and lower demand for parking lots, more land is freed up

Figure 2 Shared World illustration



for other purposes. In addition, the overall decrease in congestion will increase public satisfaction and reduce the transportation of environmental externalities. However, the emergence of autonomous buses might drastically reduce the need for drivers, and increasing demand for skilled technical expertise required for vehicle fleet management and the maintenance of autonomous driving systems. It would mean reassignment of jobs or extensive retraining and upgrading, which might not be a welcome change for workers and their union.

Industry. There will be a mix of winners and losers in industries. On one hand, the conventional taxi industry is likely to suffer from the emergence of shared mobility systems and will have to innovate to compete with the evolving industry. On the other hand, there will be new business opportunities for social network and technology companies as they are likely to form the backbone of shared mobility systems. Data analysts will find work in the space of real-time distribution of shared vehicles and autonomous PMDs. There will also be opportunities for new industry players to operate the autonomous buses within the public transport system. Finally, shared workspaces and satellite offices could result in significant cost savings for companies.

Government. In the new urban form, more meticulous planning will be required to determine the right mix of commercial, residential, and industrial developments for each district. Similarly, there will be a need to develop routes and infrastructure for autonomous buses, active mobility and intra-district travel. Moreover, as multi-zone districts start to develop, there will be a need to constantly monitor traffic patterns and underlying causes. The government will also need to establish clear resolutions on legal liability issues for shared vehicles and in freight through legislative frameworks. Public and private sector players will need to collaborate to ensure the success of shared-service models. Reforms in education and industry will take place in this scenario to support the growth of new mobility modes described, and nationwide campaigns may need to be undertaken to communicate policy and technology changes to society.

4.3 Scenario 2: Virtual World

The *virtual world* scenario depicts a future where virtual reality technology is pivotal in everyday life. In this scenario, the artificial intelligence (AI) and internet-of-things (IoT) technologies are pervasive, altering many social norms. One significant change is the concept of self-actualization. Because people can access a wealth of online information without having to rely on others, they have developed a sense of individualism. The concept of individualism is much rooted in society – everything is built tailoring to individualism. For instance, people live in small apartments that have enough room to accommodate only one or two dwellers. This small sanctuary would be a home, a virtual work, social and classroom space for an individual. Every home comes with advanced-technology gadgets, making virtual reality the "reality." Key features in this scenario are:

Government policies. In this scenario, the government plays a supportive role while the market plays a dominant role in driving innovation and systems. In the early 2020s, the regulatory environment is conducive for companies and start-ups to testbed new technologies and introduce new business models quickly in Singapore. Government policies are directed to entice major technology companies to consider Singapore as their base for research and innovation development. In so doing, local companies tend to benefit from increased investments by international venture firms and hedge funds. As a result, Singapore quickly became one of the most tech-savvy cities in the world. In 2030, Singapore earns the title of the "Silicon Valley of the East." The change in policies helps Singapore transformation from technology importer to technology net exporter. Technology exports contribute significantly to Singapore's GDP.

Mobility modes. The primary mode of transport in this scenario is the personal travel pod. The innovation of autonomous travel pod originated from advanced PMDs and autonomous city concept cars, which both had gained prominence in the 2010s-2020s. An autonomous pod is a fully enclosed capsule that seats two people and comes with a fully functional workstation. The pod is not only a mere mobility device but also an artificial intelligent "life form," acting as owners' personal assistant and "avatar." Owners can program their pods to carry out various tasks, such as picking up groceries from stores or attending office meetings *in situ* as instructed. To accommodate these traveling pods, transport infrastructure is redesigned, constructing dedicated pod lanes with built-in electrified strips to recharge the battery of the electric-powered travel pods on-the-fly. The government embarks on an ambitious plan to "pod-everything" in the late 2030s. According to this plan, all personal vehicles on the road are autonomous pods. These individually owned pods are complemented by the city's extensive vast MRT network.

Life and work style. While personal travel pods have emerged the primary mode of transport, travel demand has reduced significantly due to the emergence and rapid adoption of virtual travel and communications. Virtual travel – the use of technologies such as holography, augmented reality and virtual reality – has enabled people to engage in constructive meetings despite not being physically present at the same location. The mass commercialization of virtual reality gadgets started in the late 2010s and by the late 2020s, individuals own at least one personalized virtual reality gadget, replacing smartphones in 2020s. By the mid-2030s, virtual reality technology is capable of augmenting real-life environments, allowing people to work, study and shop without leaving the comfort of their homes.

Urban freight. E-commerce is widely adopted as the preferred mode of shopping after 2020. By the late 2030s, AI is able to predict individual buying behavior, and goods are delivered even before the purchases have been made, aided by anticipatory logistics. In this age of technology, urban freight is being moved primarily by autonomous freight robots and delivery drones. In the food sector, robots and drones are now the primary modes of home/office deliveries.

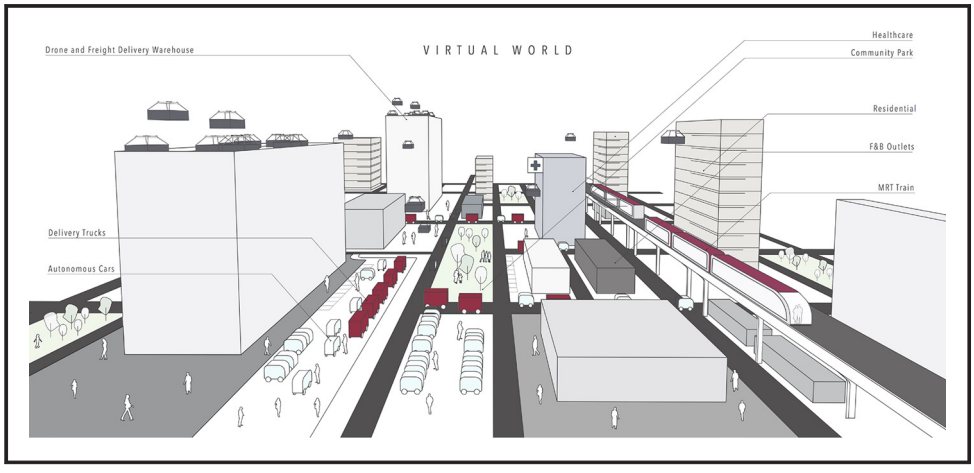
In this scenario, overall travel demand is significantly reduced as people spend most of their time plugged into virtual reality and assisted by AI. When people travel, they use personalized autonomous travel pods. This future has not only much less congestion but also much fewer physical interactions and vibrancy. Singapore has evolved into a productive, connected, and futuristic city where people have all but replaced the real world with virtual ones. Figure 3 shows an illustration of the key aspects of the *Virtual World* scenario.

4.3.1 Virtual World scenario implications.

Individual. The *Virtual World* scenario is likely to be favorable for individuals because of tremendous time savings. Individuals can conduct their day-to-day activities in virtual worlds, and autonomous pods provide personal transportation services to all segments of society. Time freed up from commuting becomes leisure time for people to engage in recreational and social activities. This scenario will also make it possible for the elderly and handicapped to participate actively in their communities with little travel constraints. Moreover, AI will take human productivity to unprecedented levels. However, the *Virtual World* might increase the risk of social isolation as individuals pursue their interests in their own virtual worlds.

Society. Singapore will experience much less congestion as people adopt virtual lifestyles, reducing travel demand and its associated traffic and environmental impacts. Also, schools and colleges can transcend capacity constraints as virtual classrooms can accommodate a larger number of students. This may allow wider audience access to excellent education. On the flip side, society might experience large-scale unemployment woes as automation and AI can replace human workers in several industries. In terms of social interaction, there

Figure 3 Virtual World illustration



could possibly be a negative implication on society should individuals become increasingly more isolated with little social engagements or none at all.

Industry. As with the industrial revolution of the nineteenth century and the technological revolution of the twentieth century, this scenario is likely to create tremendous advancements and opportunities. For instance, sensor systems, IoT, and connectivity around the island will be implemented, providing opportunities for companies and start-ups to expand their businesses. Similarly, there will be tremendous opportunities to advance research and development in specific fields such as AI, robotics and virtual reality. There is also a business case for developing virtual world software and technologies that can lead to a new age of architects, designers and engineers. Finally, small- and medium-sized retail shops might suffer as they are replaced by experience stores or warehouses.

Government. The regulatory environment may change to support high-technology developments in Singapore. For example, the transport planning authority may consider supporting certain telecommunication regulations necessary to ensure the smooth operation of intelligent transportation system.

As roads will be dominated by autonomous pods, road infrastructure requires redesigning to include new dedicated lanes with charging capabilities, and V2X infrastructure as Singapore shifts toward "pod-everything" transport policy. This may also result in redundancy and excess capacity in the existing public transport system. Finally, for this scenario to function seamlessly, the onus will be on the government to collaborate with industry players by sharing data collected throughout the island from various smart sensor systems.

5. Discussion and conclusion

This foresight study considers various drivers of change that could influence long-term urban mobility, and produce visions that may indicate the kind of mobility services we might need in the future. These visions are captured as scenarios, which were produced in a participatory scenario planning workshop. The scenarios developed are intended to portray the future of urban mobility in Singapore holistically, which means that we considered both people and goods mobility in the urban context. By using a participatory scenario planning approach, we intended to prepare stakeholders for uncertain futures that are continuously shaped by our decisions today.

The two scenarios, *shared world* and *virtual world*, shed light on how alternative futures of urban mobility could unfold as the consequence of different policy directions and the promotion of particular technologies. In the *shared world*, for instance, the local government can play the leading role in directing the creation of specific urban form instilling the "culture" of sharing (i.e. resources and transport services). The *virtual world* scenario, on the other hand, describes how the local government can take on the supporting role; instead, society takes the lead to actively shape the dominant technologies, which transform every aspect of everyday lives.

At first glance, the two scenarios may appear similar because both scenarios depict a technological leap within the urban mobility sector. However, we observe one significant difference: the *shared world* represents a worldview that takes on a micro-scale perspective, emphasizing communal living, safety, affordability and shorter-distance travel, and also tends to display social connectedness. The *virtual world*, on the other hand, is more individualistic where people emphasize the speed of travel, either physically or virtually, and distance is no longer a barrier to mobility.

One can notice that the scenario narratives for the *virtual world* read like science fiction. Such imaginative storylines are often viewed with skepticism as storylines developed in a group setting makes scenario products subjective, which raises the questions about scientific credibility (Lloyd and Schweizer, 2014) and face validity (Kurniawan and Kundurpi, 2019). Further, Scheele *et al.* (2018) explain that storylines, as a product of scenario exercises, can be influenced simply by using different scenario methods or engaging different groups of participants. However, proponents of imaginative scenarios argue that the "process" of scenario development is more useful than any scenario "product" for integrating and mobilizing knowledge and internalizing different future options that will benefit the participants involved (Anderson, 2010; Swart *et al.*, 2004; Wilkinson and Kupers, 2014; Kitchin and Kneale, 2001). In this case, the process proved valuable for stakeholders involved in terms of identifying critical uncertainties and early signs of trends becoming dominant. This also aided with consideration of new opportunities and risks, which can help with both developing contingency plans and reviewing existing strategic plans against the possibility of alternative futures. In particular, for transport planners, this will help widen the horizon of thinking, useful for both strategic planning and operational implications.

The scenario planning method used in this study is not without a few limitations. Due to time constraints imposed during the one-day scenario planning workshop, we were unable to incorporate as many key drivers into the development of the two scenarios. The participatory approach to scenario planning, in fact, presents practical challenges regarding the availability of the participants, who are local stakeholders, such as transport planners, academics and experts. We also encountered how one individual could be more vocal in negating or amplifying a specific key driver of change. Participants are not homogenous and not entirely consensual in which individuals may have different concerns (Koontz, 1999). The question is who are they representing in the workshop? Individuals can adopt different *social roles* in various situations that come with a set of expectations of what to do and who they represent (Kurniawan and Kundurpi, 2019). We acknowledge the limitation of our study due to some aspects (i.e. who they represent) that is challenging to control.

The study does not ultimately distinguish desirable and undesirable scenarios; the two scenarios described actually appear to be the desirable futures. Desired futures have the element of efficacy because we are compelled to ensure that those futures will come to fruition (Inayatullah, 2003). This can motivate stakeholders to prompt relevant questions surrounding scenario mechanics. While each scenario has presented a different dominant transport mode, this, in turn, further begs the questions about who owns, who maintains this transport mode, what we can do to get to the future we so desire from here, and how – in other words, making sense of the scenarios, which needs further research inquiry. Hence,

one of the next steps is to organize workshops with a broader audience to stimulate dialogs that revolve around the two visions to pry more deeply into the motivation for how aspects of particular ideal scenarios can be realized.

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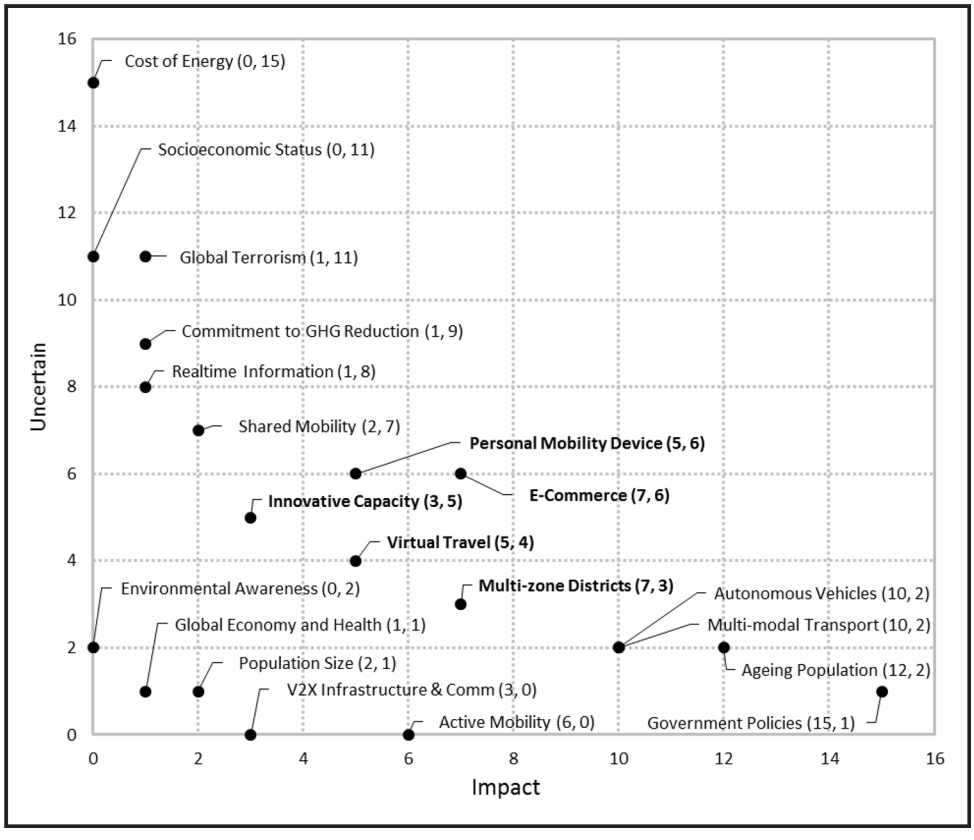
Appendix

Figure A1 Scenario planning workshop voting results, determining highly uncertain and high-impact drivers (marked in bold)



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