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► **To cite this version:**

Kulacha Sirikhan. Potentials and Challenges of The Connected Autonomous Shared Electric Vehicle (CASE) from Urban Geography Perspective in Southeast Asia Mega-Urban Regions. 2022. hal-03607999

**HAL Id: hal-03607999**

**<https://hal.science/hal-03607999>**

Preprint submitted on 14 Mar 2022

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# Potentials and Challenges of The Connected Autonomous Shared Electric Vehicle (CASE) from Urban Geography Perspective in Southeast Asia Mega-Urban Regions

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**March 2022**

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Kulacha Sirikhan

## Abstract

The introduction of autonomous vehicles (AVs) is predicted to potentially improve both transportation capacities and stimulate the worst impacts of car dependency. The concept of connected autonomous shared electric vehicle (CASE) has been introduced as an enabler of the collective mobility of the future that prioritizes ride-sharing and promotes multi-modal share with public transportation as the backbone. However, research in these areas is significant geographical imbalance upon contexts of the Global North. The future studies of CASE concepts are essential to fill the gap between fast technologies changing and long-term planning in technology's adopter like most of the Global South countries.

This research explores different policy pathways in the long-term implication of CASE in Southeast Asia Mega-Urban Regions. Bangkok and Ho Chi Minh City have been selected as case studies due to their urban dynamics of rapid expansion of urbanization areas. This research proposes novel mixed methods to synergize multiple scenario buildings stages and find robust strategies. The exploratory processes take place in three stages of scanning driving forces, identifying critical uncertainties with bibliometric analysis, developing plausible scenarios with cross-impact analysis, and identifying robust strategies with spatial analysis.

The issue on the categories of mobility solutions and governance approaches are critical uncertainties that are derived from bibliometric analysis. Then, two critical uncertainties were used to plot quadrants scenarios of everyman for himself scenario, affordable treats scenario, AVs-public transport hegemony scenario, and multi-modal prosperity scenario. The reconsideration of the current urbanization and urban mobility system in spatial analyses highlights a long path dependence of the absence of government intervention, weak transportation network, and lack of accessibility to public transportation. These inherent problems would likely lead the city to exclusiveness scenarios that fuel ignorance of CASE adoption and continue the high penetration rate of private transport.

Indeed, the reaction of anticipatory governance will be unavoidable due to the need for public democratic discussion. Integrating CASE and mobility as a service is important to deliver a seamless user experience, personalized mobility plans, and fare payments on a single digital platform. This research recommends participatory planning to develop comprehensive urban-regional planning considering multi-level governments

of local and regional levels in the metropolis and neighboring cities, private sectors, and communities. Initially, this research proposes scenario-based robust strategies underlying the idea of minimizing the maximum regret covering public rights-of-way, incentive zoning, and taxation strategies.

### **Keywords**

Autonomous Vehicles, The Connected Autonomous Shared Electric Vehicle, CASE, Scenario Building, Mega-Urban Regions, Southeast Asia, Bangkok, Ho Chi Minh City

### **Acknowledgement**

The FFJ/Valeo Fellowship supported this work. Correspondence concerning this paper should be addressed to the author at [kulacha.sirikhan@ehess.fr](mailto:kulacha.sirikhan@ehess.fr). The author gratefully acknowledges the generous support and assistance of the Fondation France-Japon (FFJ) de l'École des Hautes Études en Sciences Sociales (EHESS) and Valeo. The author would like to particularly thank Sébastien Lechevalier and Alexandre Faure for their support and helpful comments on this work. The authors would like to thank anonymous reviewers for their valuable suggestions and comments on an earlier version of this paper.

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# 1. Introduction

The car revolution of the last century transformed the urban life paradigm, and the development is still ongoing from human-driven vehicles to the integration of automation vehicles and digital telecom transformation. Multiple autonomous vehicle deployment models (AVs) will change commuting habits and eventually transform urbanization. The discussion on AVs deployment has been framed by dichotomies between optimistic and pessimistic scenarios (Papa & Ferreira, 2018). In the optimistic scenario, AVs technologies could mobilize a better urban environment by reducing space requirements in parking space and street width, eliminating car accidents, minimizing emissions and pollution, and fostering urban economic activities. The AVs can optimize transport supply by increasing transportation capacities and reducing travel time. Travel demand will increase because individuals accept to commute farther distances at lower land prices. Commuters can spend travel time to their free choices rather than paying attention to driving. This could lead to the pessimistic scenario in increasing greater urban sprawl, inducing car dependency, overloading road infrastructure, and stimulating social inequalities. Thus, it is difficult to identify a concrete scenario on how these emerging mobility technologies will impact urban lifestyle.

The coming of AVs could be critical for emerging market cities with rapid growth urbanization, incomplete urban planning, and inadequate transportation systems. The capital cities in Southeast Asia are well recognized for their world-ranking traffic congestion problems and different driving behaviors compared to cities with more advanced AV requirements such as the US, Europe, and Japan. The current national development stages of AVs technologies in Southeast Asia are varied. Singapore ranks as the top country ready to embrace AVs. Meanwhile, other Southeast Asian members, including Malaysia, Thailand, Vietnam, the Philippines, and Indonesia, are in different introduction stages of the technologies.

To avoid the pessimistic scenario, the concept of Shared AVs (SAVs) has been widely discussed recently to counterbalance negative impacts from private ownership. However, the interchangeable SAVs implications on ride-hailing and ride-sharing are important to distinguish these terms explicitly. Therefore, this research aims to introduce a concrete collective transports concept that assumes the most sustainable and inclusive results. The connected autonomous shared electric vehicle (CASE) enables collective mobility of future that prioritizes sharing vehicles between multiple users and promotes multi-modal sharing with public transportation as the backbone of urban mobility. CASE has the potential to interweave and be compatible with various mobility modes, including Private autonomous vehicles (PAVs), Connected vehicles (CVs), on-demand transportation of Shared AVs (SAVs), Electrification vehicles (EVs). The connectivity in CASE overarches connected multi-modal transportation system as well as CVs' features of real-time information exchange of vehicle-to-vehicle communication (V2V), vehicles to infrastructure communication (V2I), and vehicles to everything communication with compatible networks and devices (V2X).

However, the research on shared-urban mobility concept and AVs deployment are notable geographical imbalance upon contexts of the Global North (Thomopoulos et al., 2021). The visions on the futures of autonomous mobility may be differently imagined in the global north to the global south (Porter, 2018; Escandon-Barbosa et al., 2021). In the global south context, the rise of shared-urban mobility policies has been ambiguous and ungrounded policy. The drawback of the divergent of fast technologies changing and long-term planning is critical for a technology's adopter like most Southeast Asia countries to respond. The future study on the integration of CASE into sustainable urban mobility concepts is important for preparing policies and regulations to catch up with technological capabilities.



This research follows the exploratory scenarios approach to illustrate plausible scenarios of automated mobilities through mega-urban region cases of Bangkok and Ho Chi Minh. Then, this research discusses robust strategies in promoting CASE adoption. This research proposes the novel mix methods to synergize multiple scenario buildings stages and find robust strategies in CASE deployment. The exploratory processes take place in three stages of scanning driving forces, identifying critical uncertainties with bibliometric analysis, developing plausible scenarios with cross-impact analysis, and identifying robust strategies with spatial analysis.

This paper is organized as follows. The literature review is after this section. Section 3 describes the research methodology conducted in this research. The scan driving forces and identifying critical uncertainties stage is provided in Section 4 based on the result of bibliometric analysis. Section 5 develops plausible scenarios stage is associated with cross-impact analysis result. In Section 6, the results of the computational study on spatial analyses are used to discuss in identify robust strategies stage. Finally, the conclusion is presented in Section 7.

## **2. Literature Review**

The Society of Automotive Engineers International (SAE) has defined six automation levels from level 0 to 5, classified by the level of human-driver engagement in driving tasks. The ranges cover from fully human driver performing (level 0) to fully controlled by an automated system (level 5). The AVs technologies are undergoing development. Automation features in the level 1 to 2 are already available in mainstream vehicles as driving assistance features such as auto-parking, lane-keeping, and collision protection. Level three of conditional driving automation with driver's control in emergencies has merely become a reality in many countries. However, the lack of an effective system to ensure drivers engagement is a big struggle in safety issues (Bojic et al., 2019). In level 4, human interaction is optional for particular circumstances in driverless mode. Finally, level 5 is fully driving automation and entirely without human intervention. This study's discussion considers ubiquitous self-driving mobility with optional human attention, in line with level 4 and above.

An immense research interest around AVs discourse has been adopted in recent years. The Scopus database searches using keywords and synonyms related to AVs showed over 50,000 academic publications. The majority of the literature focused on the technology side. The academic database search resulted in approximately 4 percent of social science research on emerging vehicle technologies (Figure 1). The crux of AVs on the non-technological side is diffused and not widely explored, followed by a delayed holistic transdisciplinary understanding of the impact of the emerging mobility technology (Papa & Ferreira, 2018). The categorization of publication by country highlights a notable geographical imbalance, as seen in Figure 2. The top tenth countries' publications already cover 80 percent of total publications. Most of the countries are in the Global North except for publication from China and India. Since the richness of data is vital in decision making. The research and cars trained in the Global South countries tend to be more relatable to the SEA city context due to challenges, unpredictable traffic, and richer street experience data.

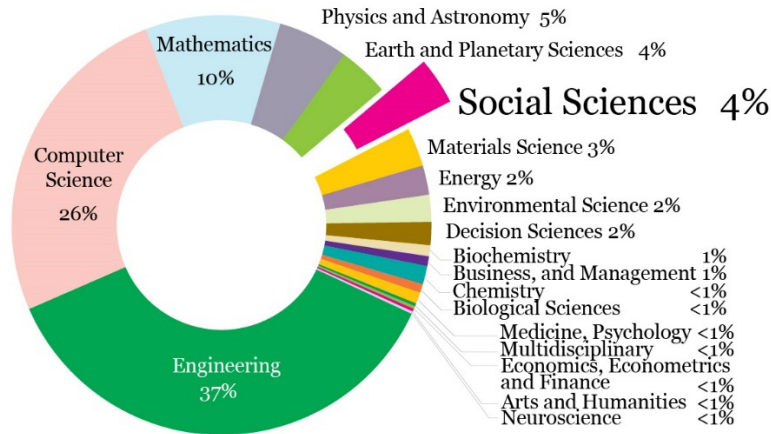


Figure 1 Scopus database on AVs, categorized by study field

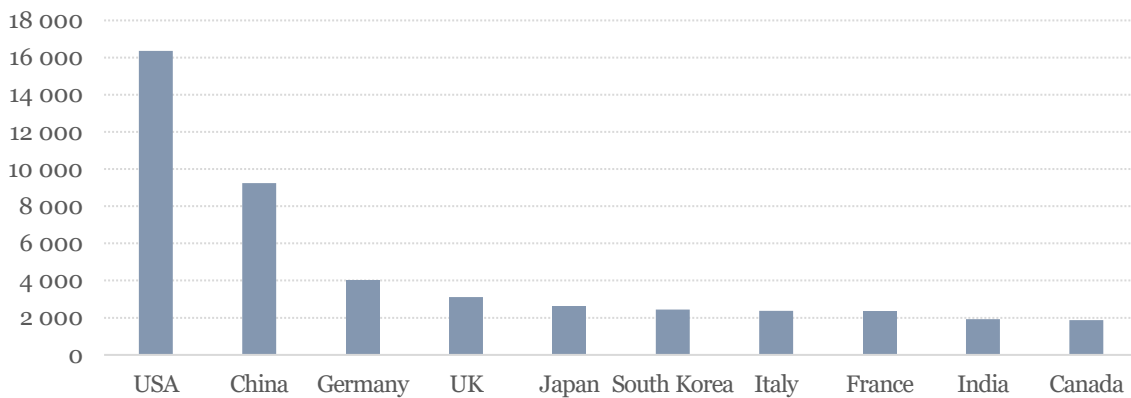


Figure 2 Scopus database on AVs, categorized by country of publication

## 2.1 Unfolding Shared Autonomous Vehicles Prophecies

The widespread introduction of AVs and their impact in stimulating individual car dependency can be witnessed among recent urban mobility literature within the last decade. The vehicle with an entirely driving automation feature will remove a driving burden and enable passengers to spend travel time to their free choice, both working or leisure. Self-driving car technologies can make longer-distant traveling more attractive. Households are more flexible to live even farther from the city center, where housing is more affordable. The reduction of travel time value could lead to a greater urban sprawl pattern and fuel the social-economic gap in different zoning (Wellik & Kockelman, 2020; Zhong et al., 2020).

The blooming ride-hailing service has become the major transportation disruption in the last decade and reflected the mobility-on-demand trend. The mobility on demand follows the user-centric approach, which offers individuals varying transportation modes to complete door-to-door trips through a digital platform, including ride-hailing taxis and ride-sharing shuttles. These features become more important in deployment between individual or collective forms of mobility than the ownership type (Mitchell et al., 2016).

The wave of digital transformation has changed transportation services dramatically, followed by a broad discussion on mobility as a service concept (MaaS). MaaS can be defined as a mobility service through a digital platform that delivers integrated travel solutions and the collection of multiple transport service offers (Jittrapirom et al., 2017). The automated vehicles technologies accelerate the growth of MaaS to become a common mobility plan due to their reliable

transportation options offer cheaper transportation options than traditional services with a driver (Moreno et al., 2018; Adler et al., 2019).

Some scholars envision the combination of AVs and collective transport as opportunities in sharing economy (Krueger et al., 2016; Grush & Niles, 2018c; Adler et al., 2019; Stead & Vaddadi, 2019; Mouratidis et al., 2021; Tsigdinos et al., 2021). The sharing concept is much anticipated to mitigate the negative impact of private AVs ownership. Various scholars point Shared Autonomous Vehicles (SAVs) are more suitable for AVs ownership due to price and cost dimensions (Hörl et al., 2016; Adler et al., 2019; Mohammadzadeh, 2021). AVs will require additional high-technology components, especially high-quality sensors. Therefore, AVs will be more expensive than conventional cars. The higher miles usage in shared-vehicle will reach the pay-off point faster than individual-owned cars. Secondly, the mobility-on-demand service with automation technologies will decrease the operation cost, such as the driver cost. According to Daziano et al. (2017), the stated preference survey result showed a heterogeneity distribution of willingness-to-pay in the commodity ownership in different socioeconomic response groups. The explicit heterogeneous price sensitivity highlights a substantial number of consumers that not willing to pay extra cost to own a self-driving vehicle.

Moreno et al. (2018) indicated the importance of distinguishing SAVs terms explicitly. At the time of writing, the discussion on Shared Autonomous Vehicles (SAVs) is referred to both ride-hailing and ride-sharing services interchangeably. These two services offer different kinds of services, with divergence path dependence on social, economic, and environment. Ride-sharing service serves multiple riders that share a single vehicle. The service may make multiple pick-ups and drop off for passengers along a route. Ride-sharing is likely to reduce the number of cars on the road to serve the same travel demand. In contrast, ride-hailing is a mobility service without car sharing among multiple riders.

Regardless of concrete distinguishing between ride-sharing and ride-hailing, the deployment of SAVs is facing a question in travel and traffic reduction, which may increase travel demand due to travel convenience. In SAVs deployment, mobility on demand can serve multiple trips in fewer vehicles and require lesser parking spaces. The ghost trip or the trip with zero-passenger will occur to get the next passenger or AVs self-park in less-expensive areas. These assumptions expect vehicle-miles traveled (VMT) to increase after full automation deployment (Fagnant & Kockelman, 2015). Meanwhile, the VMT reduction mission is important to reduce gas emission, local economic boost, and place-making. Moreover, the AVs technologies deployment in fleet operation could disrupt public transportation by offering a great supply of door-to-door service, which is more comfortable and flexible.

To this end, the diffusion of SAVs on urban mobility is critical to the sustainability transition. SAVs can only help achieve the private ownership reduction targets, the ignorance of mass public transport usage and ride-sharing orientation may worsen a situation. Hence, the adoption of SAVs should concern multi-modal share mobility schematic, in which public transportation is prioritized as the backbone of urban mobility (Papa & Ferreira, 2018; Stead & Vaddadi, 2019). The concept of connected autonomous shared electric vehicles (CASE) focuses on a shared autonomous vehicle deployment model so that connected AVs features can be compatible with multi-modal transportation. The idea of first and last-mile transportation provided by CASE fleets could enhance mass uptake of public transportation in areas outside accessible to public transit nodes. The combination of CASE and MaaS offers an individual commuting tailored service on one digital platform (Coppola & Silvestri, 2019), which its convenience persuades a commuter to use alternative transportation modes rather than an individual ride.

## **2.2 Governancing CASE deployment**

The emerging integrated multi-modal mobility system will be engaged with a diverse range of stakeholders on a national, regional, and local scale (Fenton et al., 2020). The role of government will be tested regarding more new actors who enter the autonomous mobility areas with intensive knowledge, new resources, and data, which challenge the traditional public authorities' practice and ways of working (Marsden & Reardon, 2021). The question has been raised that how CASE should be governed to promote a collective transport system?

Cohen and Cavoli (T. Cohen & Cavoli, 2019) discuss on possible government intervention approach to prevent adverse negative effects on traffic congestion and accessibility from the non-government intervention approach. The non-government intervention approach refers to the economic term of the "Laissez-faire" approach that governments remain absent from interfering with the free market system. The discussion on business-as-usual scenarios has been used as a baseline to assume less desirable scenario outcomes in terms of sustainable urban mobility. A laissez-faire approach would likely increase mass uptake of AVs in individual rides and ignore social welfare. However, a laissez-faire approach is an extreme opposite of authority-engaged assumption, which takes place in political territories anyway. The deployment of new mobility will directly impact urban space. Indeed, the reaction of anticipatory governance will be unavoidable due to the need of public democratic discussion on benefit and risk of AVs (Papa & Ferreira, 2018). Despite, it remains unclear when and what extent government intervention is to keep the degree of freedom in markets.

In uncertainty, the consequences of CASE will be for users, society, and the environment are still diffused, and difficult to define which government intervention extent should influence the development. Cohen and Cavoli (T. Cohen & Cavoli, 2019) indicated that the importance of government intervention in the early state with a long-term perspective to ensure public interest and interfere with the transition process into sustainable development. The appraisal of a range of intervention options is important to explore and open a way to take action against multiple foresight futures (T. Cohen & Cavoli, 2019). The major uncertainty factors of transport supply and transport demand should be considered in assessing a range of intervention options (S. Smith et al., 2018; Coppola & Esztergár-Kiss, 2019). Supply factors cover the features of new vehicles, the capacity of transportation infrastructure, and the improvement of traffic networks (Fagnant & Kockelman, 2014; Duarte & Ratti, 2018). Demand factors are related to social acceptance the future of consumers' travel behavior (Zhang & Guhathakurta, 2018; Marsden & Reardon, 2021).

The challenge will depend on the institutional capacity of certain governments to mobilize the political process in dealing with multi-stakeholders, planning policies and regulations, and implementation (Nikitas et al., 2017; T. Cohen & Cavoli, 2019; von Mörner, 2019; Marsden & Reardon, 2021). Likewise, governments' inaction can be considered as a response action (T. Cohen & Cavoli, 2019).

## **2.3 Adapting the city toward CASE deployment**

The government interventions are constrained to the place-specific contexts as self-evidence, where political territory and market operation are located, such as ticket distribution, pricing system, and institutional structure (G. Smith et al., 2019). Regardless unclear extent of government intervention in governing CASE, it is important to recognize that the introduction of new mobility cannot be independent of urban form and vice versa. Although, autonomous mobility will likely reduce transport infrastructure requirements such as fewer parking facilities and fewer street widths due to road capacity improvements. In parallel, large public investment will be required for the cost

of adapting infrastructure to catch up with new technologies during the development of AVs. Furthermore, the introduction of CASE will require subsidies to make public transport more attractive to gain public confidence in the multi-modal transport system, such as price incentives and the improvement of transit areas between transport modes. The four main characteristics of vehicle of the future under the CASE concept are fueled by technological breakthroughs to enable the emergence of new mobility systems. The technological breakthroughs are necessary to make CASE able to work with other urban infrastructures, covering integrated digital platforms, technology in urban infrastructure, and land-use densification planning.

First, the implementation of CASE is in line with the digital platform of the MaaS concept to offer door-to-door integrated travel solutions. The integrated digital platform is important to enabling cooperation and interconnection among multi-level actors of governance in urban transportation systems such as public authorities, public transportation providers, and private mobility providers (Jittrapirom et al., 2017; T. Cohen et al., 2017; Yigitcanlar et al., 2019). The integrated digital platform allows individual users to tailor their mobility plans from a collection of multiple transport service offers.

Second, the readiness of urban infrastructure will influence when autonomous vehicle platooning can hit the road. Autonomous vehicles notably require wide range of technologies in urban infrastructure transformation such as roadside sensors, machine-readable signs, lane markings, and connected telecommunications network infrastructure to ensure AVs' compatibility in street spaces.

Thirdly, the land-use densification planning can assure transport demand into collective transport systems with higher population density in transit node proximity and corridors (Duarte & Ratti, 2018). The flexibility of AVs could be used as the first- and last-mile feeder solution for passengers from outward distance areas to transit nodes with insufficient travel demand for mass transit service implementation.

Certainty, the urban visions are essential to shape the transition to the uptake of CASE. González-González et al. (2019) suggest that the need of policy in urban planning that consists of a principle mixed land-use orientation, improvement of urban facilities, vehicle access restriction zoning. It should be used as a foundation for participative governance in formulating policy options and creating understanding among urban stakeholders (Gavanas, 2019). Otherwise, the introduction of new mobility can be hastened or delayed by policy, regulatory, and planning practices (Grush & Niles, 2018b). Currently, the discourse on the impact of automation mobility technology toward city dynamics and urban development has been wildly discussed (Soteropoulos et al., 2019; Stead & Vaddadi, 2019). In parallel, the dependence how current urban geography, spatial setting, will influence the governance of CASE deployment have received minimal attention from previous scholars in autonomous mobility. The understanding of specific urban practices trajectories is important in decision-making for the early adoption stage. The reconsideration of the geography of urbanization and urban mobility system aim to shed light on how each city is likely to uptake CASE deployment that best fits their needs and values (Grush & Niles, 2018a). The idea relies on explaining the long-term feedback effect of the political process to what extent the institution helps generate a political coalition that works towards the continuation of the policy (Sorensen, 2006).

Whether we are ready or not, the new transportation technologies and the change of commuting habits will change our urban life. The divergence between slow institutional response to regulate and provide infrastructures during the rapid technological change is critical in technologies adopters like most Southeast Asia countries. Remarkably, the CASE concept is grounded and expected the positive effect within a context of long-term well-planned public policy (Adler et al., 2019).

Meanwhile, the capital cities in Southeast Asia are well recognized for their world-ranking traffic congestion problems and different traveling behaviors compared to cities with more advanced requirements for AVs such as the US, Europe, and Japan. Moreover, cities with underdeveloped infrastructures are challenged to prepare high-cost new infrastructures that incorporate the advancements of emerging vehicle technologies during the initial stage of introducing AVs. The existing underdeveloped infrastructures and urbanization problems in SEA metropolitan cities are questionable for the readiness of new vehicle technologies. A growing number of academic literatures on the integration of autonomous with multi-modal mobility in the Global South context is limited, especially in the Southeast Asia region. This research gap indicates the need for new related research to mitigate an insufficient theoretical contribution. Therefore, this research intends to serve as the stage zero study in the long-term implication of CASE in the context of the Southeast Asia mega-urban region. First, this paper sets the hypothesis that the lack of government intervention is likely to widen the divergence of technological advancements and sustainable urban mobility, as a result of less desirable societal benefits. Regarding uncertainty futures, this paper explored likely effects from path dependence in different the long-term implications of CASE using scenario building methods. Then, the discussion of robust strategies examines a set of interventions in governing CASE deployment.

### **3. Methodology and Data Collection**

Scenarios are a result of an intuitive estimate projection of how trends may affect the occurrence event (Helmer, 1977). The combination of scenario techniques is expected to enhance the optimum likelihood to find robust decision-making (Tiberius et al., 2020). Stead (Stead & Vaddadi, 2019) distinguished scenario development approaches into three approaches of exploratory, forecasting, and backcasting.

First, the exploratory approach illustrates a set of hypothetical future situations by focusing on a range of uncertainty factors and their complex interaction effects with each other. The critical uncertainties are identified through an inductive process by which the driving force has a high degree of impact and uncertainty level (Derbyshire & Wright, 2017). Second, the forecasting approach focuses on causality determinism (Dreborg, 1996; Geurs & Wee, 2004). The forecasting approach often adopts quantitative equilibrium-based modeling that generates a framework for comparative analysis, which depends on different assumptions in the model configuration (Soteropoulos et al., 2019). Lastly, the backcasting approach follows a prospective scenario as a desirable future and then identifies pathways back to the present. The anticipated pathways to the desirable scenario often required a participatory approach to collect a broad notion of social dynamics into account.

The interaction between AVs and the urban scene is inherently dynamic and affected by various endogenous factors such as socio-demographic, technology development, and social acceptance. Regarding the forecasting approach, comparative-static equilibrium modeling may be constrained in illustrating comprehensive scenarios for a broad understanding due to lack of endogenous factors and insufficient theoretical framework (Costa & Meyboom, 2018; Moeckel et al., 2018; Hawkins & Nurul Habib, 2019). Otherwise, the forecast model with incremental adoption technique is recommended using travel behavioral data from stated adaptation survey. But This modelling technique is data-hungry, which is a great challenge as well. Furthermore, the backcasting exercise is very complicated in translating collective views to tangible actions. Both forecasting and backcasting approach remain challenges in time limitation, resources constraints, and the

uncertainty of stakeholder involvement. Therefore, this study adopted an exploratory approach to explore plausible scenarios as the most suitable scenario development approach.

Since CASE definition is the enabler of different collective used AVs deployment solution. Besides, the focus on the CASE implementation scenario should not be considered a hard prediction (Fahey & Randall, 1997; Costa & Meyboom, 2018). Therefore, the framing upon the wide scope of AVs allows comparison of the potentials and challenges among different deployment solutions. The scenario building in this study area inevitably requires extensive fuzziness data. Combining the scenario technique with other trends reviewing methods is useful to funnel driving forces and uncertainties. This research proposes the novel mix methods to synergize multiple scenario buildings stages and find robust strategies in CASE deployment. The exploratory processes occur in three stages of scanning driving forces, identifying critical uncertainties with bibliometric analysis, developing plausible scenarios with cross-impact analysis, and identifying robust strategies with spatial analysis (Figure 3).

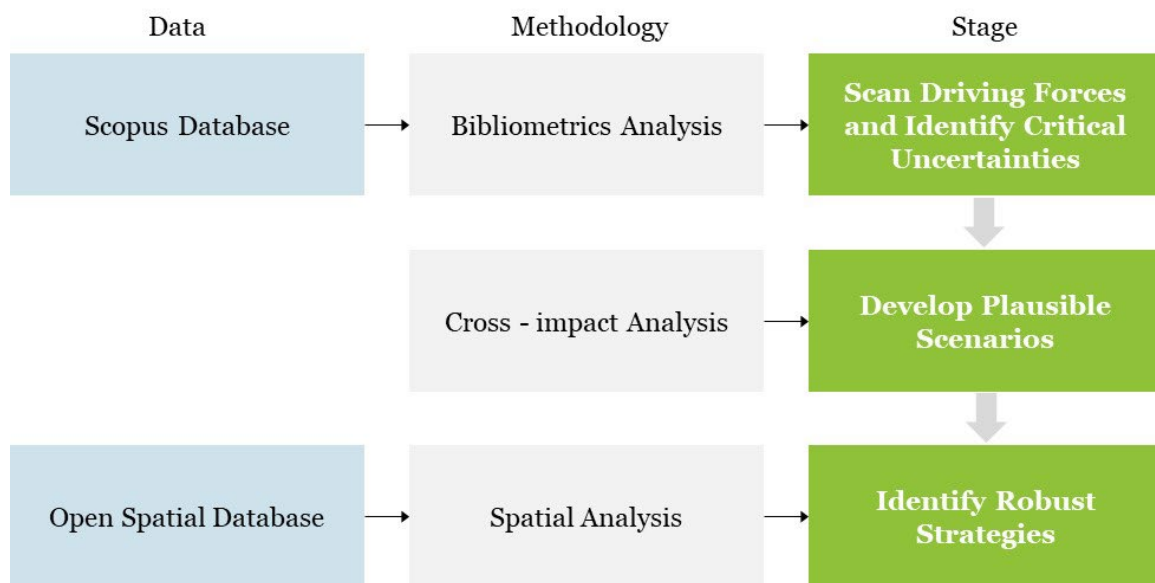


Figure 3 Research Methodology

### 3.1 Bibliometric Analysis

The scanning stage follows a quantitative text mining approach to scan driving forces, then identifies critical AVs adoption uncertainties. The bibliometric method was adopted to decode a range of research trends based on publications' meta data (publication title, year, authors' affiliations, abstract, author' keywords, journal, funding, and citation information). Keywords co-occurrence analysis is a suitable tool for extensive reviewing on research trends and cognitive structure of study areas using the author's keywords which is an important part that expresses the essential research content (Tripathi et al., 2018). The analysis adopted network clustering techniques. The cluster mapping conveys node and edge of keywords co-occurrence network. Nodes represent the frequency of occurrence of keywords. Edge represents the relationship strength of keywords' node pair from the number of publications in which both keywords occur together. The agglomeration of nodes and lines represents a cluster containing joint variations in response to unobserved latent variables.

The data is derived from the Scopus database using keywords and synonyms related to AVs (including autonomous vehicles, automated vehicles, self-driving, and driverless) through research keywords. The search was conducted in June 2021 and showed 50,142 academic publications. Next,

the screening process was performed to filter contents relevant to urban and policy dimensions. A Total of 2,721 publications were selected to perform keywords co-occurrence network analysis in VOSviewer software. Then, the filtering process is necessary to merge-common keywords of synonyms, singular and plural nouns, numeric characters, and acronyms to induce redundancy into a dataset. A threshold of 5 was applied to define the minimum number of co-occurred times the keyword appears in the documents.

The qualified co-occurrences keywords represent research hotspots, which are considered a driving force for implementing the new urban mobility with autonomous vehicles' features. The analysis follows the quasi-deterministic classifications approach provided in VOSviewer software that involves recursive decomposition output as an input to further decomposition at a next-lower level (Generating Clustered Journal Maps: An Automated System for Hierarchical Classification, 2017). The number of clusters has been initially determined into two and four clusters. The first round of processing considers a main-cluster lever, which aims to discover two critical uncertainties. The second time follows the hierarchical classification from the first round's decomposition to explore their sorts of paradoxes of critical uncertainties as a sub-cluster level.

Prioritizing and selecting critical uncertainties are preferable to form a scenario matrix with the extreme end of the spectrum for each one. The result of critical uncertainties selection can be either single or a cluster of high-impact driving forces that have a major impact on the future development paths and a high degree of uncertainty (Dean, 2019).

### **3.2 Cross-Impact Analysis**

The cross-impact analysis illustrates plausible futures by plotting two perpendicular axes. The scenarios are based on the keywords co-occurrence in bibliometric analysis. The characteristic of two prominent clusters is used to determine the critical uncertainty axis. Opposite pairs of critical uncertainties frame the scenario matrix as the polarity of the axis. Each axis is defined by polarized pair of critical uncertainties factors. The four-quadrant results show the collection of distinctly plausible scenarios, each based on a different combination of critical uncertainties factors. Each scenario contains a set of narratives, which explain a story for each scenario.

### **3.3 Spatial Analysis**

After the initial set of scenarios is determined, robustness measurement focuses on finding an optimum solution with an insensitivity performance across a range of plausible scenarios, which refers to the idea of minimizing the maximum regret (Lempert & Schlesinger, 2000; van Vliet & Kok, 2015). Spatial analyses are performed to find robust strategies for reconsidering the path dependence from a current urban mobility system. Spatial analyses consist of transit node accessibility analysis and street network capacity analysis, which were carried out using ArcGIS software and R software. The spatial data were derived from open sources of OpenStreetMap and PlugShare Portal.

First, the transit node accessibility analysis assesses the ability to reach different transport nodes. The accessibility measurement consists of the main two stage of network analysis and the cluster and outer analysis to visualize the accessibility disparity between collective versus individual transit nodes. Points of interest for collective transit nodes cover bus stops, metro stations, and regional train stations. The accessibility to individual transit nodes considers toll-way booths and charging EVs stations as points of interest. The methodology details for accessibility cluster analysis are provided in Appendix 1 - 3.



Second, structural analysis of the streets' network is very useful to understand the usage of transportation infrastructure (Hamaina et al., 2011; Kirkley et al., 2018). A streets' network is represented as a spatial graph comprised of nodes and edges. Structural analysis of the streets' network assesses street network flow capacity using centrality indices in graph theory algorithms. In this study, we focus on the betweenness centrality value, which represents a likelihood of busy path movement, and the prediction of congestion level on the given street segment (Freeman, 1977; Newman, 2010; Kirkley et al., 2018). The analysis of the connectedness of the street network was performed in RStudio software, an integrated development environment for R with SF and Tidygraph library.

#### 4. Scan Driving Forces and Identify Critical Uncertainties

The result of 195 co-occurrences keywords that passed the screening process from 2,721 publications. Figure 4 can be considered a simplified atlas of AVs development and urban dynamics, in which visualize how subdomains are also formed the relative relations among subdomains. The first round of generating the main-level cluster has roughly formed two clusters. The sub-level cluster mapping recurred decomposition outputs from the main-cluster level analysis into smaller classification.

Each sub-cluster name is coined by the meaning of the keyword's members of their particular cluster. Then, the name of main-cluster is determined by latent variables of prominent keyword nodes. The occurrences weight and total link strength information of the top 15 co-occurrences keywords were listed in Table 1.

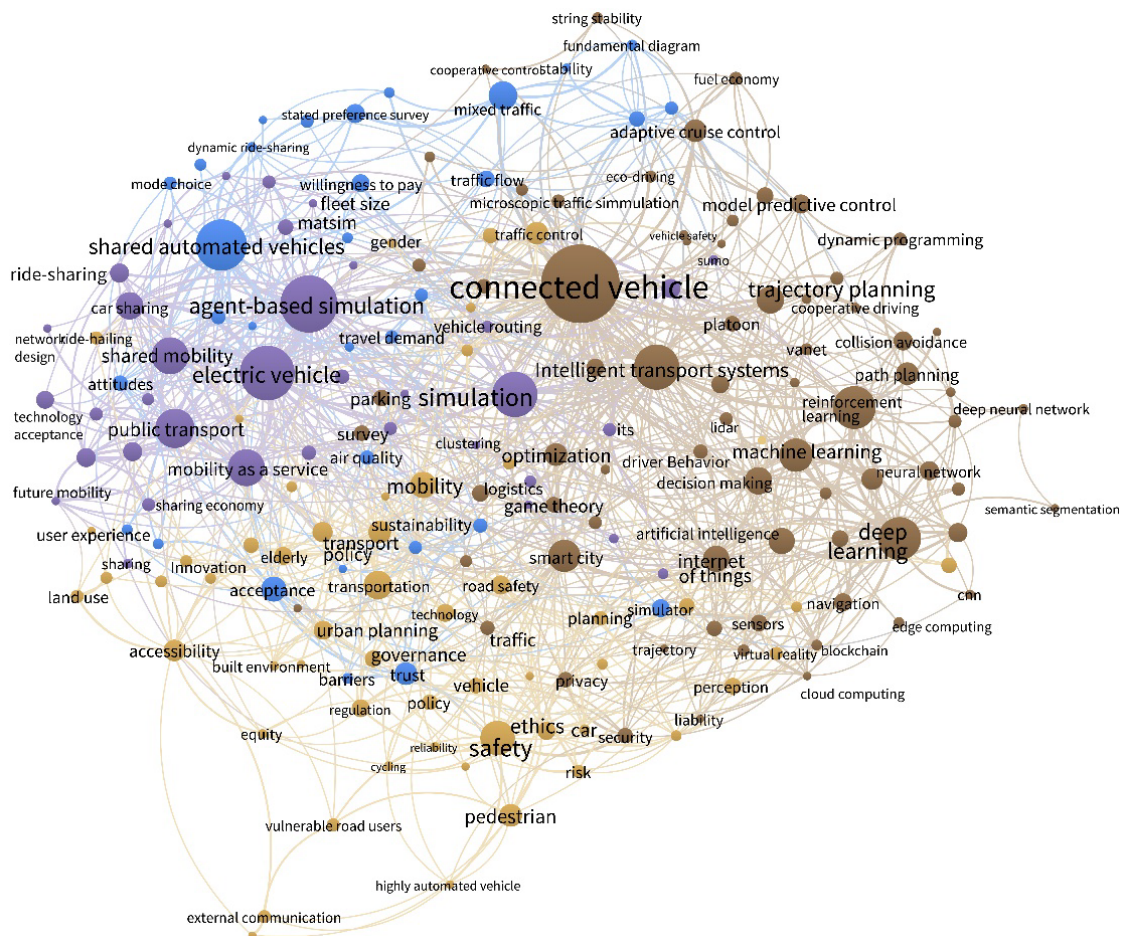


Figure 4 Keywords co-occurrence Clusters

Table 1 The occurrences weight and total link strength information of the top 15 co-occurrences keywords

Keywords	Occurrences	Total Link Strength	Keywords	Occurrences	Total Link Strength
<i>The Categories of Mobility Solutions</i>			<i>The Governance Approaches</i>		
<i>Transport supply and their consequences</i>			<i>Technology development and intelligent algorithms</i>		
<i>agent-based simulation</i>	103	123	<i>connected vehicle</i>	178	248
<i>electric vehicle</i>	97	149	<i>intelligent transport systems</i>	70	109
<i>simulation</i>	72	100	<i>deep learning</i>	66	75
<i>public transport</i>	56	61	<i>reinforcement learning</i>	66	69
<i>mobility as a service</i>	51	92	<i>machine learning</i>	43	64
<i>shared mobility</i>	50	86	<i>smart city</i>	41	66
<i>car sharing</i>	32	48	<i>decision making</i>	32	44
<i>ride-sharing</i>	18	27	<i>intersection management</i>	32	42
<i>sustainable mobility</i>	18	40	<i>artificial intelligence</i>	28	48
<i>multi-agent systems</i>	17	26	<i>internet of things</i>	28	64
<i>urban mobility</i>	17	29	<i>adaptive cruise control</i>	23	28
<i>technology acceptance</i>	15	13	<i>optimization</i>	22	39
<i>matsim</i>	13	26	<i>path planning</i>	22	19
<i>pricing</i>	11	14	<i>motion planning</i>	21	30
<i>user acceptance</i>	11	14	<i>collision avoidance</i>	18	15
<i>Transport demand and social acceptance</i>			<i>Policy Tools and Governance</i>		
<i>shared automated vehicles</i>	88	109	<i>safety</i>	46	77
<i>mixed traffic</i>	33	40	<i>transportation</i>	33	65
<i>acceptance</i>	26	24	<i>mobility</i>	28	57
<i>trust</i>	23	19	<i>pedestrian</i>	23	23
<i>stated preference survey</i>	17	16	<i>sustainability</i>	22	42
<i>willingness to pay</i>	15	20	<i>traffic control</i>	22	26
<i>simulator</i>	15	13	<i>accessibility</i>	20	26
<i>traffic flow</i>	14	29	<i>transportation policy</i>	19	33
<i>car-following</i>	13	26	<i>road safety</i>	18	26
<i>attitudes</i>	12	19	<i>urban planning</i>	18	28
<i>air quality</i>	11	18	<i>elderly</i>	15	19
<i>travel behavior</i>	11	19	<i>ethics</i>	15	23
<i>vehicle automation</i>	11	13	<i>regulation</i>	15	25
<i>travel demand</i>	10	17	<i>governance</i>	14	20
<i>congestion</i>	9	18	<i>perception</i>	14	30

## 4.1 The Categories of Mobility Solutions

The main-level cluster on the left side consists of 68 co-occurrences keywords (Figure 4). The discussion on shared mobility has caught the research interest as expected, as seen in the central nodes of the cluster. The agglomeration pattern of this cluster indicates two different patterns of a large densely clustered in the middle and a scattered pattern of small keyword groups. The prominent node group represents a mobility solution-related issue.

The purple cluster consists of 36 co-occurrences keywords, in which "agent-based simulation", "electric vehicle", "simulation", "public transport", and "mobility as a service" are ranked as the top five occurrence keywords respectively. Keywords in this cluster mainly concern on transport supply of autonomous mobility and their consequences.

The blue cluster shows a moderate cluster size with 32 co-occurrences keywords. The co-occurrences' keywords "shared automated vehicles", "mixed traffic", "acceptance", "trust", "stated preference survey", "willingness to pay" are over-represented as a predominant node. The cluster member's character reflects the discussion on Transport demand and social acceptance.

The large AVs and transport supply cluster is encompassed by a scattered pattern of small keywords from the transport demand cluster (Figure 5). This pattern captured research trends in the impact of different deployment models and social acceptance. The booming research interest on the battle between private motorized transport versus collective transport and its societal impact reflects a tremendous uncertainty in urban mobility, which will remain unknowable until years after commercialization. Therefore, the first critical uncertainty is determined by the categories of mobility solutions.

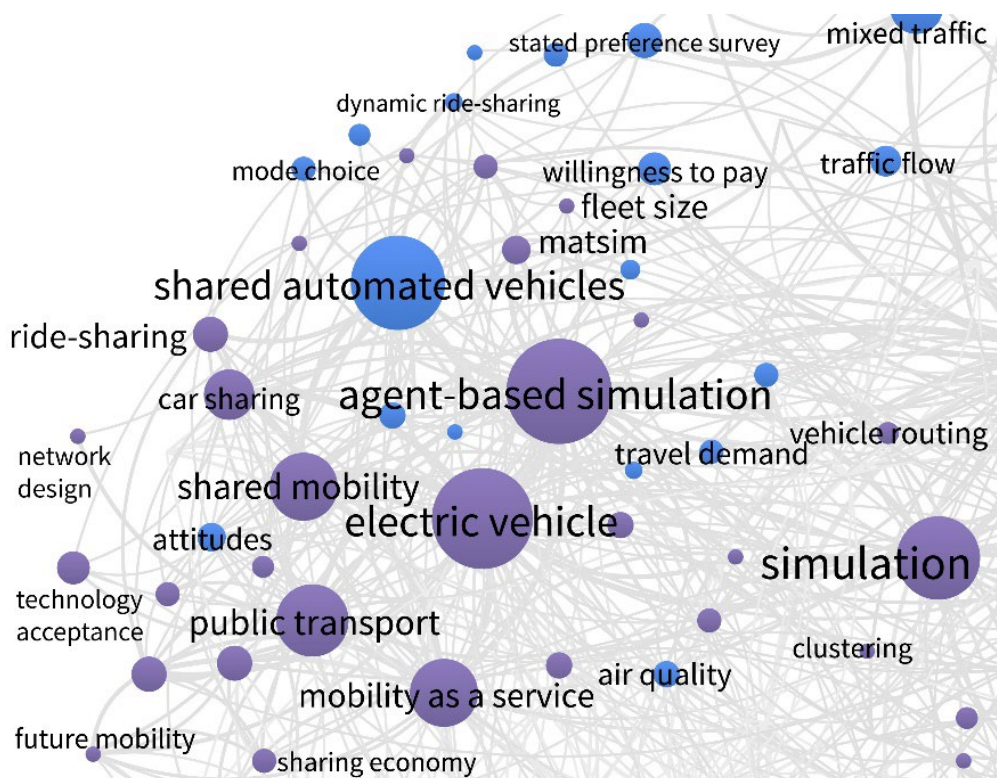


Figure 5 Highlight of top high link strength keywords in the categories of mobility solutions cluster

## 4.2 The Governance Approaches

The main-level cluster in brown color consists of 127 co-occurrences keywords. Keywords are aggregated in clumped dispersion pattern of research interests in governance-related keywords and technology-related keywords. The "connected vehicle" keyword appears as the largest node, which is encompassed in the middle triangle between a group of governance topics and a group of technology topics.

The brown cluster consists of 72 co-occurrences keywords. The top five frequently used keywords for this cluster are "connected vehicle", "intelligent transport systems", "deep learning", "reinforcement learning", and "machine learning". The cluster contains keywords with a clear meaning that are associated with technology development and intelligent algorithms topics.

The yellow cluster shows 55 co-occurrences keywords, in which "safety", "transportation", "mobility", "pedestrian", and "sustainability" are ranked as the top five occurrence keywords respectively. Overall, this cluster discusses policy tools and governance topics.

One undeniable trend is that the AVs technological development will be accelerated due to the intensity of competition within and between innovation ecosystems (Giannopoulos & Munro, 2019). However, increasing competition does not always mean more innovation. Drawing on the inverted-U shape effect in the neo-Schumpeterian growth model by Aghion et al. (2005), innovation rises and aligns with the level of competition and then eventually falls as the intensity of competition increases. Griffith and Reenen (2021) suggest the importance of competition policy to stimulate innovation-based growth, promote inclusiveness, and prohibit market power abuse by dominant firms.

Despite intelligent AV algorithms, this cluster's pattern captures the importance of connectivity issues across different research fields. Connected vehicles require a whole new supporting technology infrastructure as part of a transport network in high-speed mobilizing vast amounts of data received and processed. Whereas, connected car development poses a threat in data-security risks issues, which is why pressure on government actions in a timely manner is increasing to create new infrastructures and establish appropriate standards for communication.

Keywords that are related to governmental tools appear as "transport policy", "urban planning", "accessibility", and "land-use". The list of keywords reflects the importance of spatial planning policies requiring interdisciplinary expertise, especially in engineering and social sciences (Figure 6). Deploying autonomous mobility has explicitly spatial consequences. Unsurprisingly, the keyword "smart city" was also appeared as the top frequently used keyword and its position in the center between clusters. Indeed, this concept bridges technological and innovative governance disciplines to enable cities to confront urbanization challenges.

Although, the current AVs adoption and their impacts predictions vary wildly. The development of AVs remains persistently state of the art from test areas to streets. In parallel, the challenges are how responsible governments at all levels acknowledge their extent, which is complex and widely impacts social issues. How each city uptake the AVs and its consequence will be up to the government to sort out policy pathways and at what timing. Therefore, the polarization of governance approach is selected as the second critical uncertainty to explore different policy pathways, which cover private-led versus public-led approaches.



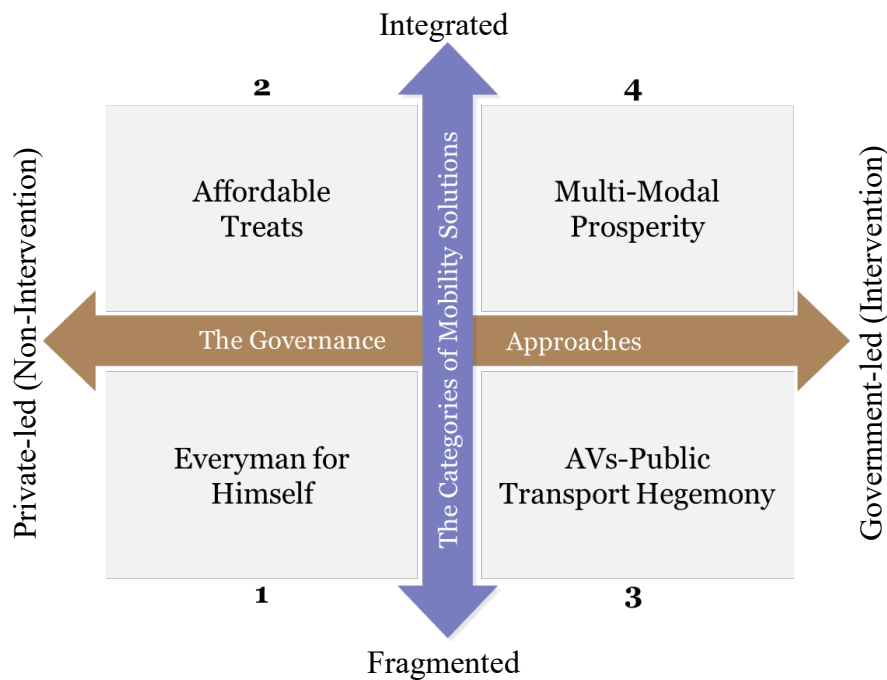


Figure 7 Quadrants of plausible scenarios for the development of AVs

### 5.1 Scenario 1: Everyman for Himself

This scenario assumes that governments stay idle or ignore growing technological trends. The great infrastructure requirement does not take place to catch up with new mobility technologies. There might be a certain private investment in infrastructure for automated driving. Traditional public transport is still operated and becomes less attractive compared to new autonomous vehicles and digitalized transport services

Every man for himself attitude leads to tautologies of the car dependency cycle, which prioritizes private cars and some AVs and EVs adoption. AVs can reduce travel time value by enabling commuters to choose flexible activity choices during their trips, resulting in a willingness to travel long distances. Then, urban sprawl problems will be stimulated by relocating households from dense inner-city areas to more affordable outer areas.

The majority of sprawling areas will be dispersed low-density areas, which may lack of mass transit services. The future of mobility in urban cities is under the pressure of mass uptake in private motorized transport. The individual travel demand will increase and overflow a road capacity to increase traffic congestion and inadequate taxi service eventually. The net effect will increase total VMT, which contrasts with the global gas emissions reduction (Anderson et al., 2016). This exclusive deployment scenario could fuel transportation fragmentation and fail to maintain social equity in urban transportation.

### 5.2 Scenario 2: Affordable Treats

The government interventions also remain absent. The integration of mobility solutions has remained constraint to established interoperability and shared value between private companies and transport authorities. Since the mobility services by private providers usually have a clear focus on market orientation. In contrast, the latter of public transportation depends on public subsidy, represents social welfare, and less profitable orientation.

In this scenario, shared mobility service becomes the predominant transportation solution, which will be operated as private property. Shared vehicles in fleet mobility services are expected to be more affordable, convenient, and attractive to a mass of users. MaaS service itself is only a platform with commercially viable, which plays a role as an aggregator of multiple offers from transport service providers rather than its role in interconnecting multi-modal journeys. MaaS providers will invest in technology and IT solutions more essential and not in charge of infrastructure improvement.

An integrated mobility solutions schematic provides options for commuters to various shared AVs mobility services; ride-hailing option and ride-sharing option. The ride-sharing services cover both forming carpool companions and introducing driverless shuttles as a small-size buses within limited-service areas. The marriage of privately shared mobility systems and digitalized MaaS mobility service offer affordable door-to-door automation mobility services, which will challenge ubiquitous private car ownership. The trip's flexibility and convenience significantly slow modal share and eventually reduce public transport demand.

Without planning policy, the shared mobility-on-demand service could only flourish within dense urban areas with sufficient travel demand. For suburban areas with poor street networks, a taxi station may be required to expand service areas and reduce waiting time. However, this challenges feasibility issues since cars have to sit idle most of the time (Grush & Niles, 2018b). Moreover, the distance-based dynamic pricing strategy in mobility on demand will be the key factor in determining the cost of the trips and, eventually, the impact on willingness-to-pay for SAVs. This scenario tends to fail on mitigating urban sprawling problems, like the first scenario. In a city with inadequate public transit systems, a demand on private ownership may be reduced, but little life luxuries and convenience like on-demand mobility services will be remained to make life worth living regardless of suffering from poor public transport services.

### **5.3 Scenario 3: AVs-Public Transport Hegemony**

The division between private and public transport would remain strong. The predominant mobility service will be operated and owned by public authorities. Governments play functions as a single leading player in promoting CASE covering supportive policies implementation, advanced infrastructure development, and service provider. The investment and operation draw different agencies to work together, such as local planning and local transportation agencies in planning, building, operating, and maintaining. The decentralized governance approach is important to allow local and regional governments to acquire authority financially.

The advent of autonomous vehicles induces a transformation of public transportation from massive fleets of transit vehicles with fixed schedules to a micro-transit fleet as described in the "transit leap" concept by Grush and Niles (2018b). The transit leap concept intends to promote social equity in transportation and overshadow a threat from reducing public transit usage due to door-to-door mobility-on-demand service. The public AVs shuttle bus is designed to close first and last-mile gaps to major public transport nodes using medium-size automation vehicles, wandering along neighborhood areas with flexible schedules.

The proactive planning policies are important to deal with urban form changes from the disruptive potentials of AVs and ensure transport demand in collective transport systems. A game-changer in urban planning is associated with various land-use implications, covering revitalizing inner areas with urban renewal, curbing the growth of urbanization with subcenter densification, and reclaiming spaces from former parking areas and roadway width reduction. Further regulations may introduce, such as housing incentive programs and road pricing.

The challenges remain as a gap widening by the different institutional structures. Some local and regional governments do not have enough authority capacity and budget to operate significant investments. Large public investments without public-private partnerships are likely to stifle innovation development due to complex institutional hierarchies, multi-layer formal rules, and lack of economic orientation (Sørensen & Torfing, 2012). Nonetheless, the government hegemony approach is inconsistent with the fundamental of an open market and democratic society.

#### **5.4 Scenario 4: Multi-Modal Prosperity**

The scenario represents a combination of a public-led governance approach with integrated mobility systems. Governments play an active role in promoting AVs' uptake through supportive policies, advance infrastructure development, and initial in setting up public-private partnerships. The government interventions in land use planning are similar to scenario 3. The importance is to balance policy tools adoption for social equity promotion and maintain profit-orientation management. Mobility services by private providers will be assimilated to integrated mobility systems, which can alleviate government risks and burdens in delivering mobility services. Private actors play a role in delivering innovative mobility solutions for public services. This approach allows the competitive on fleet operations with a transparent public performance goal (Grush & Niles, 2018b).

The CASE model refers to multi-modal shared mobility in this scenario, consisting of mass public transit systems, shared automation mobility, and micro-mobility. The connectivity is an essential component and force that allows CASE deployment to flourish. The inter-organizational collaboration approach could allow an open innovation process, which is essential in robust decision-making (Saradini et al., 2018; G. Smith et al., 2019). Public transport is prioritized as the backbone of urban mobility (Papa & Ferreira, 2018; Stead & Vaddadi, 2019). The shared automation mobility supports first or last-mile transportation, which could enhance mass uptake of public transit in areas outside accessible areas to public transit nodes. Moreover, the integration with micro-mobility modes may positively promote more localized and healthy lifestyles from walking, cycling, and using a scooter (Marsden & Reardon, 2021). The personalized mobility configuration can carry out through the MaaS platform with seamless coordination among different public and private mobility service providers.

## **6. Identify Robust Strategies**

Identifying a robust strategies process is important to develop a decision-making framework that is adaptable and effective to different plausible scenarios (Hallegatte, 2009; Alizadeh et al., 2016; Grush & Niles, 2018a). The cities with underdeveloped infrastructures are challenged to prepare high-cost new infrastructures that incorporate the advancements of emerging vehicle technologies during the initial stage of introducing AVs. Indeed, the capital cities of Southeast Asian countries are confronting a long period of urban problems in traffic congestion and inadequate public transportation. Bangkok and Ho Chi Minh have been selected as a case study as the Southeast Asia mega-urban regions and prospects mega-urban regions by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. The study areas cover metropolitan areas to capture the growth of mega-urban regions and the extent of the city's commuting zone, composed of the urban areas and its surrounding areas.

### **6.1 Scenarios Comparison and Path Dependence of urbanization**

Scenarios Comparison considers what is likely to happen from path dependence of urbanization to different scenarios, based on the synthesis between spatial analyses' results and the



assumption of character in different AVs deployment models. Regarding the literature review, the study assumes that an individual AVs model of PAVs and rail-hailing service in SAVs will stimulate car dependency for those individuals who live in limited accessibility to public transit nodes. The ride-sharing in SAVs model such as the AVs shuttle bus could fill a gap of the service area as a neighborhood feeder to a trunk line of public transportation. The AVs shuttle bus prefers a road segment in a collective road to pass through slow streets and emancipate from high-speeding motor traffic (Tsigdinos et al., 2021).

## ***Bangkok***

In Figure 8, the betweenness centrality measurement results in a lack of street network hierarchy and geographically skewed movement flow. The accessibility to transit nodes analysis shows inadequate public transportation service areas coverage. The synergic association of network connectedness and accessibility results confirm the dichotomy between the outer layer with a ribbon pattern and the inner layer with a capillary pattern, as described in Appendix 4 - 6.

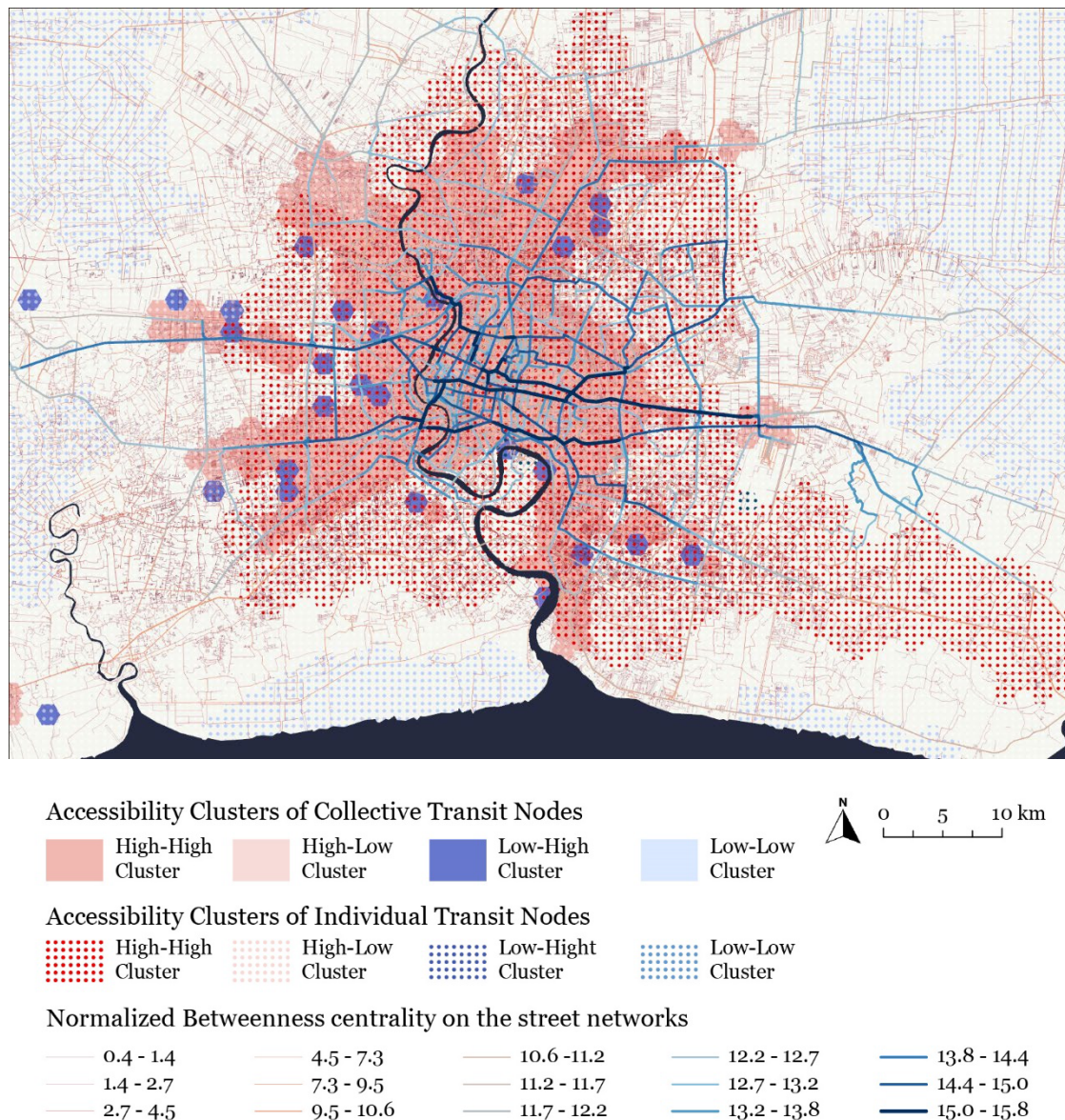
The urban core areas are piled up with positive attributes to promote multi-modal mobility, including a smaller street block with various choices of transit modes. Moreover, the railways pattern itself reveals a complete ring-radial urban rail transit network, which benefits linking commuters from the outsides to the city center and ensures better connectivity with alternative routes to reach the destination. However, many railway tracks run parallel to a road where the rails are embedded in the existing roadway. Thus, different transport modes on parallel routes become competitors to attract passengers as a preferable route choice (Pujinda & Yupho, 2017). This is critical to promote mass transit railway as the backbone structure of an integrated mobility system.

Highways and arterial roads frame a gigantic grid of an outer street block. The gigantic blocks divide urban activities into polycentric agglomeration along the trunk lines. Bangkok's polycentric urbanization pattern could promote the urban subcenter densification model, which is good for ensuring transport demand for the first and last-mile transit feeders. However, most inner-block areas have inadequate areas of lower street hierarchy and causes a bottleneck traffic congestion. Regarding the accessibility radius, the internal areas of urban superblock become a blackhole for public transportation service areas. The synchronized action between inner and outer is essential for the accessibility improvement to overcome a ribbon development orientation.

After decades of rapid urbanization, the growth of middle classes is more likely to move to suburbs, as a result, the number of gated communities is rising strongly. Expanding gated communities hinders the city and society by limiting public access. The spatial pattern of gated communities can be seen on dead-end or tortuous local streets. The idea of privatization fuels difficulties finding optimization of spatial structure and promoting collective autonomous transportation approaches.

Therefore, Bangkokians have been normalized to invest in private vehicles. Informal transportation becomes the indispensable mobility solution for those without personal cars as feeders to mass transportation systems, covering a pick-up truck mini-bus (Song Thaew), a three-wheel motorcycle taxi (Tuk-Tuk) and a motorcycle taxi. However, the government does not fully cover the informal public transport services in mobilizing regulations, fare control, and route operations. The quality and the safety level of these services remain substandard services. Meanwhile, the informal mobility's average commuting costs are higher than the average cost of conventional public buses (Ratanawaraha & Chalermpong, 2016). Long waiting for mobility-on-demand will become common in Bangkok due to a lack of street network hierarchy, bottleneck traffic congestion, and high demand from an individual from gated communities. Thus, a robot taxi

station is important to reduce waiting time length. Despite peaks time, the car may stay idle most of the time, which is questionable on ensuring transportation equity.



*Figure 8 The Summarize of Spatial Analyses of Accessibility Cluster and Street Networks in Bangkok*

## Ho Chi Minh

In Figure 9, Ho Chi Minh has a well-connected street network with good density in urban areas with a smaller metropolitan size. A pattern of high-density street networks and fine-grained urban fabric in urban cores may be associated with the European-style block planning from the colonial periods (Yue et al., 2021). The accessibility analysis to transit nodes shows the outstanding bus service accessibility (see Appendix 7). There are over a hundred bus routes with highly frequent schedules. However, the destined routes are not the most direct route.

Meanwhile, the other public transport modes are under development to enhance connectivity on an inter-urban scale. Ho Chi Minh is under the first developing stage of metro lines.

The regional train station represents the regional connection. The tollway development is recently added to road networks in the mid-2000s (see Appendix 8 - 9). Moreover, the EVs charging station's introduction has not become popular yet.

By far, personal motorbikes are the current primary transportation mode in Ho Chi Minh because they are more affordable and have lower operating costs than personal cars. Compared to other public transportation modes, people are willing to pay more for minutes reduction of travel time by motorcycles due to its convenience for door-to-door trips (D. C. Nguyen et al., 2019). Ho Chi Minh has the largest share of motorcycles nationwide, with 15% in 2010 and continuously increasing (Huu & Ngoc, 2021). The result of the street networks pattern also reveals the consistent between motorbikes mode with the urban morphology. The fine-grain street pattern can create a better flow movement pattern. Their small size has a maneuverable and flexible feature, allowing motorists to move between lanes and move along space between cars during traffic congestion.

Ho Chi Minh has been transitioning from monocentric to polycentric in the last decade (A. M. Nguyen, 2015; Ton, 2020). The growth of peri-urban areas is rapidly expanding due to large-scale development projects towards areas previously characterized as former agricultural areas. The large-scale development projects result from the new development of industrial zones, which aims to draw foreign investment (Kontgis et al., 2014). The new industrial zones will attract the migration of blue-collar workers. This factor will significantly impact travel behaviors shaped by land use transformation, economic activities, transportation, and housing.

The existing spatial characteristic could be efficient with multi-modal mobility. The benefits cover the trip generation, more affordable with short duration ride, potential to have fewer trips with an empty car. However, the currently available public transit mode (only bus) is challenging to increase transport demand in shared mobility and compete with massive penetration of private motorcycles. Lastly, the challenges remain in expanding and connecting to the upcoming development zones surrounding urban core areas to avoid repetitiveness to the ribbon orientation like Bangkok.

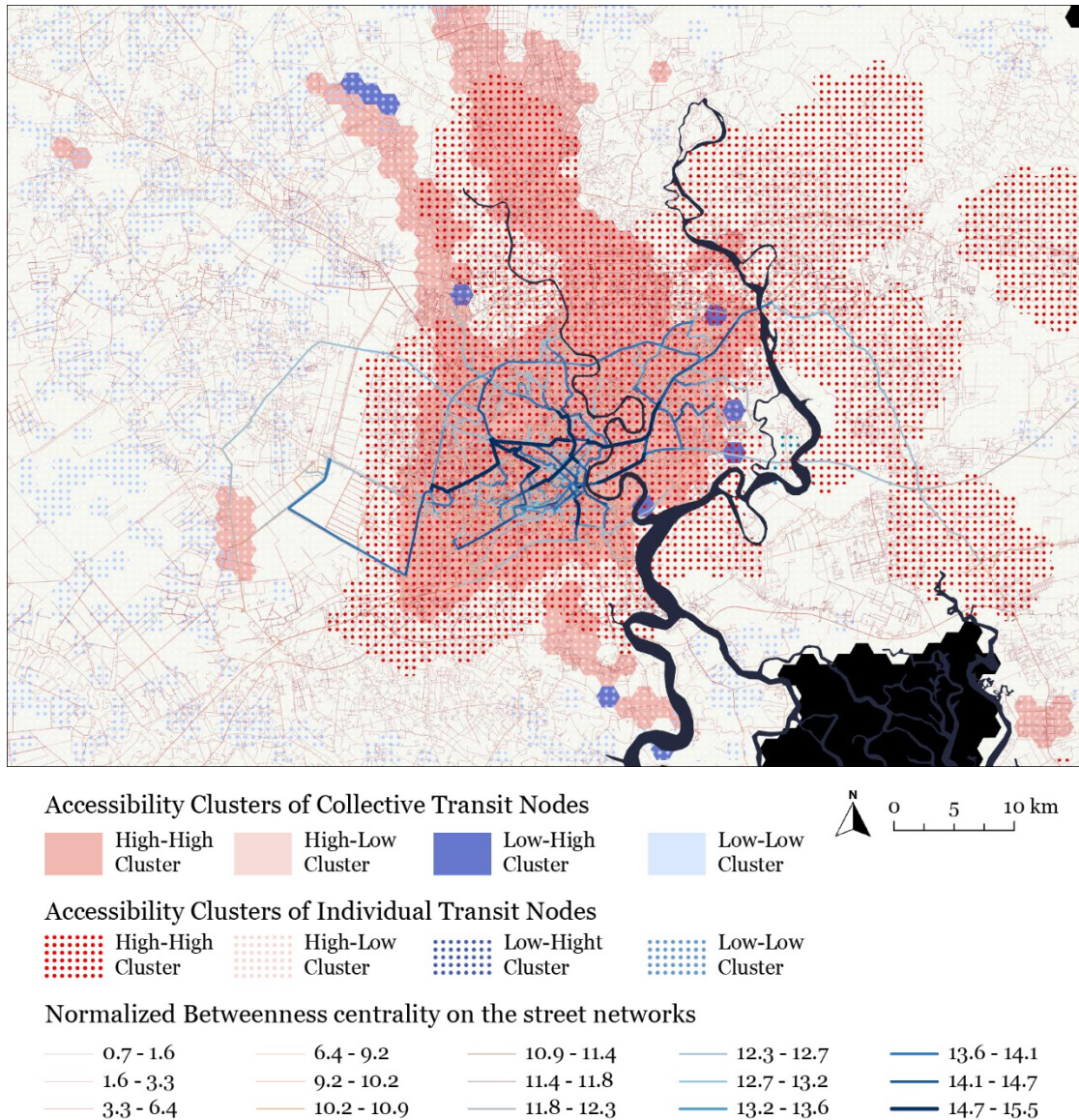


Figure 9 The Summarize of Spatial Analyses of Accessibility Cluster and Street Networks in Ho Chi Minh City

## 6.2 Proposed Strategies to Ensure a Robust Performance of CASE

The discussion on urbanization problems of mega-urban regions in SEA context captures additional challenges from an extra layer of informal transit mode and gated communities compared to the Global North context, in which the number of research is limited as well as a lack of richness of data that are important in decision making for the early adoption stage. The synergic between quadrant scenarios and path dependency of urbanization sheds light on long-term strategies planning requirements in response to different autonomous mobility deployments. Indeed, the disruption by AVs will be on various dimensions of social, economic, and environmental. Therefore, the reaction of anticipatory governance will be unavoidable due to the need for public democratic discussion. The intensity level of government intervention remains a matter in balancing the degree of freedom in markets and ensuring public interests.

The introduction of autonomous mobility and the expansion of ICT will stimulate the spreading of city areas undergoing a spatial agglomeration within large urban regions. Preimus and Hall (2004) indicated that strengthening the urban network and regional level to deal with the increasing scale of housing markets, labor market, and mobility. The listed implications cover the increasing scope of urban planning beyond the city borders, strengthening accessibilities of urban cores and subcentres, and promoting interoperability in personal mobility and freight transport. It is clear that comprehensive urban-regional planning and governance networks are important in promising CASE adoption. The governance actor should consider multi-level governments of local and regional levels in the metropolis and neighboring cities, private sectors, and communities. This research recommends participatory planning as the essential tool to define what best fits place-based social needs and common values.

In the context of uncertainty, the implications could branch into a broad spectrum of the action plan. Initially, this research proposes scenario-based robust strategies underlying the idea of minimizing the maximum regret. The proposed robust strategies involve building seamless user experience, encouraging the attractiveness of public transportation, and enhancing social acceptance of autonomous ride-sharing and multi-modal transportation through four applicability of government interventions as follows.

- **Public Rights-of-Way:** The allocation of public rights-of-way such as dedicated lanes, curb space, and parking aims to overcome mixed traffic situations. Local authorities should provide public rights-of-way for shared autonomous mobility operators such as AVs shuttle buses to ensure the efficiency of vehicle operation, safety, congestion, and equity implications
- **Incentive Zoning:** Urban densification strategies are essential to fasten adoption rates of CASE by giving developer incentives for the inclusion of collective autonomous mobility (A. Cohen & Shaheen, 2016). First, AVs are expected to consume fewer parking areas in the city. The reclaiming of parking areas introduces the reduction of the minimum parking ratio requirement in exchange for parking space for the AVs-sharing program. In parallel, the lesser private parking space availability could induce people to use more shared mobility. The substitution of parking space allows increasing density as well as increasing of accessible green areas for the public in exchange for a greater floor-to- areas ratio bonus. The densification schemes can be seen as a way of promoting quality of life in cities which eventually assure transport demand in collective transport systems.
- **Taxation:** The taxation policies could expand collective autonomous mobility as a tax-deduction program in claiming transportation costs with a mobility subscription model, which the CASE and MaaS operate. The tax incentive strategies could encourage commuters to use app-based mobility services and influence energy efficiency in the city.

## **7. Conclusion**

The main purpose of this research is to explore different policy pathways in the long-term implication of CASE in the SEA mega-urban region. This study focuses on ubiquitous self-driving mobility with optional human attention, which is in line with level 4 and above. Bangkok and Ho Chi Minh City have been selected as case studies due to their urban dynamics of rapid expansion of urbanization areas. This research proposes the novel mix methods to synergize multiple scenario buildings stages and find robust strategies in CASE deployment. The exploratory processes take

place in three stages scanning driving forces and identifying critical uncertainties with bibliometric analysis, developing plausible scenarios with cross-impact analysis, and identifying robust strategies with spatial analysis

The quadrant scenarios are based on critical uncertainties derived from quantitative text mining in bibliometric analysis. The first axis is the categories of mobility solutions. This axis covers integrated versus fragmented mobility solutions. The second axis is governance approaches. This axis covers the government intervention versus the non-intervention approach. Then, plotting two perpendicular axes produces four quadrants, covering everyman for himself scenario, affordable treats scenario, AVs-public transport hegemony scenario, and multi-modal prosperity scenario. Overall, government and political commitment are important to ensure public benefits from the early adoption.

However, these quadrants scenarios discuss plausible scenarios only at the general level regardless of a place-specific context. Identifying a robust strategies process is important to develop a decision-making framework that is adaptable and effective to different plausible scenarios that best fits the Southeast Asia mega-urban regions context.

The reconsideration of the current urbanization and urban mobility system in spatial analyses highlights a long path dependence of the absence of government intervention, weak transportation network, and lack of accessibility to public transportation. These inherent problems of weak transportation networks would be highly likely to follow the exclusiveness scenarios that could fuel ignorance of CASE adoption and continue the high penetration rate of private transport.

In contrast, the inclusive scenarios assume the great government intervention to promote public transportation and the shared automation mobility as the backbone and the feeder for the first and last-mile transit, respectively. Moreover, the integration with MaaS is important to deliver a seamless user experience on personalized mobility plans and fare payments. Promoting the decentralization governance approach is important to strengthen local mobility governance efficiency in local mobility improvement and become the innovation-based incubator and accelerator for local and small micro-mobility providers to adapt to the AVs technologies.

The discussion on urbanization problems of mega-urban regions in the SEA context captures additional challenges from an extra layer of informal transit mode and gated communities compared to the Global North context. Both cities highlight the importance of feeder mobility improvement and completing the transportation network standard. Bangkok can develop an urban subcenter densification model due to the existing polycentric urban pattern to ensure travel demand for the multi-modal approach and curb urban sprawl spreading. The synchronized action between inner and outer is essential for the accessibility improvement to overcome a ribbon development orientation. In Ho Chi Minh, the existing spatial characteristic is concentrated with high-density urban morphology and could be efficient with multi-modal mobility. However, the challenges remain in expanding and connecting to the upcoming development zones surrounding urban core areas to avoid repetitiveness to the ribbon orientation like Bangkok.

Indeed, the reaction of anticipatory governance will be unavoidable due to the need for public democratic discussion. This research recommends participatory planning to develop comprehensive urban-regional planning considering multi-level governments of local and regional levels in the metropolis and neighboring cities, private sectors, and communities. Initially, this research proposes scenario-based robust strategies underlying the idea of minimizing the maximum regret covering public rights-of-way, incentive zoning, and taxation strategies.

Further research may consider combining individual-level data and simulation modeling to forecast the most robust decision-making following the quadrant scenarios framework. The individuals' level's primary data, such as the stated adaptation survey, is important to understand travel behavior and social acceptance towards different autonomous mobility deployments.

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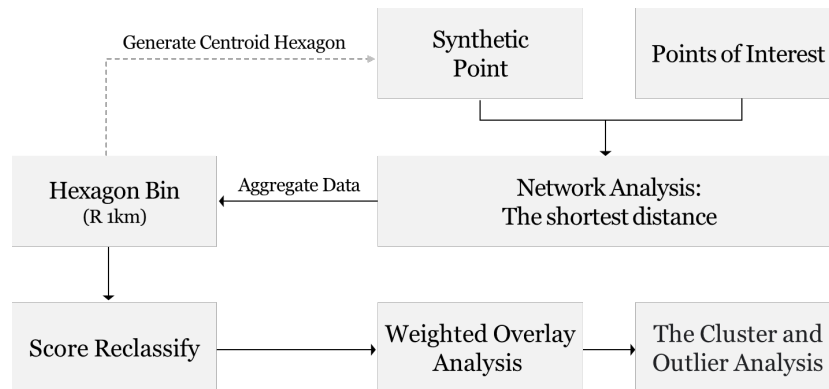
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## Appendices

### Appendix 1. Methodology for Accessibility Cluster Analysis



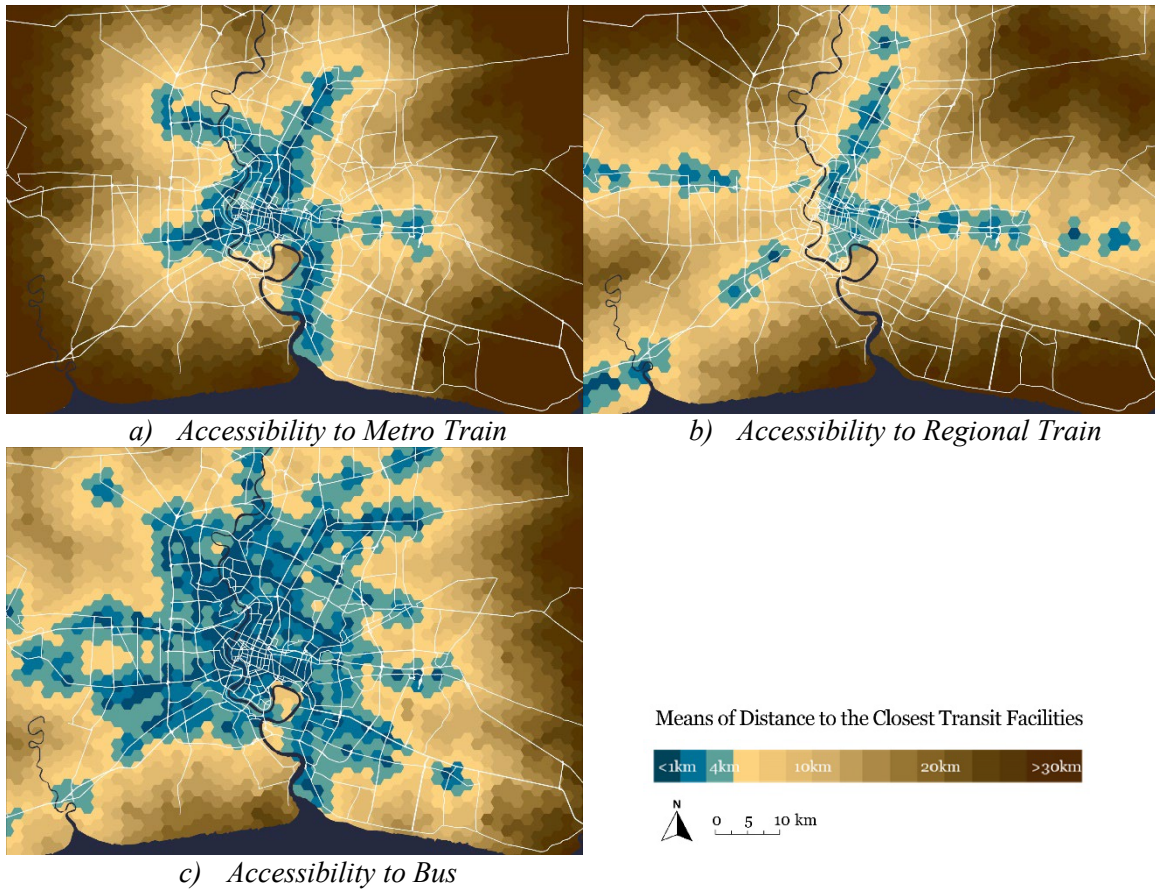
### Appendix 2. Criteria for the Score Calculation in Weighted Overlay, Based on Distance to Collective Transport Nodes

Score	Distance (km)	Walking (mins)	Bike (mins)	Car (mins)
10	$\leq 0.4$	5.0	1.2	0.6
9	$0.4 > x \leq 0.8$	10.0	2.4	1.2
8	$0.8 > x \leq 1.6$	15.0	4.8	2.4
7	$1.6 > x \leq 2.4$	20.0	7.2	3.6
6	$2.4 > x \leq 3.3$	25.0	10.0	5.0
5	$3.3 > x \leq 5.0$	30.0	15.0	7.5
4	$5.0 > x \leq 6.3$	35.0	18.8	9.4
3	$6.3 > x \leq 7.5$	40.0	22.5	11.3
2	$7.5 > x \leq 8.8$	45.0	26.3	13.1
1	$8.8 > x \leq 10.0$	50.0	30.0	15.0
0	$> 10.0$			

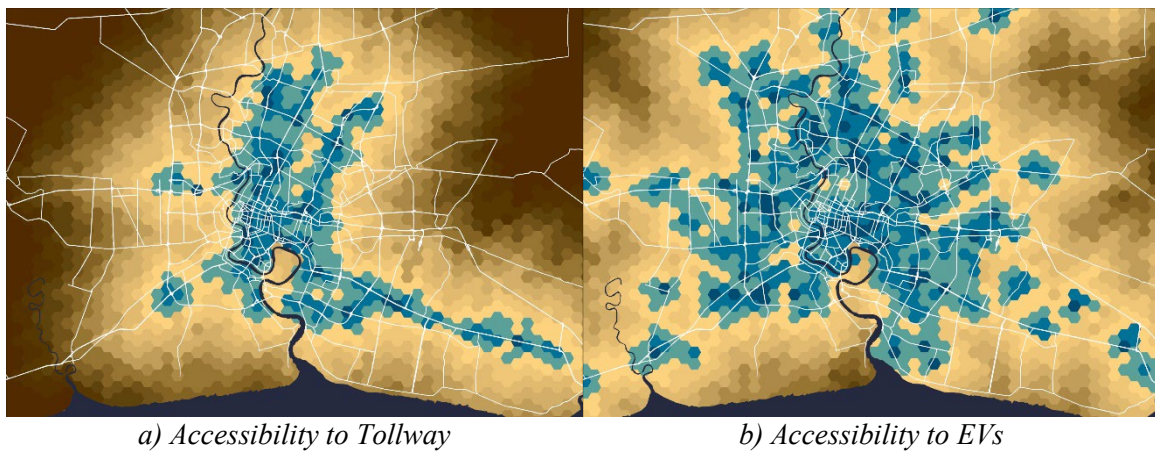
### Appendix 3. Criteria for the Score Calculation in Weighted Overlay, Based on Distance to Individual Transport Nodes

Score	Distance (km)	Car (mins)
10	$\leq 1.3$	2.0
9	$1.3 > x \leq 2.7$	4.0
8	$2.7 > x \leq 4.0$	6.0
7	$4.0 > x \leq 5.3$	8.0
6	$5.3 > x \leq 6.7$	10.0
5	$6.7 > x \leq 8.0$	12.0
4	$8.0 > x \leq 9.3$	14.0
3	$9.3 > x \leq 10.7$	16.0
2	$10.7 > x \leq 12.0$	18.0
1	$12.0 > x \leq 13.3$	20.0
0	$> 13.3$	

Appendix 4. Accessibility to Collective Transit Nodes in Bangkok



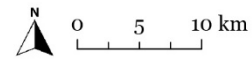
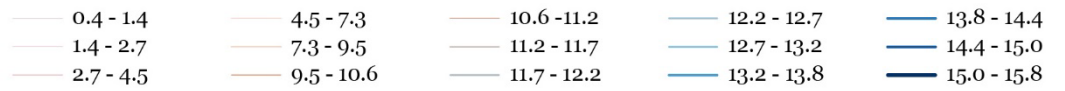
Appendix 5. Accessibility to Individual Transit Nodes in Bangkok



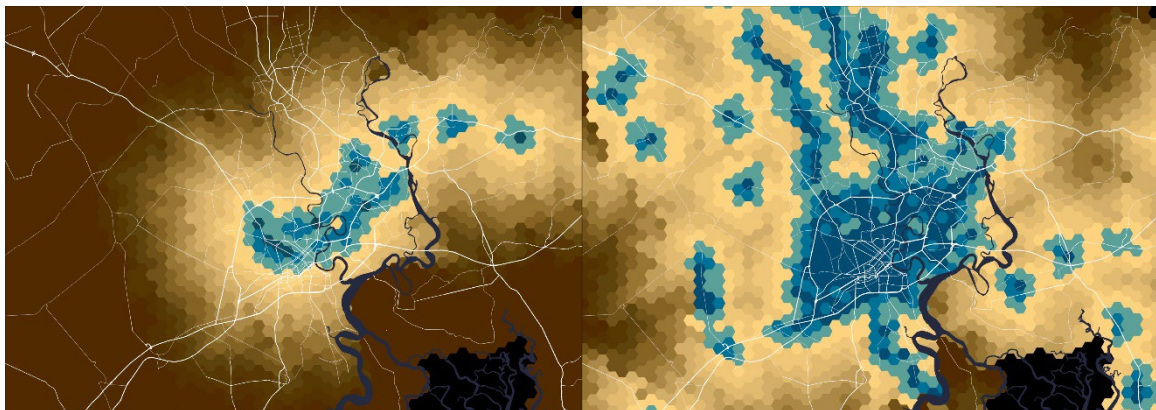
Appendix 6. The structural analysis of the streets' network in Bangkok



Normalized Betweenness centrality on the street networks



Appendix 7. Accessibility to Collective Transit Nodes in Ho Chi Minh City

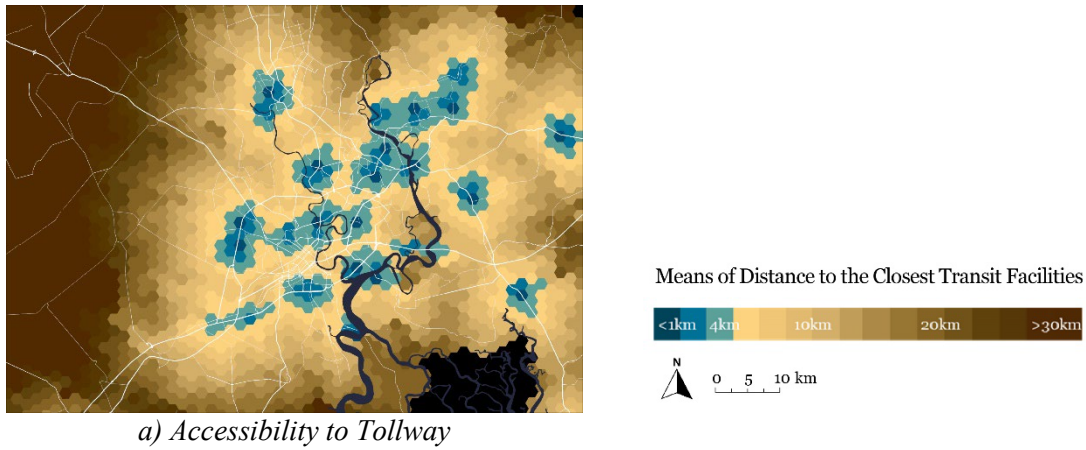


a) Accessibility to Metro Train

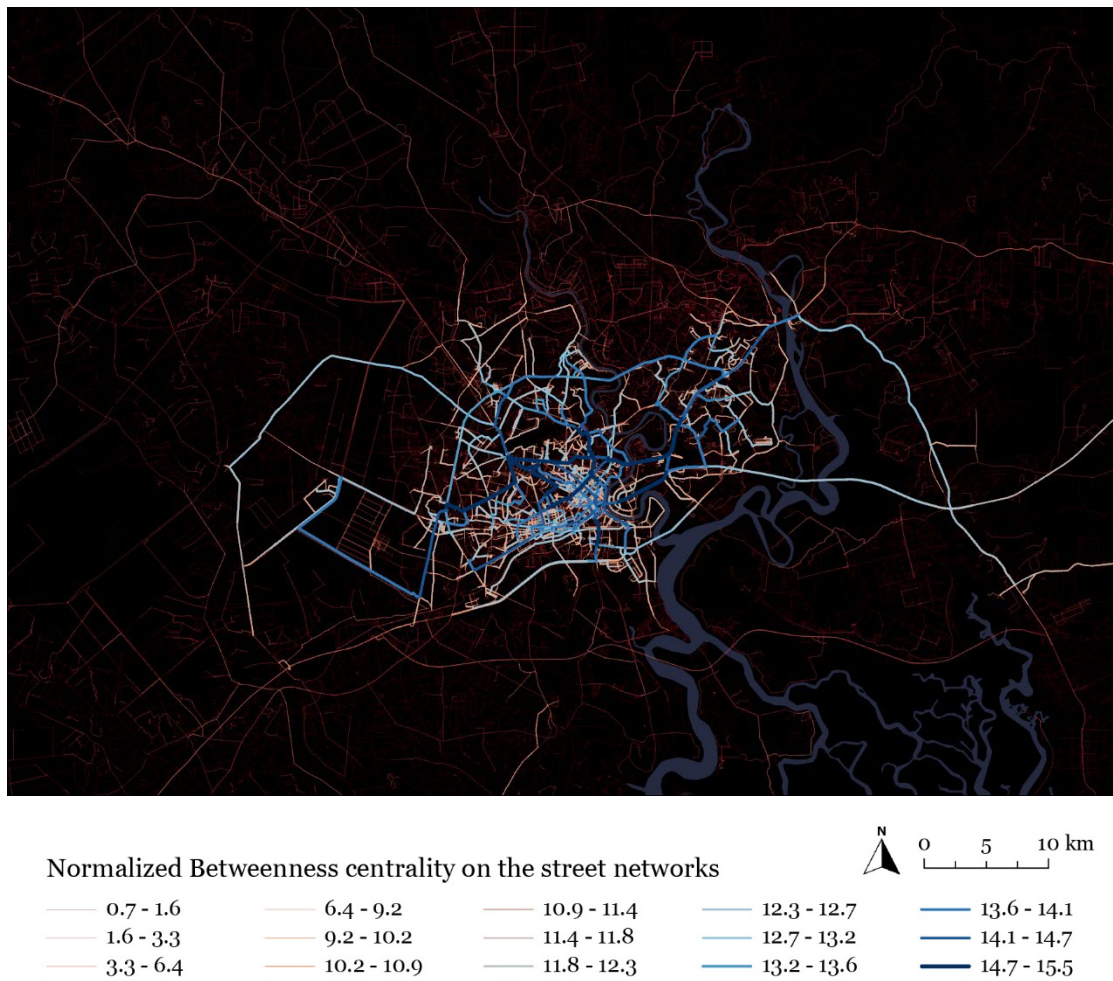
b) Accessibility to Bus



Appendix 8. Accessibility to Individual Transit Nodes in Ho Chi Minh City



Appendix 9. The structural analysis of the streets' network in Ho Chi Minh City



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## **DP 19-05 (November 2019)**

“Credit Guarantees and Zombie Firms: A Case Study of Small and Medium-Sized Enterprises in Japan”, Scott Wilbur (Yale University), 2018 FFJ/Banque de France Fellow

## **DP 19-04 (October 2019)**

“Impact of R&D Activities on Pricing Behaviors with Product Turnover”, Yasushi Hara (Hitotsubashi University), 2018 FFJ/Michelin Fellow, Akiyuki Tonogi (Toyo University) & Konomi Tonogi (Rissho University)

## **DP 19-03 (September 2019)**

“From Agribusiness to Food Democracy. Comparative Study on Agricultural Policy and Organic Farming in France and in Japan”, Shoichiro Takezawa (National Museum of Ethnology, Japan); 2018 FFJ/Air Liquide Fellow

## **DP 19-02 (June 2019)**

“Legitimation of Income Inequality in Japan: A Comparison with South Korea and the United States”, Shin Arita (The University of Tokyo), Kikuko Nagayoshi (Tohoku University), Hirofumi Taki (Hosei University), Hiroshi Kanbayashi (Tohoku Gakuin University), Hirohisa Takenoshita (Keio University) and

Takashi Yoshida (Shizuoka University); Prizewinners of the 2019 FFJ/SASE Best Paper Award.

**DP 19-01 (May 2019)**

“A Study on New Mobility Services and Sustainable Urban Development”, Ai Nishimura, 2017 FFJ/Renault Fellow

**DP 18-06 (December 2018)**

“A Study of New Technologies of Personal Mobility and Robot Suit for the Elderly and Persons with Disabilities”, Toshiaki Tanaka (University of Tokyo, Hokkaido University of Science), 2017 FFJ/Valeo Fellow

**DP 18-05 (November 2018)**

“Developments in Well-Being at Work in Japan: A Survey and a Comparison with France”, Louise Baudrand (EHESS), César Castellvi (EHESS), Nao Kinoshita (EHESS), Adrienne Sala (Sciences Po Lyon) & Sébastien Lechevalier (EHESS, Fondation France-Japon de l'EHESS)

**DP 18-04 (November 2018)**

“Understanding AI Driven Innovation by Linked Database of Scientific Articles and Patents”, Kazuyuki Motohashi (University of Tokyo, NISTEP and RIETI, 2017 CEAFJP/Michelin Fellow)

**DP 18-03 (November 2018)**

“The Yen Exchange Rate and the Hollowing-out of the Japanese Industry”, Ansgar Belke (University of Duisburg-Essen) & Ulrich Volz (SOAS University of London, 2017 CEAFJP/Banque de France Fellow)

**DP 18-02 (October 2018)**

“Cross-cultural (France and Japan) and Multidisciplinary Discussion on Artificial Intelligence and Robotics: Tendencies and Research Prospects”, Naoko Abe (CEAFJP Research Fellow)

**DP 18-01 (July 2018)**

“Impact of Shareholder-Value Pursuit on Labor Policies at Japanese Joint-Stock Companies: Case of Nikkei Index 400”, Kostiantyn Ovsiannikov (University

of Tsukuba, Prizewinner of the 2018 FFJ/SASE Best Paper Award)

**DP 17-05 (November 2017)**

“Female Board of Directors and Organisational Diversity in Japan”, Yukie Saito (CEAFJP Associate Researcher, University of Geneva, Institut de Recherches Sociologiques)

**DP 17-04 (August 2017)**

“*Keiretsu* Divergence in the Japanese Automotive Industry: Why Have Some, but Not All, Gone?”, Akira Takeishi (Graduate School of Economics, Kyoto University; CEAFJP Visiting Researcher) et Yoshihisa Noro (Mitsubishi Research Institute, Inc.)

**DP 17-03 (June 2017)**

“Globalization and Support for Unemployment Spending in Asia: Do Asian Citizens Want to Embed Liberalism?”, Sijeong Lim (University of Amsterdam) et Brian Burgoon (University of Amsterdam) ; Prizewinners of the SASE/FFJ Best Paper Award.

**DP 17-02 (April 2017)**

“Does ‘Driving Range’ Really Matter? The Hidden Cost of Internal Combustion Engine Vehicles and the Potentially New Value Proposition of Electric Vehicles: Two Cases from Countryside and Urban Side of Japan”, Hidetada Higashi (2016 CEAFJP/Valeo Fellow)

**DP 17-01 (March 2017)**

“How Can We Understand the Differences between France and Japan in the Growth of Shared Mobility Services? The Paradox of Trust and its Social Construction”, Naoko Abe (2016 CEAFJP/Renault Fellow)

**DP 16-03 (September 2016)**

“Parameter Bias in an Estimated DSGE Model: Does Nonlinearity Matter?”, Yasuo Hirose (Keio University) and Takeki Sunakawa (University of Tokyo)

**DP 16-02 (April 2016)**

“Financialization and Industrial Policies in Japan and Korea: Evolving Complementarities and Loss of Institutional Capabilities”, Sébastien Lechevalier

(EHESS), Pauline Debanes (EHESS), and Wonkyu Shin (Kyung Hee University)

**DP 16-01 (April 2016)**

“How Do Credit Hours Assure the Quality of Higher Education? Time-Based vs. Competency-Based Debate”, Ayaka Noda (National Institution for Academic Degrees and Quality Enhancement of Higher Education (NIAD-QE)

**DP 15-04 (December 2015)**

“Government Policy and the Evolution of Japan’s Photovoltaic Industry, 1961-2014”, Maki Umemura (Cardiff University, 2015 CEAFJP/Michelin Fellow)

**DP 15-03 (December 2015)**

“Japan’s Financial Crisis and Lost Decades”, Naohisa Hirakata (Bank of Japan), Nao Sudo (Bank of Japan), Ikuo Takei (Bank of Japan), Kozo Ueda (Waseda University, 2015 CEAFJP/Banque de France Fellow)

**DP 15-02 (May 2015)**

“Can Increased Public Expenditure Efficiency Contribute to the Consolidation of Public Finances in Japan?”, Brieuc Monfort (CEAFJP Associate Researcher)

**DP 15-01 (May 2015)**

“Policy Regime Change Against Chronic Deflation? Policy Option under a Long-Term Liquidity Trap”, Ippei Fujiwara (RIETI, Keio University, Australian National University), Yoshiyuki Nakazono (Yokohama City University), Kozo Ueda (Waseda University, 2014 CEAFJP/Banque de France Fellow)