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No. 92

Environmental Sustainability of Transport Systems

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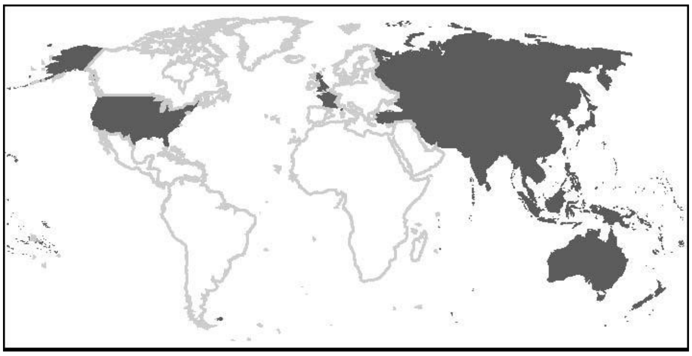

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THE ESCAP SECRETARIAT SUPPORTS INCLUSIVE, RESILIENT AND SUSTAINABLE DEVELOPMENT IN THE ASIA-PACIFIC REGION

Editorial Statement

The *Transport and Communication Bulletin for Asia and the Pacific* is a peer-reviewed journal that is published once a year by the Transport Division of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). The Bulletin is a medium in which knowledge, experience, ideas, policy options and information on the development of transport infrastructure and services in the Asia-Pacific region are shared. The main objectives are to stimulate policy-oriented research and to increase awareness on the policy issues and responses of the transport industry. The Bulletin attempts to widen and deepen the debate on various topics of interest and concern in the transport sector. For the 92nd issue, the Bulletin focuses on the theme of “Environmental Sustainability of Transport Systems”.

Passenger and freight volume is expected to increase by over 100 per cent between 2015 and 2050 in Asia and the Pacific due to continuous economic development, population growth and motorization. As a result, its environmental impact, including local and global pollution, will be significant over the next few decades. Transport sector accounts for 25 per cent of carbon dioxide (CO_2) emissions from fuel consumption, while road transport alone is responsible for 75 per cent of total emissions. As a key emitting sector that is still heavily dependent upon fossil fuels, the transport sector plays a critical role in reducing global climate change impact and to limit global warming to 1.5°C.

Asia is leading in many fronts towards environmental sustainability and decarbonization of transport such as the adoption of low carbon transport strategies; development of mass transit systems in cities; shift to renewable energy resources, including the transition towards electric mobility, and prioritizing active mobility. However, the pace is not fast enough to decarbonize transport by mid-century as committed by many countries. Therefore, transport policy makers, planners and stakeholders from the region need to accelerate actions in the transport sector to further enhance the environmental sustainability of transport systems.

The adoption of a low-carbon development path, use of renewable and alternate energy, development of mass public transport system, prioritization of electric and active mobility, and enhancement of efficiency of transport operations are some of the policies reflected in the Nationally Determined Contributions (NDCs) of Asia-Pacific countries. Analysis of transport systems using the Avoid-Shift-Improve framework can offer some policy insights towards environmental sustainability, especially for urban passenger transport. As countries in Asia and the Pacific are subject to increasing extreme weather conditions, raising sea level and other climate change impact, the resiliency and adaptation of transport infrastructure, systems and services will also need to be better understood and support by appropriate policy frameworks.

Each of the six papers selected for this issue contribute to different aspects and novel perspectives on the theme of “Environmental Sustainability of Transport”. They present various approaches and case studies from the region and beyond in addressing the environmental challenges of transport in Asia and the Pacific.

The first article by Miole, Joshi and Mohanty examined the policy guidelines and frameworks that would be necessary to increase the resilience of Asian cities through more robust transport systems. The linkages between sustainable and resilient transport were discussed supported by case studies from Japan, China, Singapore, and the Philippines. The authors also argued for a greater need to integrate transport resilience into the Sustainable Development Agenda, especially to better prepare countries for disruptive changes due to climate change, disasters and pandemics.

The second article by Sinha and Gupta presented the impact of mobility applications on transport mode in Delhi, India. Through a latent class cluster analysis of mobility application users, the authors observed different types of user groups and their characteristics, including those with a very high dependence on public transit and intermediate public transportation, a very low dependence on private vehicles, and no usage of taxis or app-based taxis. The characteristics of users who extensively rely on various modes of mobility or depend more significantly on private automobiles were also observed to better understand the implementation of effective sustainable transport policies that could affect transport mode choices.

The third article by Turbaningsih, Nisa, Mutaharah and Imron is focused on the development of green port strategies that can support sustainable maritime transport in emerging countries in Asia, including China, India and Indonesia. The importance of financial feasibility was highlighted, as well as the matching of green port strategy with port capacity and demand. Specific policy recommendations for port operators and countries were also derived from the research analysis.

The fourth article by Kant, Sinha and Gupta demonstrated the impact of off-hour freight strategy on the distribution of urban freight in Jaipur, India. This paper applied an agent-based modelling and simulation framework to evaluate stakeholder's behavior and to examine how fleet utilization, vehicle kilometers traveled, and total deliveries made could be affected by off-hour freight strategy. Urban freight policies that can improve the efficiency of freight deliveries will ultimately improve the sustainability of the system.

The fifth article by Fukuda, Tsumita, Wahyulinata, KikuchiI, and Schreiner analyzed activity patterns in Jakarta, Indonesia, to understand the impact of teleworking on transport demand and CO_2 emissions. Policy insights were developed for the implementation of a teleworking policy that can reduce congestion and CO_2 emissions through changes in activity patterns, traffic flows, mode share, and vehicle kilometer traveled.

The final article by Rosandi and Chatterjee assessed the involvement of non-state actors in the development and implementation of sustainable transport policy in the Mekong countries, within the scope of global policy making, governance and institutionalism processes. This article examined policies that are developed collaboratively, between state and non-state, national and regional actors, as well as the roles played by various non-state actors in achieving sustainable transport. Non-state actors have the potential to increase the sustainability of the sector through collaborative governance.

The editor is grateful to all internal and external reviewers who have contributed to the review process in preparation of the Bulletin.

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Increasing Resilience of Asian Cities through Sustainable Transport Solutions

Giselle L. Miole, Ganesh Raj Joshi, and Choudhury Rudra Charan Mohanty

ABSTRACT

As Asia remains to be at the forefront of natural disasters, rapid economic growth, and urbanization, improving the resilience of infrastructures and transport systems is essential for Asian cities. This paper demonstrates that high-quality transport infrastructures and integrating people and environmentally sustainable transport solutions (STS) are crucial for enhancing the resilience of cities in Asia and the Pacific. Resilient transport systems include but are not limited to non-motorized and low-carbon transport solutions, such as walking and cycling, integrated, electromobility, inclusive, and affordable public transport systems, and disaster and climate-proof transport systems that enhance the urban mobility, accessibility, and connectivity options, are key for strengthening the resilience of cities and communities. Moreover, state-of-the-art advanced technologies, big data, digitization, and advanced public transport system including mass rapid transport and railways not only enhance the resilience of cities but also improve the quality of life. However, it is equally important to address under-the-radar issues such as digital vulnerabilities, cybersecurity, and criminal and terror attacks to minimize the risk and vulnerability of transport infrastructures and services. The paper recommends policy guidelines and resilient frameworks to policymakers, planners, and city authorities for making transport infrastructures and services robust, resilient, and sustainable.

Key words: Resilience; Sustainable transport, Asian cities; Transport systems; climate change

Introduction

Asia is the world's most populous and rapidly urbanizing region in the world. According to the United Nations world urbanization prospects report, the Asian urban population will exceed 2.6 billion by 2030. These unprecedented changes lead to the growing demand for urban transportation in Asian cities. To accommodate the high demand for transportation, many emerging economies are building new transport infrastructures and transport systems whereas other counties fail to lag behind in the strengthening of transportation infrastructures and services. Meanwhile, Asia experiences greater intensity and frequency of climate-induced natural disasters (e.g., flooding, earthquake, typhoons) (UNESCAP, 2019a). With the growing number of natural disasters, the degree of interdependencies between hard and soft infrastructures, and the complexity of technology, the transport system has become more complex and vulnerable. Unless these transport infrastructures and services have in-built robust and resilient, they can be seriously disrupted by natural disasters and man-made impacts that affect economic growth, livability, and sustainability of the region.

Cities remain to be the leading vulnerable areas to threats and impacts of unprecedented changes in the environment, demography, society, and economy. By 2050, around 70 per cent of the global population will reside in cities and 60 per cent of new urban settlements are yet to be established. Thus, there is a huge scope and opportunity for building resilient cities and communities in Asia and the Pacific. Meanwhile, cities are also facing a lot of other man-made challenges such as traffic congestion, air, and noise pollution, road accidents and fatalities, and inadequate transport infrastructure and services, among others that threaten the resilience of cities and undermine their sustainability. Therefore, it is important for city authorities to build their overall infrastructures and transport services that can tackle existing challenges and can be able to withstand in case of disruption. If countries remain in a business-as-usual scenario without any significant investment in robust and resilience infrastructures and transport services, the costs of natural disasters would rise to USD 314 billion every year and may likely push 77 million more citizens to the poverty line (UN-Habitat, 2018).

Transportation remains an essential need and right for people to move freely from one place to another. The transport infrastructures and services are critical for the socio-economic development of the country. Thus, proper planning, design, development, regular inspection, and maintenance of transport infrastructures and systems are necessary to improve the resilience of cities and communities. Both resilience and transportation have interplayed with each other. Transportation has always been among the key evaluation measures for the resilience of cities, and resilience influences various areas of the transportation sector including policymaking and urban planning (Berdica, 2002; Husdal, 2005; Victoria Transport Policy Institute, 2019). Furthermore, cities have become a key target for resilience to work as they compose systems that intertwine multiple sectors of society. Given that urban populations are among the leading factors responsible for the economic growth of respective countries (OECD, 2016), the resilience of cities has become an important agenda targeted and spearheaded by the United Nations (UN). Realizing Sustainable Transport Solutions (STS) is the key to increasing transportation resilience in Asia. The most recent, widely recognized global commitment is the 2030 Agenda for Sustainable Development. Sustainable Development Goal (SDG) 11 calls for "safe, affordable, accessible, and sustainable transport systems for all". Stakeholders are urged to address road safety and invest in public transport to give accessibility and proper mobility to all, including women, children, persons with disabilities, and the elderly (UN, 2015). Another major agreement in the development agenda is the Sendai Framework for Disaster Risk Reduction, which focuses on achieving resilience. It further addresses the risks and impacts of natural and human-made disasters on our cities and communities.

In this paper, we discussed the importance of building transport resilient for achieving sustainable urban development. We further explore the possible ways of improving transport infrastructure and system resilience through a systematic review of related literature in the transport sector. Finally, we presented a few best practices, case studies, and way forwards of resilient and sustainable transport solutions in Asia.

Cities in Asia: Major Issues and Challenges in the Transport Sector

Asian cities are facing a lot of issues and challenges in the transport sector. Based on a literature review of previous studies and policies, this section discusses the ongoing major issues and challenges faced by the transport sector in Asia.

Population Growth, Urbanization, and Motorization of Asia

The world population is projected to increase at a 10 per cent rate, and reach 8.5 billion in 2030 (UN, 2019). By 2050, there will be 2.4 billion urban inhabitants, as compared to 4 billion in 2015. Asia is the home of the ten most populous cities including Tokyo, Mumbai, Beijing, Dhaka, and Shanghai. While Asian megacities account for 11 per cent of the region's urban population, they remain to be the centers of economic development, knowledge, and business. Internal migration is the key main factor behind rapid urbanization (UNESCAP, 2013b; UNESCAP, 2018). Rapid population growth entails rapid urbanization and motorization, leading to substantial demand for mobility in cities (ITF, 2017). As a response to rapid urbanization, Asian cities tend to implement the widening of roads and expanding road networks which encourage to use of private vehicles thereby increasing motorization (Joshi, 2020). According to a report by the Asian Development Bank (ADB), by 2030, Asia is projected to have 1.5 billion vehicles, covering nearly half of the world's total number of vehicles (ADB, 2017). Rapid motorization can further lead to urban sprawl increased dependency on private modes of transportation, and traffic congestion (Joshi, 2020).

2.2. Increasing Air and Noise Pollution, Traffic Congestion, and Road Accidents and their Implications

The latest TOMTOM Traffic Index shows that out of the top ten most congested cities, 4-cities are in Asia-Mumbai (2nd), Manila (4th), New Delhi (8th), and Bangkok (10th)[1]. According to the ADB, on average travel time is increased by 24 per cent in peak hours in most Asian cities. However, in major cities in Asia where the population is greater than 5 million, the average congestion is increased by 51 per cent during peak hours (ADB, 2019). The report further highlighted that the traffic congestion in Asian cities is mainly caused by rapid population growth, high demand for transport, increase in automobile ownership, inadequate transport infrastructures, lack of efficient and affordable public transportation, faulty land-use planning, and slow policy response to urban growth.

According to WHO (2021), worldwide around 1.3 million people die every year and about 50 million more people suffer non-fatal injuries and disabilities due to traffic road accidents. More than half of the affected people are pedestrians, cyclists, and motorcyclists. Road accidents are the leading cause of fatality for youth

[1] https://www.weforum.org/agenda/2021/01/covid-19-10-most-congested-world-cities-congestion-traffic/

aged between 5 and 29 years. Road accidents cost most developing countries 3 per cent of their gross domestic product[2].

Road vehicles are also the top contributors to both air and noise pollution. An estimated 92 per cent of Asia and Pacific populations are exposed to air pollution (CCAC and UNEP, 2019). Based on the Live Air Quality (AQI) ranking 2020, the top nine out of ten capital cities with the most PM2.5[3] concentrations in the world are in Asia- Delhi, Dhaka, Ulaanbaatar, Kabul, Doha, Bishkek, Sarajevo, Manama, Jakarta, and Kathmandu.

Apart from air pollution, noise pollution mostly comes from transport vehicles. According to a recent report “Frontiers 2022: Noise, Blazes and Mismatches” published by the United Nations Environment Programme (UNEP) revel that Dhaka, the capital of Bangladesh is the top city that had the most noise pollution in the world. The succeeding four cities are also based in Asia, namely Moradabad, India (2nd), Islamabad, Pakistan (3rd), Rajshahi, Bangladesh (4th), and Ho Chi Minh City of Viet Nam (5th)[4].

Greenhouse Gas Emissions and Climate Change Impacts

Transportation is one of the major drivers of greenhouse gas (GHG) emissions. UNEP Emission Gap Report 2022 also indicated the transport sector is the second-largest source of energy-related GHG emissions globally. It makes up 14 per cent of worldwide GHG emissions for the last decade (UNEP, 2022). Road transportation contributed around 72 per cent of GHG emissions for the transportation sector from 1970 to 2010 (IPCC, 2014). In the latest IPCC report land transportation, along with fossil fuel combustion and industry, is the largest contributing sector of GHG emissions on a 100-year time scale (IPCC, 2021).

In the Climate Change Vulnerability Index of the Environmental Risk Outlook 2021, Asian cities that face extreme risks of climate change are Karachi, Manila, and Jakarta. East Asia (IPCC, 2021). The IPCC report (2021) cited, “present-day global land-based transport pulse emissions cause a net global warming on all time scales (high confidence) and are detrimental to air quality (high confidence)”. This includes GHG emissions (mainly O_3, NO_x, $PM_{2.5}$) from gasoline and diesel combustion, and two of the three major contributors are from Asia — India, and China. However, developed nations had a higher GHG emission rate in terms of the transportation sector, almost two times higher than that of developing regions (Wu, and Chen, 2021). While 7.1 per cent of GHG emissions have been reduced during the COVID-19 pandemic in recent years, most emissions are expected to rebound again after the crisis (UNEP, 2021).

Natural and Human-made Disasters and their implications in Asia and the Pacific

With increasing the frequency and intensity of natural disasters in Asia and the Pacific, Asian cities are highly vulnerable to natural disasters. Out of the 100 world’s riskiest cities, 99 are in Asia, (Environmental Risk Outlook, 2021)[5]. Guangzhou and Dongguan in China are among the cities at risk of being exposed to natural hazards due to constant flooding. Seismic activity also constantly threatens Asian cities such as Delhi, Kathmandu, Beijing, Taipei, Jakarta, and Manila which are situated along earthquake prone zones (Joshi, 2020).

Human-made disasters such as road accidents, infrastructure failure, armed conflict, economic and political shocks, and pandemics are a few of the most striking challenges the transport sector has faced until the present. The COVID-19 pandemic has forced a huge portion of the transportation sector to close, making it difficult for the supply chain to operate (Rodrigue, 2020).

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[2] https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries

[3] Ambient airborne particle, a pollutant that is considered the most harmful to human health.

[4] https://www.unep.org/resources/frontiers-2022-noise-blazes-and-mismatches#:~:text=The%20UN%20Environment%20Programme%20(UNEP,for%20effective%20and%20timely%20responses.

[5] Jakarta was ranked top riskiest of all 414 cities in the world. Jakarta does not only face air pollution but also threats of natural disasters such as earthquakes and flooding.

Resilience Concept and Framework

At first resilient concept was used in academic work by Tredgold in 1818 (Tredgold, 1818). Resilience is about planning, preparing, preserving, and quickly restoring the basic structures, network, and system, and continuing to function at an acceptable level of efficiency in the face of disruption and unwanted events or shocks. There are large numbers of definitions of resilience in different disciplines and contexts. Multiple sectors such as health, transport, and environment have employed resilience as the framework for the development of strategies and prevention against nature and humans, as well as for reducing international emergency response (Bourbeau, 2015).

According to the United Nations Office for Disaster Risk Reduction (UNDRR) resilience is defined as "*the ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management*"[6]. Resilience further refers to the system's ability to adapt and absorb foreseen and unforeseen impacts and conditions, and its ability to adjust and run the system at a functional level (Foster, 1993; UNISDR, 2009). Thus, building resilience is a critical step for protecting, better functioning, and achieving sustainable development in cities and communities. It further helps to reduce the risk of a health crisis like COVID-19 and supports better performance during and after health emergencies.

Compared to other disciplines, the concept of resilience has been introduced and expanded in transportation recently. Therefore, there are no universal definitions for transportation resilience. However, the most acceptable definition includes "the ability to adapt to, recover from and respond to a variety of threats to physical infrastructure, operations, cybersecurity, terrorism, and all hazards" (Wan et al., 2018; Weilant et al., 2019). There are two types of threats to the transport system internal and external. Internal belong to technical failure, managemental failure, human error, and negligence or system collapse. Whereas the external consist of natural disasters, weather conditions, terror or criminal attacks, and wars, among others. These internal and external disruptions have different effects ranging from simply delay of the trip, interrupted journeys, missed travel connections, and delays the goods and services to more severe such as accidents, injuries, and even deaths. The effect of these external and internal events further depends on the transport mode, location, geography, conflict situation, time, and technology involved. Resilience is encapsulated by three main themes: (i) reducing the likelihood of a disaster and increasing the ability of a community to absorb or resist a shock; (ii) increasing the adaptability of a system while maintaining functions in the presence of a shock; and (iii) reducing the time to recovery to normal functioning (Weilant, et al., 2019).

Transportation resilience needs further discussion in the context of the Sustainable Development agenda, as it is impacted not only affected by climate change and disasters, but also by health emergencies like the COVID-19 pandemic. Stakeholders have largely adopted and debated resilience as a key guideline for policies and programs on both global and local scales, particularly in addressing sustainable development and environmental challenges.

Transport Infrastructures and Systems

The transportation infrastructures and systems include both hard and soft infrastructures. Hard infrastructures include- roadways, highways, and road transportation systems; railways and rail transportation systems; seaports, waterways, and marine transportation systems; airport and air transportation systems, and freight and logistic-related infrastructures and services. Soft infrastructures or non-physical infrastructures which include policies, planning, regulations, financing, institutional, governance, and regulation pathways; and occupations related to all aspects of the design, development, operation, and maintenance. With economic growth and technological improvement, these hard and soft transport infrastructures need to be upgraded and improved. In general, transport infrastructures and operating systems can be divided into four major components. All the above components are crucial for improving the resilience of the transport system.

i) *Physical Infrastructures*: This includes all physical infrastructures such as rail, roads, bridges, ports, airports, vehicles, traffic signs, singles, etc.

[6] https://www.undrr.org/terminology/resilience

ii) *Transport Actors*: This includes direct or indirect transport users and beneficiaries including drivers, passengers, transport operators, producers, managers, and other actors associated with the transport infrastructure and services.

iii) *Technology Used*: In this part, all used and associated and interlinked technology for the transport infrastructure and services such as Information and Communication Technology (ICT), Internet of Things (IoT), Intelligent Transport System (ITS), Artificial Intelligence (AI), Geographic Information System (GIS) and Global Positioning System (GPS), Automation, Blockchain Technology (BT), and Bigdata, among others.

iv) *Planning, Operation, and Management System*: This includes the planning ideas, operation mechanisms, and management plans of the involved stakeholders in the transport infrastructure and system.

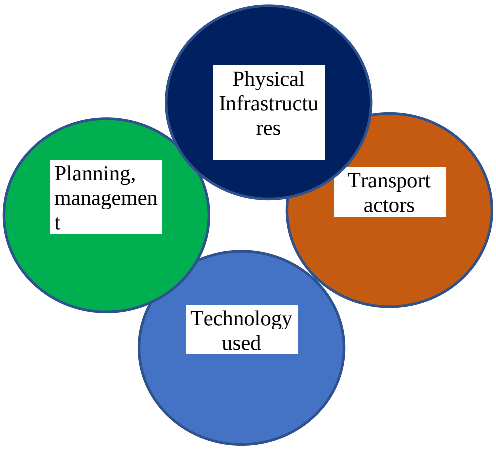

Figure.1: Different components that are crucial for improving the resilience of the transport system.

Enhancing Resilience in the Transport System

In the digitization age, transport infrastructures and services are becoming complicated and interlinked with a different complex system. For example, the electrified public transport system is interconnected with electric power, information and communication technologies, the internet of things, and a more complex system of automation and artificial intelligence (AI). Due to natural disasters or shocks, any of these transport system components or all of them can be seriously damaged and disrupted. Any disruption in one system can directly affect other systems. For example, the impact of electric power on the train system can paralyze the entire rail transport system. This complexity and the interdependency that rise because of the interlinked transport systems are highly vulnerable to external or internal threats and disasters. It is important to understand these interdependent and technical complexities in transport systems, and these complexities usually make transport systems less resilient. However, in terms of sustainability, electrified public transport systems are highly sustainable. Thus, it is important to note that not all sustainable transport measures can improve the resilience of cities.

There are different strategies and measures for enhancing the resilience of transport infrastructures and systems. Appropriate preparedness, planning, and actions on time can help to identify potential threats, avoid possible potential risks, and reduce the impact in case of event occurs. Particularly threats from natural disasters such as earthquakes, floods, landslides, volcanic eruptions, and other climate and weather-related adverse impacts can be manageable if well-planned and prepared. However, planning and preparedness demand continued observation, maintenance, a high level of technological improvement, big data analysis, and accuracy of predictions.

Transport Resilience Framework

To achieve a high level of resilience in transport infrastructures and systems, cities should consider the overall transport resilience framework, which includes the improvement and balance in four major dimensions of resilience, which are indicated by the 4Rs: robustness, redundancy, resourcefulness, and rapidity.

i) *Robustness:* It is the ability or the capacity to withstand or overcome shocks, stress, and adverse conditions. Robust transport infrastructures and systems can withstand and absorb internal and external shocks and are able to function continuously in the face of disruptions. Robustness can be improved by high-quality infrastructures, regular inspection, maintenance, repair of the physical infrastructures, and up-to-date technology and services. By improving its robustness, the transport system will be able to resist and function during and after the crisis.

ii) *Redundancy:* Redundancy is the preparedness or readiness for an alternative that prevents failure in the future. Redundancy can be achieved by providing other options or way-outs that enable the continuity of work and communication through diverse alternative methods. In the case of transport, the availability of alternative routes, different transport modes, different and alternative modalities, alternative vehicles, drivers, and technical staff can help to improve resilience.

iii) *Resourcefulness*: Resourcefulness reflects the ability to identify problems, prioritize actions, and mobilize necessary human capital and resources that reduce the total consequences through relief and restoration. The capacity to handle shocks, stress and unwanted disruption can be strengthened through policy, planning, and readiness. In this regard, equipment, and a well-trained workforce are necessary to tackle technical failures, accidents, and disaster events. Adopting high-quality equipment, adequate information and communication system, availability of emergency funding, coordinated rescue and relief efforts, and repair and better construction can help to reduce the impact of the disaster on the transport system.

iv) *Rapidity*: Rapidity is the ability to restore functionality in a timely manner so that the system can function in a short period of time. The systematic and smart arrangement of the necessary workload, proactive and quick response, well-organized management, and problem-solving capabilities in stressful conditions can significantly enhance the capacity and quality of emergency response and reduce the restoration time.

Table 1: Potential threats of disasters and their consequences on the transport system.

	Potential Threats	Type of disasters	Possible impacts on the transport system	Action needs to be taken to protect the transport infrastructures and services
1	Natural Disasters	Earthquakes, landslides, flooding, volcanic eruptions, and tsunami, among others.	- Transport services could be stooped. - Partial or full infrastructure damage and destruction. - High chance of possible accidents, loss of lives, and property damage. - Travelers get highly affected by the incident.	-Building high-quality and robust infrastructures - Avoid possible vulnerability and risk of disasters and internal/external stresses - Improve the technology, design, inspection, and maintenance - Improve the operation, management, and governance of the transport system.
2	Climate and Weather events	Heavy rain, heavy snow, strong wind, strong heat waves, etc	-Interrupt or delay the journey - Possible infrastructure damage - Chance of accidents, loss of lives, and property damage -Travelers get affected by the incident.	-Building high-quality and robust transport infrastructures and services. - Avoidance of possible vulnerability and risk of climate and weather event -Provide a proper alternatives route and networks
3	Criminal and Terror attacks	Bomb blasts, gunshots, cyber-attacks, and transport infrastructure and system attacks such as bridges, airport railways, and public transport system	-Interrupt or delay or stop the journey - Possible infrastructure damage - High chance of possible accidents, loss of lives, and property damage -Travelers get highly affected by the incident	- Improve safety and security of the transport infrastructures and services. - Improve the technology - Improve cyber security
4	Design faults, inadequate infrastructure	Mistakes or errors in the design, low-quality materials used, reinforcement failure or	- Interrupt or delay or stop the journey	-Building high-quality and robust transport infrastructures and services

	and maintenance	lack of inspection and maintenance	- High level of infrastructure damage - High chance of possible accidents, loss of lives, and property damage -Travelers get highly affected by the incident.	- Use high-quality materials - Improve technology and design - Proper inspection and maintenance

Role of Sustainable Transport System (STS) to Improve the Resilience of Cities

There is a significant demand for STS to increase the resilience of city components such as roads, buildings, and open spaces. Although Asia remains lagging behind other regions in such components, several major cities have come in strides in implementing STS. High-quality and less complex public transportation and e-mobility infrastructures development, and non-motorized modes of transport can enhance the resilience of transport infrastructures and systems.

Non-motorized Transport (NMTs) for Resilience city

According to a UNCRD report, NMTs are “the transportation of passengers via human or animal powered means including bicycles, rickshaws, pedicabs, animal-drawn carts and walking” (UNCRD, 2018). But in most urban areas, the primary NMTs are human-powered modes such as walking, bicycles, and rickshaws. In most Asian cities, NMT is widely used, however, the dedicated NMT infrastructure and facilities are remains underdeveloped. In the era of COVID-19 and climate change, NMT can play a vital role to realize the resilience of cities as it also curbs urban sprawl, encourages multimodal transportation, improves air quality, promotes fitness and wellness, and does not emit vehicular greenhouse gas emissions (Mansoor et al., 2021). NMT allows purposive movement through open space without endangering human contact, which is an essential requirement in during the pandemic for social isolation. It further provides better opportunities for physical exercise, which helps to reduce stress and anxiety. Similarly, bike-sharing services are widely popular in many cities around Asia and the Pacific.

There are numerous NMT initiatives in Asia for making cities and communities resilient and livable and a few of them are discussed. In ADB’s “Creating Livable Asian Cities”, NMT has emphasized that to make Asian cities livable and to develop sustainable urban transport systems, public transportation and non-motorized modes of transport should be prioritized (Susantono & Guild, 2021). UN-Habitat (2013) has cited examples of which NMT can be implemented to create sustainable transportation in Asian cities[7]. The Unified Traffic and Transportation Infrastructure Planning, and Engineering Centre in Delhi is an example of dedicated institutional support for NMTs. The Eco Cabs in Fazilka and Chandigarh is a successful initiative of how technology can promote NMT and build partnerships. Singapore’s National Cycling Plan is an excellent example of prioritizing NMT in planning. Republic of Korea and its large budget investment in cycling (e.g., bikeways, bike paths, supporting cycling as a transport mode) exhibit priority in cyclability. Hong Kong, China pedestrianization program has shown how NMT can be prioritized in designing cities. Jakarta's car-free days exhibit examples of building allies to promote NMT together with city administrators and local NGOs. Shanghai, China U-bicycle uses blockchain technology to promote decentralization and connects city centers to other regions.

Light Rail Transit (LRT) and Trackless Tram

Light Rail Transit (LRT) is an advanced, pollution-free, and people-friendly transport system. As a result, environmental pollution -air and noise pollution and greenhouse gas emissions can be reduced significantly which helps to promote green growth development. The lower construction cost compared to subways and the ability to use existing suburban tracks can provide better opportunities for cities to develop LRT. The integrated public transport system of LRT based on electricity can also reduce pollution, help to improve transit ridership and increase local businesses. The frequent services and faster speeds – boarding and embarking from low floors and barrier-free stations and easy-to-use system can provide barrier-free access to all including

[7] A few examples are discussed in the next section of the paper, highlighting how NMT can enhance the resilience of cities and communities in Asia and the Pacific.

children, elderly, and disabled persons. For example, Japan International Cooperation Agency's (JICA) project in Sri Lanka's Colombo Light Rail Transit System was enhanced to cater to visually challenged and wheelchair users. Improvements such as accessible ticket gates, installation of an emergency button, and color contrast to minimize the gap between train vehicles and platforms to promote public awareness of accessibility through Universal Design were achieved (UNESCAP, 2019b).

The Trackless Tram is an example of how light rails, buses, and other private vehicles can be merged and operate on the same road. Trackless Tram, developed by the CRRC Corporation, China. It runs on rubber tires on the road and does not require any dedicated lane and can function with the traditional transport system. Compared to the Light Rail system, it is cost-efficient and provides safer and cleaner transportation (Newman, 2020). As a result, the trackless tram is more resilient than the other traditional transport systems which are more complex and need special infrastructural arrangements. The trackless tram is not only efficient but also affordable transportation for all sectors of society.

Figure 1: Trackless Tram in the city of Zhuzhou (Photo credit: CRRC Zhuzhou Institute)

Electromobility Mobility Solutions

Electromobility or E-Mobility represents the concept of using electric power technologies, in-vehicle information, communication technologies, and connected infrastructures to enable the electric propulsion of vehicles and fleets[8]. Zero-emission public transport systems which are well-integrated, cost-effective, electric drive solutions are widely used to set the world on a net-zero carbon trajectory addressing climate change impacts. E-Mobility is among the recommended ways to integrate STS in the form of hybridized and electric vehicles (Susantono and Guild, 2021). The shift towards electric vehicles is not optional but it is required to fully realize a sustainable transport system. To fully harness E-Mobility momentum, ADB gave recommendations for high-mileage commercial vehicles, adequate power infrastructure, and incentive systems that support sustainable business models (Susantono, 2021)[9]. Electromobility, as a public transport system is widely used in different cities, worldwide.

Transport for All: Inclusive Public Transport Facilities

In most cities in developing countries, public transport facilities are unsafe, difficult, and stressful to use for many commuters, especially for children, pregnant women, senior citizens, and people with disabilities. It is

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[8] https://www.gartner.com/en/information-technology/glossary/electro-mobility-e-mobility#:~:text=(e%2DMobility)-,Electro%20Mobility%20(e%2DMobility),propulsion%20of%20vehicles%20and%20fleets.

[9] Recently, Jakarta has been decarbonizing its public transport system starting with its bus networks and taxi fleets. Bangkok is also investing in e-ferries to replace fossil fuel vehicles (Susantono, 2021).

important to make the public transport system more inclusive and accessible and incorporate comprehensive facilities for all including those with economic, social, physical, and mental disadvantages to heighten the resilience of the city (UNESCAP, 2020)[10]. The main barriers that limit inclusion on public transit are overcrowded vehicles, poorly designed transportation systems, expensive ticket prices, lack of user-friendly infrastructures, and safety regulations that fail to account for the travel requirement of different commuters.

In the past decades, international communities and United Nations have made a concerted effort to improve the inclusive public transport system. The global agenda of the sustainable development goals particularly Target 11.2 of the SDG 11 calls for "*By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons".* For achieving this target, Asian countries are improving their public transport system to make public commutes safer and accessible for everyone.

In recent years, many Asian cities are building inclusive transport infrastructures and transport systems. For instance, many cities are incorporating mobile ramps have been used to make roads and paths accessible to persons with disabilities. The organization, Make Level Paths, started the initiative that allowed persons with disabilities to have improved road access while having a cost-efficient solution customized to tailor-fit the shape of the infrastructure (UNESCAP, 2019b). Busan, Republic of Korea has opened digital kiosks in the city's train and subway stations that provide information on the best routes people with disabilities can take (Park, 2021). Singapore has launched Priority Cabins (two center cabins for vulnerable commuters that have in-cabin signages and visual identifiers, and customer service officers)[11] to secure senior pedestrian's safety and avoid road accidents involving senior pedestrians (Mehmet, 2020; LTA, 2020). Most of the railway and sub-way companies in Japan provide special facilities for women by providing Women-only passenger carriages. In Bangladesh, Khulna City Corporation's pro-poor and green urban transport project focused on strengthening and extending existing access routes for walking and cycling to urban slums (Lumbera and Ringhof, 2016). For developing accessible transportation through building resilient and inclusive infrastructure facilities can be built through the introduction of universal and accessible design, affordable ticketing prices, opportunity to acquire the same infrastructures, information, and service integration that can provide equal opportunity for all sectors of society.

In Table 2, we present a summarized table of various STS practices, and their general benefits in response to positive changes for city resilience such as road safety improvement, traffic decongestion, vehicular emissions reduction, and disaster reduction, following the current global frameworks.

Table 2: Summary of the resilient sustainable transport system and their co-benefits

Resilient Transport System	Road safety improvement	Traffic decongestion	Decentralization	Vehicular emissions reduction	Disaster reduction
Non-motorized transport (NMT)	✓	✓	✓	✓	*
Intelligent transport system (ITS)	✓	✓	✓	✕	*
Inclusive facilities	✓	✓	✕	✕	✓
Electromobility	*	*	*	✓	*

[10] Economic sectors include transport poverty. Social sector includes gender discrimination or racial discrimination, and physical and/or mental disadvantages include persons with physical disabilities or mental health conditions,

[11] A scheme with traffic-calming measures and senior-friendly road safety features.

Note on framework (✓ = beneficial; ∗ = depending on the city's context; ✕ = no effect)

Best Practices of and Case Studies from Countries in Asia and the Pacific

Japan's Natural Hazard Resilience Transport System

Japan has constantly been hit by earthquakes and floods but has been able to shape its transport system to be resilient to natural disasters by learning from its past experiences in dealing with natural disasters. Japan is a global leader in railway infrastructure development which makes them resilient and sustainable. Japanese railways are also well known for their speed, service, and punctuality. Disaster risk reduction, prevention, and climate change adaptation are the core focus areas of many Japanese railway companies. Usually, Japanese roadways and railways companies are installing resilient infrastructures associated with the transport system including huge mechanical ventilation systems cool tunnels, platforms, and carriages; giant water stop plates, shutters, and doors are installed at tunnel openings and station entrances to block out flood water. Drainages are well managed inside the stations to pass the underground water seepage. Commonly, ground heights and barricades were built along the railways and bus rapid transit system to avoid flood damage. In Japan, the Ministry of Land, Infrastructure, Transport and Tourism's (MLIT) large-scale projects have allowed Tokyo's transport sector to be more resilient when typhoons occur. The flood control channel is composed of five underground shafts that collect runoff from five rivers and then pump it to the sea through a subterranean tunnel.

To protect subways from flooding, the Tokyo Metro Co., Ltd, has improved its anti-flooding mechanism to withstand up to 6 meters of water pressure, as well as increased flood barriers and improved flood-proof designs of entrances. There are floodgates in the tunnel entrances and drainage pumps as well. By predicting floods by measuring the distribution of rain in 3D, trains can be stopped, and disasters can be avoided. This is possible through the Precipitation Radar (DPR) of JAXA (Japan Aerospace Exploration Agency) which measures precipitation data over the ocean, providing more accurate forecasts. Aside from road policies and infrastructures, railways in Japan utilize the role of ICT through the Urgent Earthquake Detection and Alarm System (UEDAS), which automatically activated 27 Shinkansen train lines' emergency brakes in case of an earthquake. This early warning system is activated by a seismometer that detects seismic waves and puts trains to a stop. This avoids the derailment of trains that could cause further damage and casualties (Gamez, Darido, D'ocon & Shibuya, 2017; Takemoto, Shibuya & Sakoda, 2021). During the past 2011 Great Japan Earthquake, although the railway experienced massive damage and losses, however, due to this early warning system they were able to avoid worse and more critical damage because of seismic countermeasures - including having zero casualties (Railway Technology, 2011). Five trains were destroyed after the tsunami but none of the passengers became casualties and were safely evacuated (The World Bank, 2019). In 2017, a more advanced system was introduced which can sense tremors 20 seconds earlier than the previous system.

China: Building Resilient Road, Rail and Water Networks

China is investing heavily in road, rail, and water transport infrastructures and transport systems. In 2021, more than 168,000 kilometers of highways and over 16,000 kilometers of waterways network were constructed. The year 2022, China is planning to build 3,300 kilometers of the new rail line, 8,000 kilometers of expressways, and 700 kilometers of high-grade waterways. It is expected that the country will spend more than USD 115 billion per year to build its rail network alone. By the end of 2021, the total operating length of China's High-speed Railway (HSR) network had exceeded 40,000 kilometers. China is aiming to build about 70,000 km of high-speed railway network by 2035[12].

By having numerous intercity highway systems and high-speed rail networks, China has allowed companies to operate in other regions and reduce regional imbalances. It has also allowed poverty reduction through investment in roads and rails. These transport networks have allowed for the decentralization of resources and administration facilities at regional and local levels. Ultimately, China's investment in road networks and transport infrastructure has paved the way for them to become the world's most important manufacturing center (Kaplan & Teufel, 2016). China's HSR network has improved travel time for both cities and rural areas.

[12] http://global.chinadaily.com.cn/a/202203/01/WS621d8e75a310cdd39bc8989d.html

HSR has enhanced access to opportunities for all cluster city clusters, decreased disparity in spatial access, and has also a key role in lifting per capita productivity (Liu & Zhang, 2018).

There are several projects and initiatives going on in China for improving the resilience of rail and road networks and transport systems. One of the prominent is the 'Technology for Resilience - Belt and Road Initiative Capacity Building Project,' which aims to provide better tech-based solutions for disaster risk information including the early warning system, identify the accuracy of post-disaster damage assessments to enhance disaster preparedness and response capacities and disaster reduction efforts. In addition, advanced technologies such as remote sensing solutions, geographic information systems, and satellite navigation technology are widely used to strengthen the resilience of infrastructure and transport systems. China is further investing in climate-resilient logistic transport infrastructures to mitigate climate risks by providing an integrated approach that spans the entire life cycle of infrastructure assets.

Singapore's Transit-Oriented Development Approach

Singapore's transit-oriented approach prioritizes the use of public transport. By increasing their rail networks, increasing connectivity of major transport nodes and facilities, and extending bus networks, the country aims to achieve at least 85 per cent of morning and evening peak journeys made through public transport by 2050. Furthermore, developers in the city are required to comply with the Walking and Cycling Plan (WCP) where their designs should meet the needs of pedestrians and cyclists.

Incentives are also done when developers include active mobility-friendly facilities such as bicycle lots among others. Sheltered walkways, in general, have been increased to encourage walking. Singapore's National Cycling Plan has mainstreamed cycling as a major mode of transportation through increasing cycling path networks and bicycle parking facilities. Inclusive transportation has been promoted in public transportation by having barrier-free entrances and access routes, priority queue zones, lifts, tactile guidance systems, and wheelchair-accessible toilets among others. Another inclusive development is the implementation of Silver Zones which provides a safe space for the elderly and persons with disabilities. Silver Zones are areas with road safety features, that slow down motorists to avoid accidents relating to senior pedestrians or persons with disabilities. Schemes that promote green transportation have also been started, such as electric car-sharing programs, and the deployment of hybrid buses and electric buses. Rebates were also promoted for low-emission vehicles and levied surcharges for high-emission vehicles (MOFA Singapore, 2018).

The Philippines' Pasig City Bike Sharing Program

In the Philippines, Pasig City has been committed to contributing to decreasing emissions through the Pasigreen Bike Share Program or the Pasig Bike Share program. It is the first local government-operated bike-sharing system in the Philippines that promotes active transport (Siy, 2020). Ten stations were set up around the city's business center, with a total of 100 units. Smart cards are used to avail the bike services. During the COVID-19 pandemic, the bike share service released their bicycles for medical and emergency personnel as a mode of transportation due to limited access to public transportation services (GMA News Online, 2020). This program has highly contributed to the Pasig City residents during the COVID-19 pandemic situation.

Lessons from Global Commitments

Global Commitments: *World Cities Day- Urban Resilience*

Given the issue of rapid urbanization and motorization, international and local non-governmental organizations adopted global commitments in the past decade. These include establishing "World Cities Day" in 2013 as part of the implementing guidelines to strengthen UN-Habitat (UN, 2013). World Cities Day is designated every 31 October to "promote the international community's interest in global urbanization", address challenges of the changing demographic landscape, and contribute to the Sustainable Development of urban systems in the world (UN, 2020). The marking of this international day has been created following rapid urbanization and unprecedented changes and challenges in demography, environment, economy, and society. In 2018, World Cities Day focused on urban resilience. Urban resilience possesses the same characteristics as resilient cities as discussed previously. It refers to the "measurable ability of any urban system, with its inhabitants, to maintain continuity through all shocks and stresses" (UN-Habitat, 2018). Another major objective of this initiative is to reduce both foreseen and unforeseen costs of emergencies, disasters, and economic damages in the future. Acknowledging the major issues discussed, urban resilience matters as it is a continuous ability that every city must possess persistence, adaptability, and inclusivity to strengthen capabilities to absorb all possible threats and shocks, “while positively adapting and transforming toward sustainability”. Their main call to action is the need for innovative tools that empower and strengthen the capabilities of citizens that “must be integrated into urban planning and management practices”.

Global Commitments Making: Cities Resilient 2030 (MCR2030)

The most recent global strategy spearheaded by the UN is the MCR2030 (UNISDR, 2020). Much like the Sendai Framework, MCR2030 is also a joint-stakeholder initiative but focuses more on the strengthening of resilience holistically such as the resilience of cities and communities. This initiative is the culmination of local commitments to the achievement of SDG 11. It is a collaboration formed by several international organizations, including ICLEI (Local Governments for Sustainability), C40 Cities, JICA, United Cities and Local Governments (UCLG), the World Bank, and concerning UN bodies such as the UNDRR (UN Disaster Risk Reduction) and UN-Habitat. The initiative takes on a three-stage resilience roadmap: (i) cities know better; (ii) cities plan better, and (iii) cities implement better. To perform these stages, the initiative lays out twelve thematic areas particular to the needs of cities, ranging from promoting awareness to the improvement of skills and analysis; ensuring resilient infrastructure; to the strengthening local (within the city) and national (city-to-city) networks.

In general, the initiative focuses on strengthening resilience at the local level (UN-Habitat, 2019; UNDRR, 2020). It calls for the participation of citizens themselves by having them aware of disaster risk reduction and enabling decision-making for strengthening accessibility and mobility. While the commitments above are promising, however, challenges at hand are mostly related to implementation and planning to realize the resilience of cities. The challenges include but are not limited to political will and agreement among different units of government, slow adoption of newly crafted policies, and bureaucratic processes.

Regional Commitments: Regional EST Initiative in Asia

One of the notable initiatives in the Asian region is the Environmentally Sustainable Transport (EST) Initiative in Asia. The overall objective of the Asian EST Initiative is to provide a strategic platform for advancing environmentally sustainable transport in Asia by organizing the annual Regional EST Forum in Asia and related capacity-building activities at regional, sub-regional and national levels. In the post 2015-era, the policy discussions at the Forum are aligned with the 2030 Agenda/SDGs, the Paris Agreement, the New Urban Agenda, and other relevant global agendas and agreements that have set out objectives and/or targets for improving rural and urban access, national connectivity, and economic, social, and environmental sustainability to guide the development of the transport sector in Asia.

As an integral part of the Initiative, the EST Forum is organized annually by UNCRD/UN DESA and the Japanese Ministry of the Environment, and supported by the UNESCAP, ADB, and other international organizations. The EST Forum started in 2004 with the collaboration of the Japanese Government. Since then, the event is conducted annually with a different theme and focal point each year. The Forum was attended by various 25 EST member countries in Asia, academic institutions, multilateral banks, donors, private sectors, and experts working on different areas of sustainable transport.

At its 14th Forum in October 2021, EST member countries voluntarily adopted the Aichi 2030 Declaration (2021-2030), a non-legal and non-binding resolution focusing on sustainable transport in Asia. This declaration is a successor to the Bangkok 2020 Declaration (2010-2020) which was adopted during the 5th Regional EST Forum covering six goals, highlighting three dimensions environment, social and economic, and passenger and freight transport systems. The Aichi 2030 Declaration is strongly connected to achieving SDG 11 particularly targets sustainable, clean, safe, and affordable access to transportation (UNCRD, 2021). In the Aichi 2030 Declaration, the resilience of transportation falls under Goal 1: Environmental Sustainability. Goal 1 urges stakeholders to promote resilient, adaptive transportation to climate change, disasters, and infectious diseases. The goal also aims to support SDG 13: Climate Action, the Paris Agreement, and the Sendai Framework.

Policy Measures and Recommendations to Improve the Resilience of Transport Infrastructures and Services

Prioritizing Non-motorized Transport (NMT)

Based on a broad consensus among scholars and key stakeholders, allowing cities that cater to walking, cycling, and other integrated modes of transport can also make cities more resilient. It contributes to health, social and environmental aspects such as decarbonization, social interaction, and ease of mobility from one place to another, and helps reduce air pollution and GHG emissions. However, incorporating NMT programs for disaster risk reduction is strongly recommended to further establish factors of resilience. Examples include establishing dedicated pedestrian lanes, bicycle paths, and provision of bike-sharing services, especially to the city center and core zones for improving mobility. Prioritizing NMT, however, may also entail modifying road networks that should provide more walkable cities, entailing a great paradigm shift from private vehicle-centered infrastructures. As such, it may take time and financial resources for a city to be fully implemented a feasible NMT system.

Promoting E-Mobility in Developing Countries

Asia continues are emitting more GHGs, and noise pollution compared to other regions. There is a demand for hybrid and electric vehicles that no longer need the use of fossil fuels and rely more on electric power. However, the challenge remains in combating the financial burdens of purchasing E-Mobility transportation and building charging infrastructures that may take time to fully incorporate the system in many developing countries. We encourage central and local government, development banks, donors, and international organizations to support the funding of E-Mobility system integration and foster international cooperation and public-private partnerships.

Integrating Inclusive Facilities in Urban Transport

Inclusive facilities in urban transport increase accessibility and ease of mobility, thereby increasing the resilience of cities. Acknowledging the issues faced by people with disabilities such as the visually impaired and wheelchair users help develop policies that employ resilient thinking and the universal design and accessible mobility options that address the needs of all sectors of society including women, children, the elderly, and person with a disability. Enabling a city system with inclusive facilities such as ramps, and yellow blocks reduce vulnerabilities against people with disabilities in times of disasters. Policymakers should continue incorporating inclusivity in the transport system to improve the resilience of cities. Another feature of inclusive resilient cities is to make transportation fares accessible and affordable to all socio-economic classes, free from discrimination against ethnicities, races, and gender.

Enabling Financial Incentive Systems for Smart Cities

New state-of-the-art technologies such as ITS, IoT, AI, and blockchain continue to enable cities to be smarter, more efficient, resilient, and sustainable. However, limitations of technology transfer and financial burdens may get in the way, particularly for developing countries. We encourage develop countries, multilateral development banks, and donor agencies to continue enabling financial incentives and technical support for developing countries for building resilient transport systems.

Addressing Under-the-Radar Issues: Cyber-attacks, Terrorism, and Digital Vulnerabilities

Cyber-attacks have become inevitable that compromise infrastructure information such as road conditions, weather forecasts, accidents, and security. These attacks enable data and security breaches of officials' and citizens' personal information, compromising their privacy and identity. They have also been deemed as an informal new kind of human-made disaster. Thus, we encourage to development of a tighter security system and radar on ITS and blockchain transport infrastructures, including smartphone applications that employ GPS tracking systems against possible risks and vulnerabilities.

To tighten the security system, we suggest the following: (i) capacity building and training staff and personnel about ICT use, password management, and data security; (ii) utilizing multi-factor authentication (MFA)[13] of access to sensitive information and account management; (iii) regularly update software and system in

[13] MFA is a structured strategy of protecting data of users by presenting two or more information to verify a users' login credentials (Cybersecurity & Infrastructure Security Agency, n.d.).

transport technologies and apps; (iv) backing up data stored; and (iv) strengthening wi-fi connections[14] to prevent connection vulnerabilities.

Conclusion

Improving the resilience of infrastructures and transport systems is vital for improving the resilience of cities and communities. Due to emerging issues and challenges, including rapid urbanization, motorization, climate change, and disasters, there is a high demand for the resilience of Asian cities. Equipping resilient thinking in policies, planning, operation, management, and governance as well as crafting and developing sustainable transport solutions can significantly enhance the resilience of infrastructure and transportation systems.

For making city infrastructures resilient, a city also must improve transport infrastructures and public transport facilities by integrating walkability, biking, and integrated and inclusive public transport systems. Following the principle of leaving no one behind of the sustainable development agenda / SDGs, the inclusion of ready-to-use equipment and facilities that cater to people with disabilities and other special needs are vital in the process of building transport systems easily accessible, affordable, and inclusive, which makes the city more socially integrated and resilient.

To address climate change and reduce GHG and carbon emissions, we encourage the establishment of E-Mobility solutions in cities, where vehicles are to adopt the use of hybrid/electric power. Though the challenge of financial burdens remains at large, for E-Mobility to be incorporated into many developing countries, fostering partnerships, and international cooperation is essential for making e-mobility infrastructures and services.

Integration of state-of-the-art technologies and digitization of the transport infrastructures improve the safety, efficiency, and quality of the transport systems that can withstand the impact of internal and external disaster events. The complexity of the system and interdependency over the technology also makes the modern transport system more vulnerable (less resilient) if not well-considered resilience framework in overall policy, planning, infrastructure development, and operation. Addressing under-the-radar issues such as criminal and terror attacks and cyber-attacks are also vital and must not be overlooked to minimize the risk and vulnerability of transport infrastructures and services.

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[14] WPA3 is the most secured wi-fi network security as of 2022.

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Investigating the Impact of Mobility Apps on Transport Mode Usage: A Latent Class Cluster Analysis of App Users in Delhi, India

Kushagra Sinha and Sanjay Gupta

ABSTRACT

One of the significant drivers of climate change and its consequences in Indian cities can be attributed to the rapid increase in privately owned vehicles due to the lack of high-quality integrated mobility services, and it is anticipated that smartphone-enabled mobility services can potentially help in shifting people away from private vehicles, thus possibly leading to sustainable transportation. However, for most people in Indian cities, the smartphone apps use is a relatively novel trend, and the impacts of smartphone apps on the usage patterns of transport modes by users belonging to various socio-economic backgrounds are not known. So, the actual benefits of introducing such mobility services as an effort towards low-carbon mobility cannot be predicted. Considering this, the current study employs Latent Class Cluster Analysis to empirically investigate the effects of smartphone app usage on transportation choices in the National Capital Territory of Delhi by grouping users of various socio-economic backgrounds into latent classes based on their patterns of smartphone app usage, mode usage and attitudes. The revealed characteristics of the clusters, as well as the factors influencing an individual's likelihood of being classified into them have been examined, and some measures for encouraging sustainable transport choices have been recommended.

Key Words: *Mobility App Usage, Transport Mode Usage, Latent Class Cluster Analysis, Multimodality, Environment*

INTRODUCTION

The socio-economic progress of society is strongly influenced by the transport sector. Today, it would not be easy to live without modern transportation services. Almost all human activities are connected to this sector, including but not limited to connecting students to universities, schools, and other places of education, connecting employees to the workplace, connecting buyers and sellers, and facilitating social and recreational activities. However, as fossil fuels mainly fuel the sector, it has also become a major contributor to environmental issues, including emissions of Greenhouse Gases (GHGs). Around 25 per cent of global emission of Carbon Dioxide (CO_2) gas came from the transportation sector in the year 2016, which is a 71 per cent increase from 1990 levels, and road-based transport accounted for 75 per cent of all these transport emissions (International Energy Agency, 2018). In order to have a cleaner environment while promoting economic activity, there is a need to efficiently transport people, commodities, and services (Kwakwa, Adjei-Mantey, & Adusah-Poku, 2022), especially in the case of developing countries like India where urbanisation and rapid economic expansion have significantly increased the demand for mobility services (NITI Aayog & BCG, 2018). However, as passenger traffic increased significantly, the number of private cars rather than the use of public transport increased (Gupta & Garg, 2020). One of the significant drivers of climate change and its consequences on urban sustainability can be attributed to the rapid increase in privately owned motorized transport, the provision of road infrastructure and the lack of high-quality integrated mobility services in Indian cities.

Following the United Nation's Paris Agreement of 2015, India announced an Intended Nationally Determined Contribution (INDC) for reducing Greenhouse Gas (GHG) emissions from India's Gross Domestic Product by 33-35 per cent by the year 2050 compared to the 2005 levels (Kwatra, 2015) and low-carbon mobility is critical to achieving that (Dhar, Shukla, & Pathak, 2017). Policymakers in India are considering comprehensive measures, including technologies and policy measures for reducing emissions from transport sector. This covers a wide range of actions such as improving automotive technology and fuel economy, encouraging a move away from private vehicles and toward public transit and non-motorized transportation, and simultaneously lowering travel demand using travel demand management techniques. Technology plays a key role in this, primarily through recent advances in Information and Communication Technologies (ICT) and their applications in the transport sector (ESCAP, 2019).

In the last decade, ICT has become much more available in the form of handheld mobile devices. According to the latest figures, the use of mobile phones has grown exponentially, and India has 85 mobile phone connections for every 100 individuals (TRAI, 2022). These mobile phones have also evolved from an essential communication tool to trusted information, communication, search, and entertainment device known as a smartphone. Smartphone applications or “apps” are capable of providing quick access to previously unavailable transport-related information, including real-time data for enabling users to make informed mobility decisions. In Indian cities, smartphone app users are increasingly adopting apps to access various transportation services. People are increasingly utilising their smartphones to start a journey, guide a trip, check the departing time for the next bus, rail, or subway, hail a cab, or utilise app-based shared transportation services to access mobility "as required" (Shaheen, Chan, Bansal, & Cohen, 2015).

Many researchers and decision-makers are interested in smartphone-enabled transport services as an innovative way to enhance sustainable transportation systems. It is anticipated that using smartphone apps for reserving, scheduling, and paying for on-demand door-to-door services will reduce the need for consumers to use private vehicles, and possibly even delay or even forego purchasing a vehicle altogether, thus possibly leading to sustainable transportation (Bian, et al., 2021). For instance, work on such mobility services has already begun in India. The public agencies and industry partners are working together for developing a framework for introducing smartphone-enabled connected mobility platforms. This is being done with the aim of integrating all types of shared transportation services (including public transport) through a single app with multiple functions, including route/mode choices and payment gateways (Cities Forum, 2021). Because of rapidly expanding penetration of smartphone in all parts of the country due to decreased handset and data costs, along with other government initiatives like the ‘Smart Cities Mission’ (MoHUA, 2015), which aims to develop 100 prominent Indian cities that are meant to procure and integrate the most advanced technologies that the industry can provide to create a highly connected and technology-friendly infrastructure (Deokar, 2020) and ‘Digital India’ (MeitY, 2019) for improving access to the internet in all urban and rural areas, it is not going to be long when smartphone-enabled mobility services will start emerging even in non-metropolitan Indian cities.

However, the demand for smartphones and associated apps in Indian cities is still in the early stages, and it is unknown how they are influencing users' daily mobility habits (Brazil & Caulfield, 2013). Simply put, the actual benefits of introducing such cutting-edge smartphone enabled technologies as an effort towards low-carbon mobility cannot be predicted if it is not understood how the current mobility apps are already influencing the travel decisions of the users, since it then also becomes unclear how people from various socio-economic backgrounds would respond to them. According to research conducted in developed nations, the usage of such ICT-based gadgets has impacted everyday activities and travel decisions such as time of activities, start and finish times, selection of travel destination, selection of mode of transportation, route selection, and so on (Mokhtarian & Tal, 2013; (Kaplan, Monteiro, Anderson, Nielsen, & Dos Santos, 2017; and Windmiller, Hennessy, & Watkins, 2014). The adaptability of smartphone is transforming the way people are traveling on a daily basis. Instead of physically travelling, people may utilise numerous apps for business, shopping, banking, and other purposes. Smartphone apps could also become a popular resource for information regarding various locations and activities, cultural celebrations, and community activities, which can lead to visits to new areas and social gatherings. Smartphone users may use ratings and reviews to determine whether or not to visit new places. Users may be motivated to engage in community events as a result of easily accessible information about local activities (Khan, Habib, & Jamal, 2020). Examining the relationship between daily app usage and mobility patterns might thus give insights into the potential influence of smartphone app usage on people's mobility choices. Such research might assist policymakers in developing policies for smartphone-related travel enhancements and alternatives such as ridesharing, real-time information, shared mobility resources, and so on (Khan, Habib, & Jamal, 2020), contributing to a low-carbon future for urban transportation.

The study's aims are twofold in this context. First, it seeks to investigate the factors that considerably impact people' transportation decisions as a result of their app usage. Using a rich set of covariates, including socio-economic characteristics, app usage patterns, and attitudes, Latent Class Cluster Analysis (LCCA) has been employed to probabilistically classify users into groups that share similar transport usage patterns, while ensuring maximum heterogeneity of these patterns between groups. So, the variations across the transport choices of different user groups as a result of smartphone app usage have been assessed. Further, it also seeks to analyse these mentioned covariates as factors which affect the probabilities of individuals to belong to these clusters.

MATERIALS AND METHODS

Study Area

The National Capital Territory (NCT) of Delhi has been selected as case study area. It has compelling arguments for being considered a Case Study – deployment of almost all platforms and aggregators, a variety of transportation options such as the metro, rails, public buses, private buses, auto-rickshaws, and informal three-wheelers and the presence of significant policymakers and their ministries. As per the Census of India (2011), more than 18.9 million people (MHA, 2011) live in the city. The city has a relatively higher literacy rate of 86.2 per cent and the per capita income (INR 4,01,982) is also higher than other cities in the country (Planning Commission, 2022). Delhi's telecommunications network is well-established and with 52.4 million wireless customers, it has a high tele-density (TRAI, 2022). This makes this city the perfect location for introducing Smartphone apps for various travel requirements (Jamal, Habib, & Khan, 2017), and it already has several such apps operational (Table 1).

Table 1. Smartphone Apps for various Travel Needs available in Delhi

App Type	Travel Requirements	Examples
Mobility Apps for Trip Planning Activities	Deciding Departure Time	Map Services (Google, Apple, etc.)
	Deciding Trip Destination	BookMyShow, Zomato, etc
	Selecting Mode of Transport	Map Services (Google, Apple, etc.), One Delhi App, etc.
	Selection of Route	Map Services (Google, Apple, etc.)
	Communicating & Coordinating	Social Network Services, Chat Services, etc.
	Online Tasks	e-Tickets (IRCTC, BookmyShow, PayTM, etc.), smartcard recharge (Paytm, Phonepay, etc.)
Mobility Apps for other Travel impacting purposes	Reserving Taxis/Cabs	Ola, Uber, Rapido, Zoomcar, Volar, etc.
	Checking Bus/Metro Schedules	Map Services (Google, Apple, etc.), One Delhi App, etc.
	Navigation	Map Services (Google, Apple, etc.)
	Online Shopping	Shopping (Amazon, Myntra, etc.) Food Delivery (Swiggy, Zomato, etc.) and Quick Grocery Delivery (Swiggy Instamart)
	Virtual Activities	Banking (UPI, Internet Banking, etc.), Education (EdX, Byjus, Unacademy, etc.) and Utilities (Urban Company).
	Scheduling Meetups	Social Network Services, Chat Services, Video Conferencing (Facebook, WhatsApp, Zoom, etc.)

Source: Authors

Data and Variables

The primary data for this research was gathered through an online survey of smartphone users. Between September 2021 and December 2021, 530 participants who formed a representative sample for NCT of Delhi responded. Following types of information were asked –

- **Transport Usage:** As previously stated, Delhi has a diverse range of transportation options; however, this study concentrated on four main types of systems: personal vehicles (such as four- and two-wheeled motorized vehicles), public transit (including public transport and subway services), intermediate public transportation or "IPT" services (such as autorickshaws and battery-powered rickshaws), and app-based shared mobility services. Respondents were asked if they would utilise the aforementioned modes of transportation on a 5-point Likert scale, with responses - Never, Rarely, Sometimes, Often, and Always.
- **Socio-economic Data:** Personal information such as gender, age (users under the age of 18 were excluded from this study), educational qualification, and years of smartphone use were collected, as well as household details such as household composition (with and without children younger than 18 years),

household income, four-wheeler ownership, and two-wheeler ownership. All of these socio-economic data at the individual and household levels have been captured as categorised choices.

- **App Usage:** Smartphone users were asked how often they used travel-related apps, such as finding out when to leave for a trip, choosing destinations, choosing a mode of transportation, communicating with others, performing necessary tasks online rather than going somewhere specific, as well as other activities that had an impact on travel like checking public transit schedules, navigation, and more. A 5-point Likert scale with options - Never, Rarely, Sometimes, Often, and Always was used to collect the data.
- **Attitudes:** The dataset also includes respondents' levels of agreement with 12 statements regarding their attitudes on a 5-point Likert scale ranging between "Strongly disagree" and "Strongly agree." The asked statements are documented in Table 2.

Table 2. Statements for evaluating smartphone users' attitudes toward transportation choice

S. No.	Statements
1.	It does not matter what type of mode I use, as long as it suits my travel needs.
2.	I often compare different travel options and modes of transportation before starting a trip.
3.	To improve transport, it is essential to be able to easily combine different modes of transport, such as buses, cars, bicycles, or car sharing.
4.	I am willing to try new ways to travel
5.	It is uncomfortable to ride public transport with strangers
6.	Public transport lacks in cleanliness
7.	Use of public transport is important to preserve the environment
8.	I choose to use public transport or share a ride to reduce travel costs.
9.	I would prefer to enjoy the convenience of a car without owning it.
10.	I like privacy offered by a private car or bike
11.	People like me only use privately owned cars and/or bikes
12.	If there was a cheaper alternative, I would reduce my private vehicle usage

Methods

First, the common variance between the variables has been described using Exploratory Factor Analysis (EFA), which has been employed as a variable reduction approach (Williams, Onsman, & Brown, 2010). The SPSS software was utilised to carry out this analysis. Low factor loading statements—less than 0.5 in this study—have been deemed inactive and excluded from the model. So, apart from the first statement (factor loading of 0.4), all the others have been considered in the study. Further, Latent Class Cluster Analysis (LCCA) has been employed to probabilistically group smartphone app users into traveller groups, each of which is distinguished by a relatively consistent pattern of mode usage while maximising their heterogeneity across groups. Latent Gold software was used for the same. This model classifies users in accordance with an unobserved (latent) variable which explains the responses of users for a set of observed indicators (Molin, Mokhtarian, & Kroesen, 2016). The relationships between indicators, active and inactive factors, and the latent structure of the mobility types studied are depicted in Figure 1.

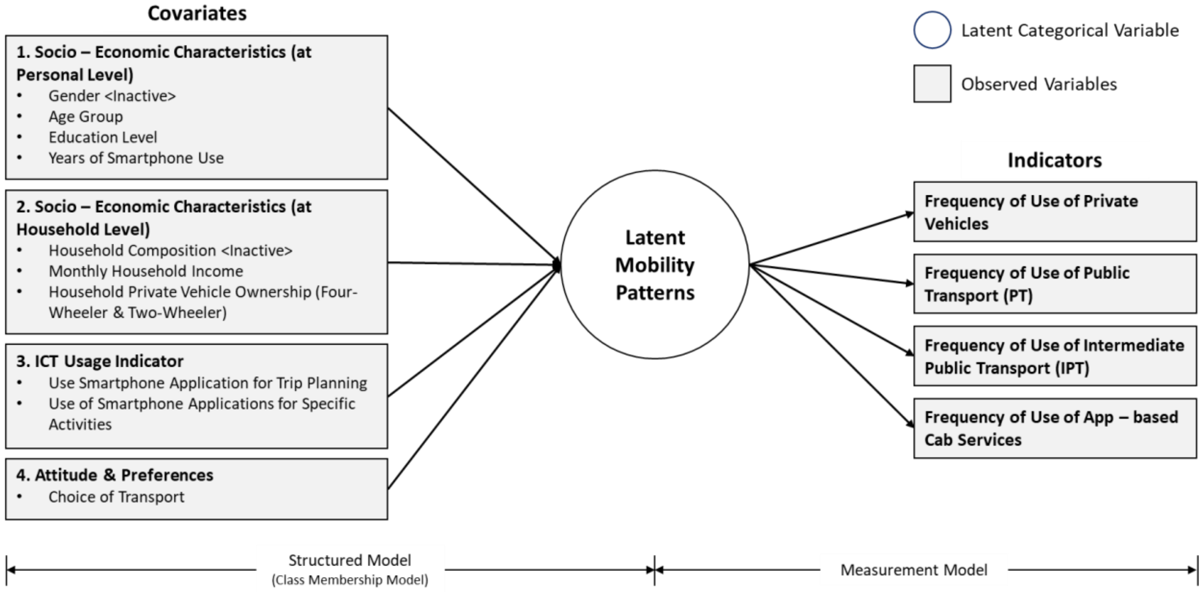

Figure 1. LCCA model with considered covariates, indicators, and latent mobility patterns

The LCCA attempts to classify people into potential (latent) groups by employing a variety of indicators that represent the distinct user behaviour of each class. This approach, unlike deterministic classification methods, calculates an individual's likelihood of belonging to a latent class. Based on the average frequency of usage of various means of transportation, each of these groups has a distinct profile (Lee, Circella, Mokhtarian, & Guhathakurta, 2020).

RESULTS

The stated analytic and modelling techniques were applied to the specified dataset, which represents the population of Delhi. First, the model was run in software numerous times with varying numbers of classes, and the best one has been chosen from among them (Section 3.1). Then, cluster - wise utilisation patterns of the considered modes of transport for different trip planning and travel influencing purposes have been shown (Section 3.3), which established technology penetration across consumers in diverse clusters. Further, class memberships have been shown, in which the evaluation of the aforementioned variables (socio-economic, app usage, and attitudes) as determinants that impact the likelihood of persons belonging to these clusters has been presented (Section 3.4).

Model Selection

The model was run four times in the Latent Gold software, with varied counts of latent classes (one to four), and the best model fit was chosen using the Akaike Information Criteria (Akaike, 1987) and the Bayesian Information Criteria and Bayesian Information Criteria (Schwarz, 1978). Low values for such global goodness-of-fit indicators have been related with improved model fit in the 3-cluster model. Within the three-cluster model, 41 per cent of respondents were assigned to Cluster-1, 34 per cent to Cluster-2, and the remaining 25 per cent to Cluster-3 (Figure 2).

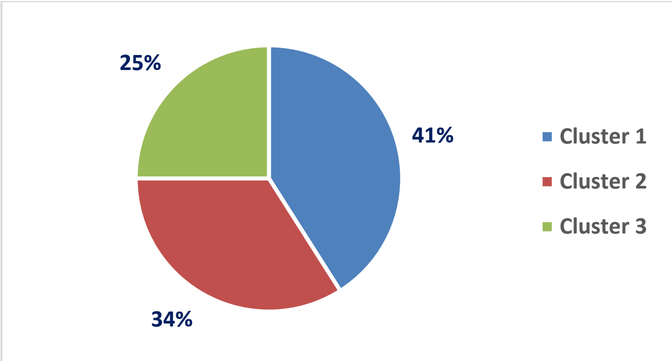

Figure 2. Proportions of samples grouped into three clusters using the LCCA model

Furthermore, the differences in transportation choices of different user groups due to app usage across all these clusters have been analysed, as have their distinct attitudes.

Pattern of Transport Usage

Figure 3 depicts the frequency patterns of respondents categorised into the three latent clusters based on their use of various forms of transportation in the National Capital Territory of Delhi. The deeper colour tones indicate more usage.

Figure 3. Transport Mode Usage Patterns by Cluster

Cluster 1 respondents were found to rely heavily on public transport services and intermediate public transport systems, have a low reliance on private automobiles, and do not utilise app-based cabs or taxis. Individuals in Cluster 2, on the other hand, have been found to be multimodal with considerable reliance on all modes. Finally, Cluster 3 respondents were seen to be more reliant on private automobiles. As a result, the three latent class clusters may be labelled as follows –

- Cluster 1: **Public Transport (PT) & Intermediate Public Transport (IPT) Users**
- Cluster 2: **Multimodal Travellers**
- Cluster 3: **Private Vehicle User**

These latent classes can now be used to group both active and inactive factors.

Pattern of App Usage

Figure 4 shows the frequency profiles of the usage of smartphone apps for various trip planning activities by the respondents clustered into the three latent class clusters.

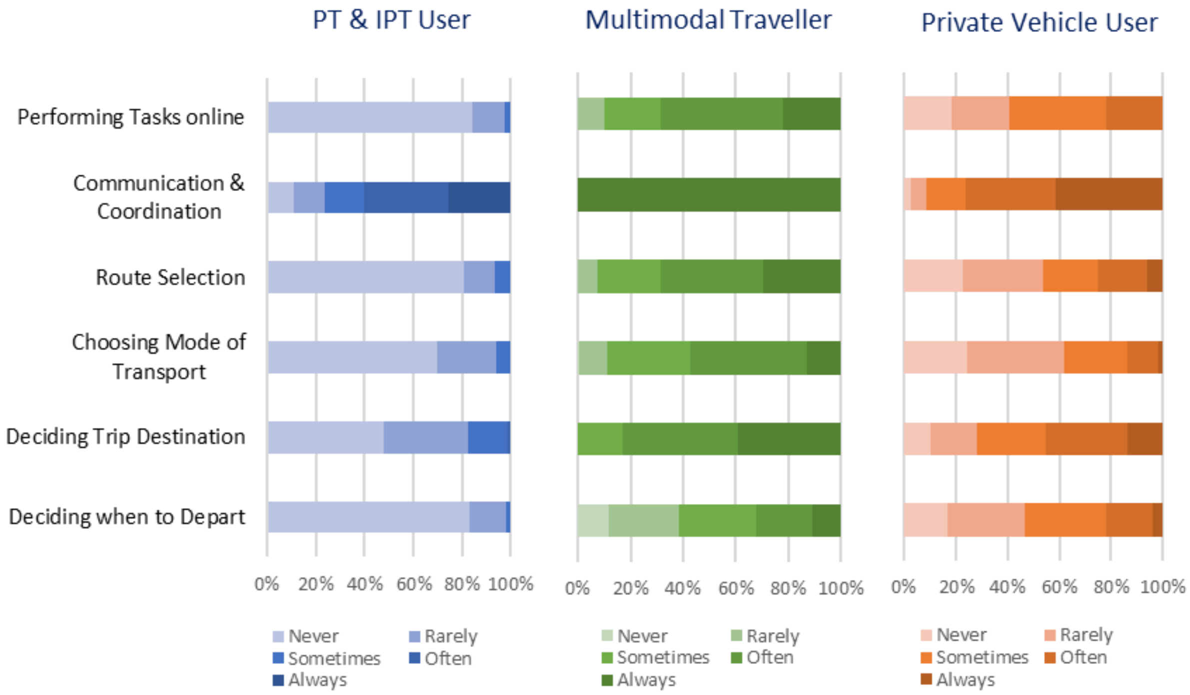

Figure 4. App usage pattern for trip planning purposes by cluster

The cluster-wise smartphone app usage pattern for trip planning is shown below –

- **PT & IPT User Cluster:** As previously indicated, respondents have a relatively stronger reliance on coordination and communication, with the majority stating that they always or often utilise them. Most respondents stated that they never use smartphone apps to decide their departure time, select a mode of transportation, route, or conduct online activities. In contrast, a proportionally higher percentage of users reported that they only seldom utilise apps to choose their vacation destinations.
- **Multimodal Traveller Cluster:** All the respondents indicated that they always use communication and coordination, indicating a very high dependence on these skills. Most respondents said they frequently or always use smartphone applications to decide on travel destinations, select a mode of transportation, routes, and perform activities online. The majority of respondents stated that they occasionally use apps to decide when to leave.
- **Private Vehicle User Cluster:** Respondents' reliance on apps for coordination and communication is strong. Most users use apps to decide their departure time, select a transportation mode, and perform tasks online, with a huge majority reporting ‘Rarely’ to ‘Sometimes’ usage. The majority of respondents said they use apps ‘Sometimes’ or ‘Often’ to choose their travel destinations.

Figure 5 shows the frequency profiles of the usage of smartphone apps for other travel impacting purposes by the respondents clustered into the three latent class clusters.

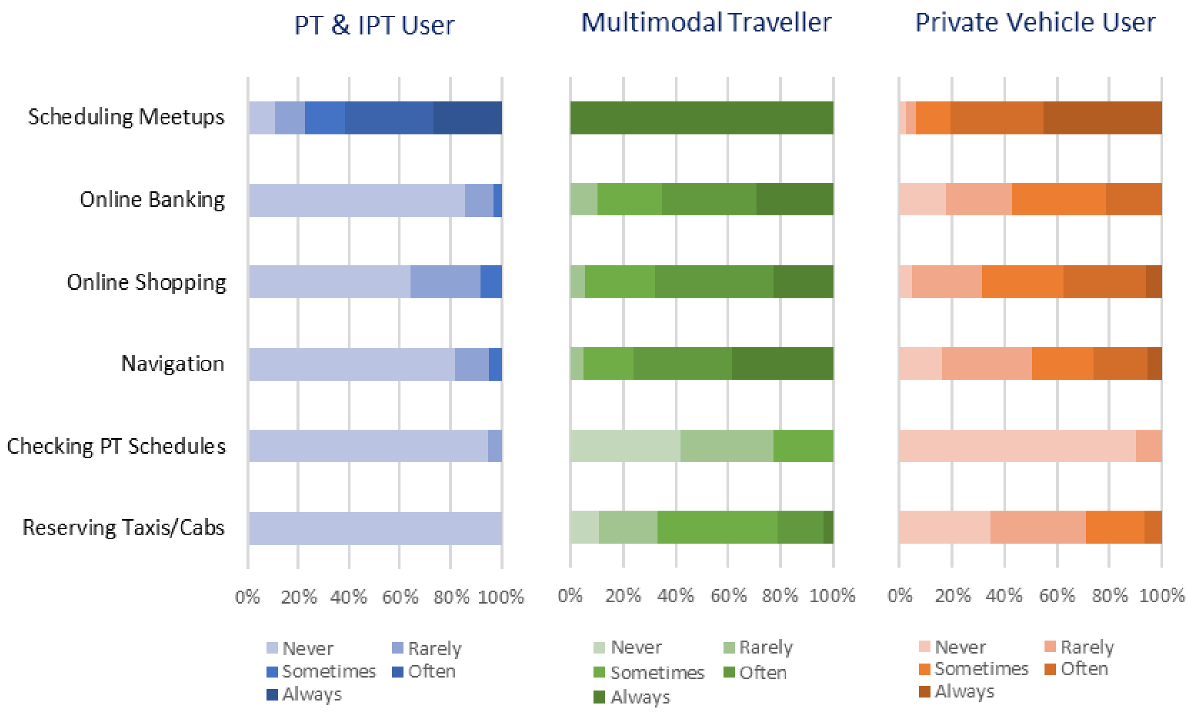

Figure 5. App usage pattern for other travel impacting purposes by cluster

The cluster-wise smartphone app usage pattern for other travel impacting purposes is shown below.

- **PT & IPT User Cluster:** The users in this cluster stated that they never use apps to make taxi or cab arrangements. As previously stated, respondents had a strong reliance on meetup scheduling, with the majority reporting that they do so "Always" or "Often". The vast majority of respondents claimed that they never use smartphone applications for internet banking or navigation services. In contrast, a bigger number of users have reported that they only use apps for online shopping occasionally. The respondents claimed that they depended on checking PT schedules the least.
- **Multimodal Traveller Cluster:** All respondents stated they 'Always' use meetup scheduling, demonstrating a very high dependence on it. Most respondents said they occasionally use smartphone applications to make taxi/cab reservations. For examining PT schedules, less reliance on apps is seen, although it is still higher than in other groups. A significant proportion of respondents said they rely heavily on apps for navigation, online shopping, and internet banking.
- **Private Vehicle User Cluster:** More than Cluster 1, most respondents indicate less reliance on apps for booking taxis or cabs. Most users use apps for deciding departure time, selecting a mode of transportation, and doing tasks online, with a huge majority reporting "Rarely" to "Sometimes" usage. Most respondents said they use apps "Sometimes" or "Often" to choose their trip destination.

As per the assessment of both categories of app usage, it has been found that users who rely less on apps are more likely to be grouped as PT & IPT users (Cluster 1), users who rely more on apps are more likely to be grouped as multimodal travellers (Cluster 2), and users who rely on apps moderately are more likely to be grouped as private car users (Cluster 3).

Class Memberships

In this section, an attempt has been made to analyse the aforementioned covariates as influencing factors on people's probabilities to belong to the latent class clusters of travellers.

Socioeconomic Characteristics

The likelihood that respondents will be placed in a cluster based on their socio-economic characteristics has been discussed in this section. The characteristic-wise cluster probability are as follows –

- **Gender:** Figure 6 shows that the probability of being grouped as a PT & IPT user for respondents who were both male and female was somewhat higher than that of multimodal travellers and much higher than that of private car users (41.5 per cent and 41.6 per cent, respectively). Gender, however, has been considered as an inactive covariate, meaning that it does not contribute to the model and is only used to evaluate the full set of socio-economic variables, due to nearly identical probabilities.

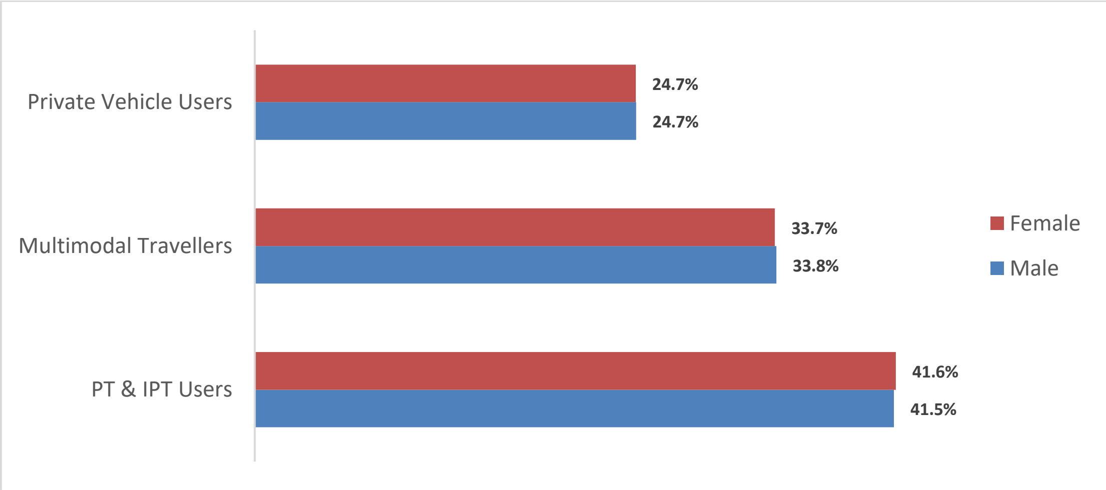

Figure 6. Gender - wise Cluster Probabilities of Respondents

- **Age:** Figure 7 illustrates that there was no probability of grouping younger users (18 to 34 years old) as private automobile users, but there was a greater likelihood (60 per cent) of grouping them as multimodal travellers. The likelihood that a respondent in the 35 to 44 years age group will utilise a private vehicle or PT & IPT is equal to 40 per cent for each respondent. While respondents aged 45 to 54 years and 55 to 64 years had a greater likelihood of being grouped as private automobile users (60 per cent and 56 per cent, respectively), respondents aged 65 and above have a high probability of being grouped as PT & IPT users (60 per cent).

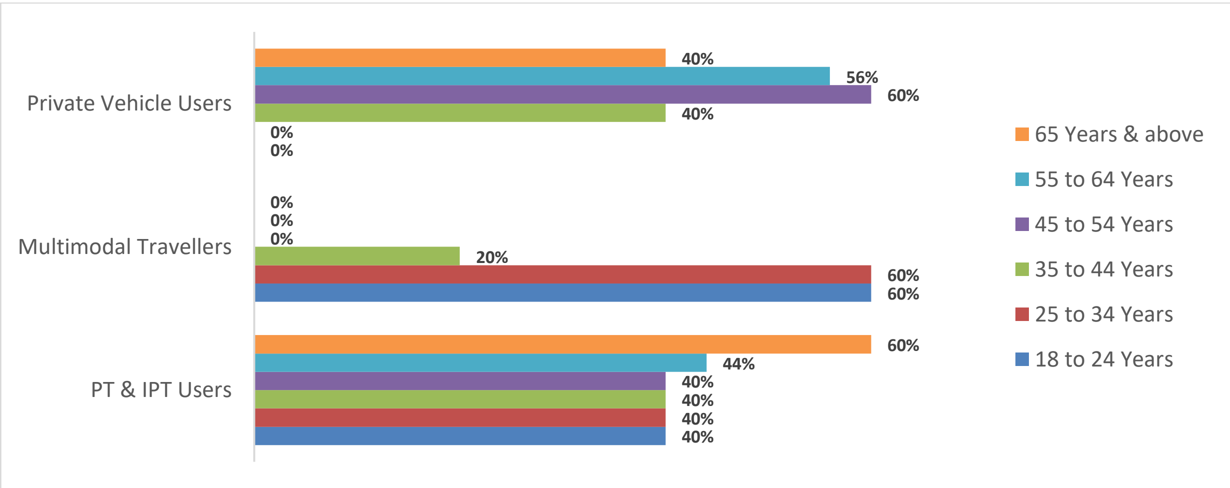

Figure 7. Age Group - wise Cluster Probabilities of Respondents

- **Educational Qualification:** As shown in Figure 8, respondents with higher level of education have a higher probability to be grouped as multimodal travellers (71.7 per cent), while respondents with lower educational backgrounds are more likely to be categorised as PT and IPT users (81.7 per cent).

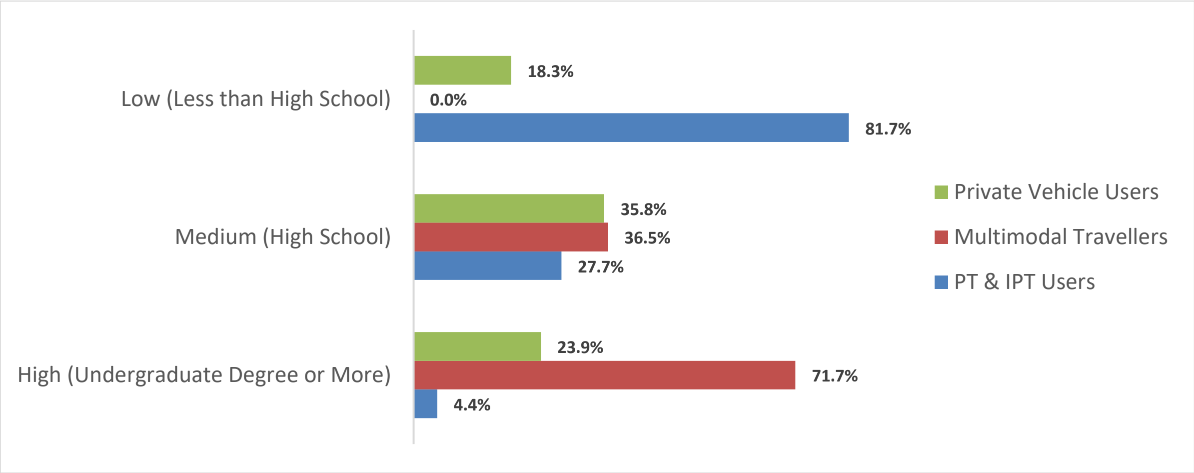

Figure 8. Educational Qualification - wise Cluster Probabilities of Respondents

- **Years of Smartphone Usage:** As demonstrated in Figure 9, experience with smartphone usage has a substantial impact on app use, and all users with less than three years of experience have been grouped as PT & IPT users. Although users with 3 to 5 years of smartphone experience have a high likelihood (86.9 per cent) of being grouped as PT & IPT users, there is also a small likelihood (13.1 per cent) of being grouped as a multimodal traveller. Users with more than five years of smartphone experience had a 47.9 per cent likelihood of being grouped as a multimodal user, a 37.9 per cent likelihood of being grouped as a private car user, and a 14.2 per cent likelihood of being grouped as PT & IPT users.

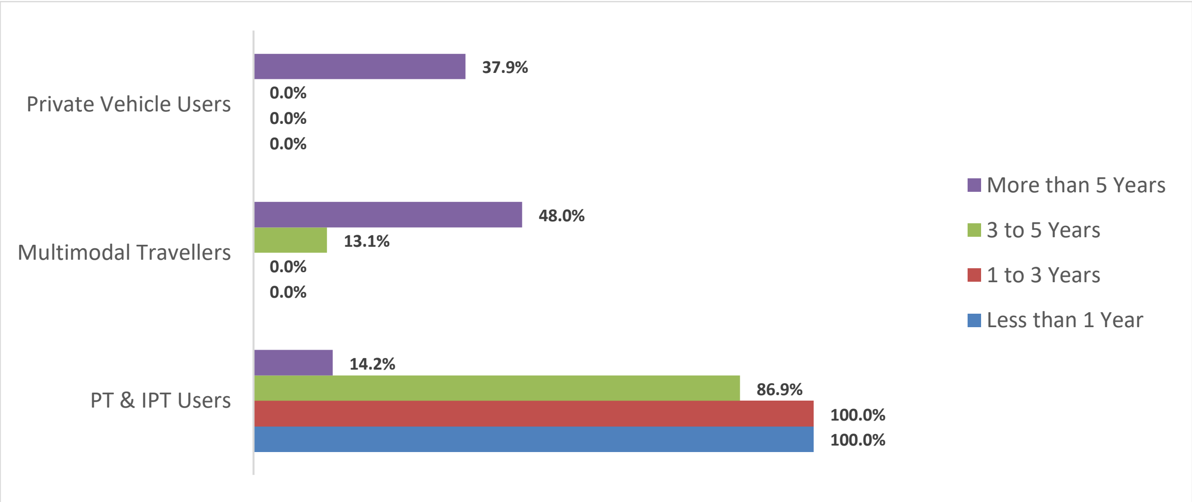

Figure 9. Smartphone experience - wise Cluster Probabilities of Respondents

- **Household Composition:** This has also been considered as an inactive covariate. According to Figure 10, respondents having children under the age of 18 had a slightly greater likelihood (36.3 per cent) of being grouped as a multimodal traveller, whereas those without children under the age of 18 have a greater likelihood (46.6 per cent) of being grouped as PT & IPT users.

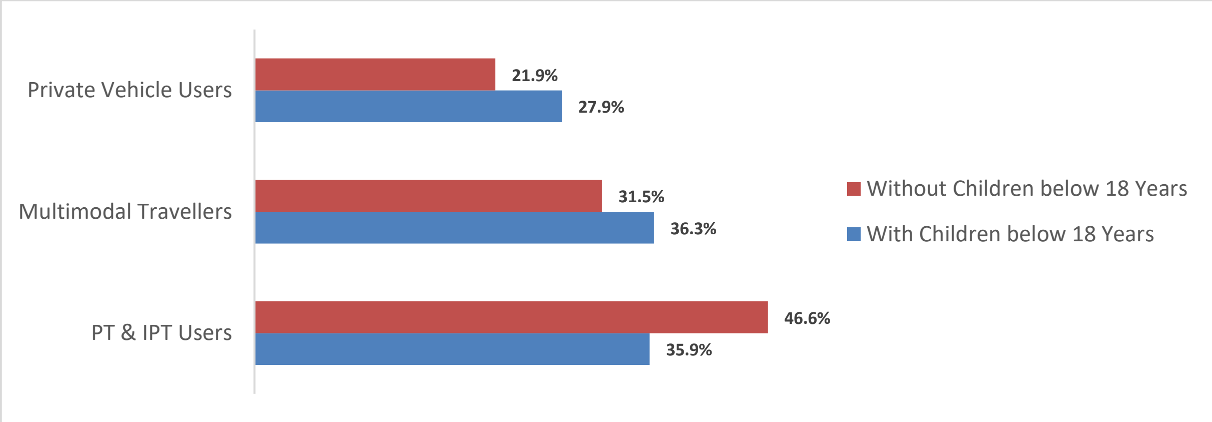

Figure 10. Household Composition - wise Cluster Probabilities of Respondents

- **Monthly Household Income:** As shown in Figure 11, respondents earning less than INR 20,000 per month were grouped as PT & IPT users whereas those earning INR 20,000 to 50,000 are more likely (49.1 per cent) to be grouped as multimodal travellers. Among high-income households, individuals earning INR 50,000 to 100,000 had a somewhat greater likelihood of being grouped as a private car user (50.9 per cent) than a multimodal traveller (49.1 per cent). Surprisingly, respondents from families earning more over INR 100,000 per month have a substantially higher likelihood of being grouped as a multimodal traveller (70.8 per cent).

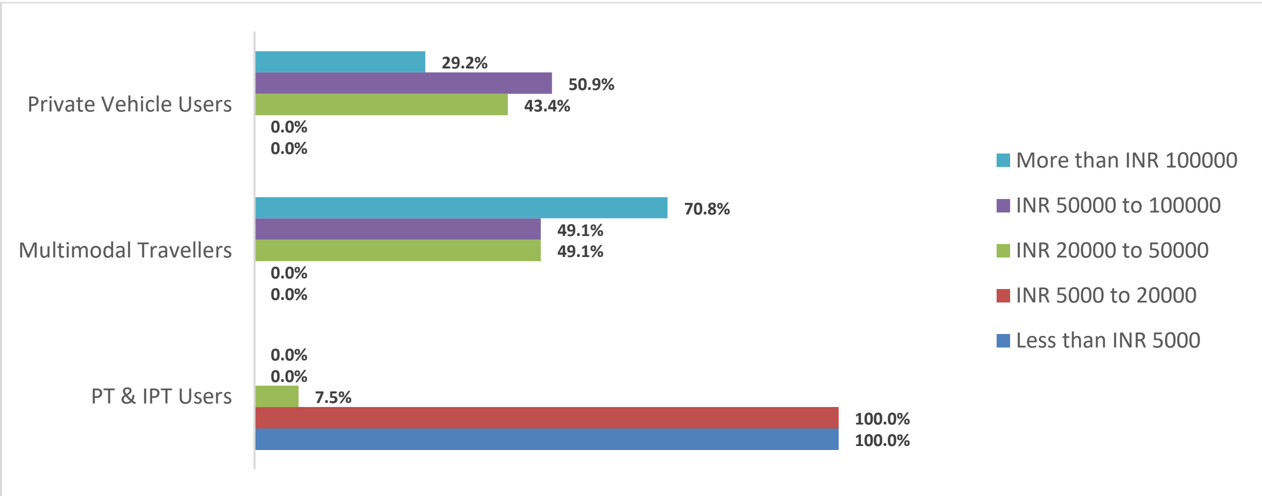

Figure 11. Monthly household income - wise Cluster Probabilities of Respondents

- **Vehicle Ownership:** As shown in Figure 12, respondents from households without any vehicle ownership (four- or two-wheeler) have a very high likelihood of being grouped as PT & IPT users (91.8 per cent and 89.6 per cent, respectively). However, owning even a single four- or two-wheeler guarantees that household have a high likelihood of being grouped as private vehicle users (48.9 per cent and 38.9 per cent, respectively) and a considerable probability of being grouped as multimodal users (47.6 per cent and 36.1 per cent, respectively). Respondents from households with more than two automobiles are more likely to be grouped as private vehicle users.

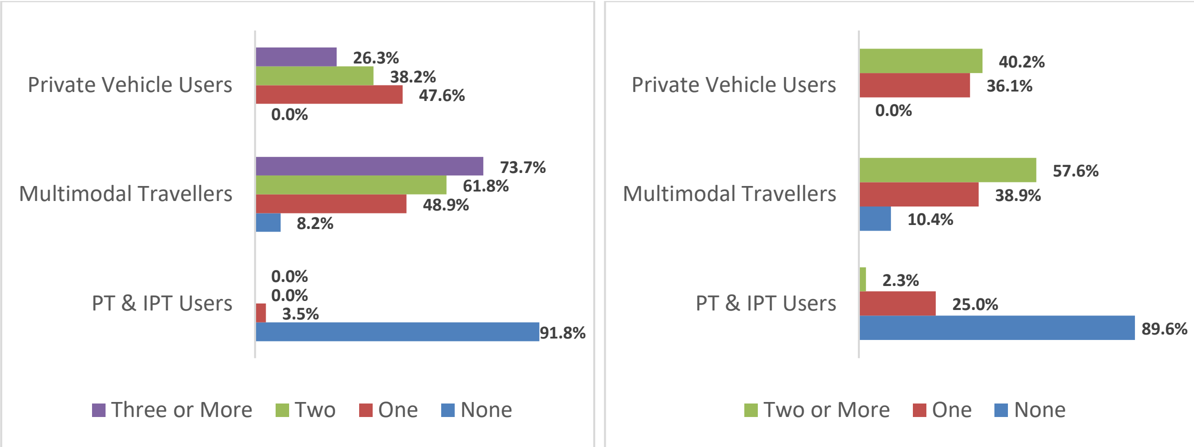

Figure 12. (a). Four – wheeled and (b). Two - wheeled private vehicle ownership - wise Cluster Probabilities of Respondents

Attitudes

The attitudes of users grouped under various latent class clusters have also been assessed in this section. Figure 13 shows the cluster-wise mean scores (weighted) for statements related to the choice of travel from exploratory factor analysis. Statements omitted from the LCCA model have also been included here to provide a complete picture of all the aspects under examination.

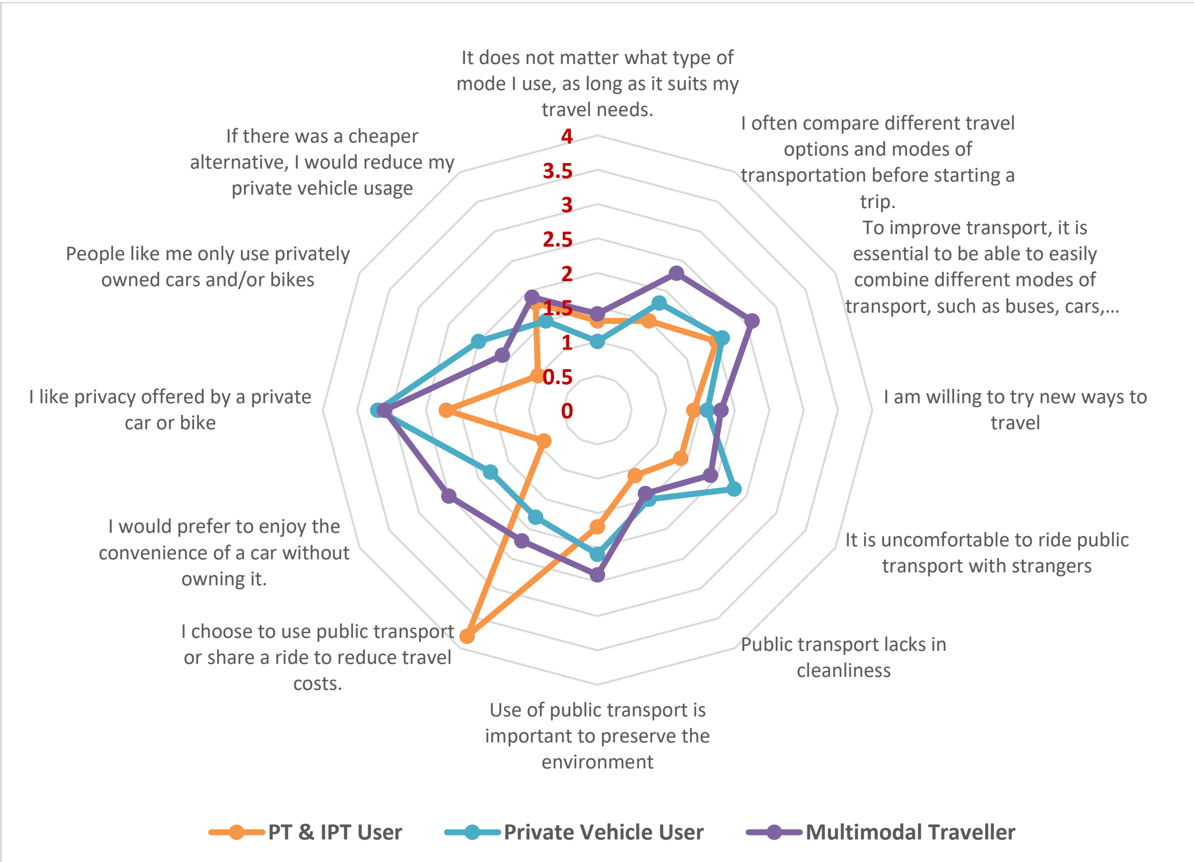

Figure 13. Cluster-wise mean scores (weighted) from EFA for choice of travel

A very high probability exists that respondents who assess travel alternatives, pick a mode of transportation based on their needs, and are open to trying new modes of transportation will be grouped as multimodal travellers who highly value multimodality. As per the responses, these users are pro-environment, who although find it unpleasant to travel with strangers, are still most inclined to reduce their dependency on vehicles if a less costly choice is available, particularly one that can provide the conveniences associated with car ownership without actually owning one. To reduce the expense of the journey, they contemplate utilizing shared mobility services and public transit. However, if a respondent is extremely cost-conscious, he or she is more likely to be grouped as a PT & IPT user who has the most expressed disagreement with all the statements. Users that indicate a strong desire for owning a private car, are less comfortable utilising public transportation, and are only somewhat receptive to testing new options are more likely to be grouped as private vehicle users.

DISCUSSIONS

The study's primary findings are presented in this section, along with some policy recommendations for each latent class cluster.

- Respondents who primarily rely on using public transportation and intermediate public transportation belong to the ***PT & IPT User*** cluster. It consists of either younger or extremely old individuals who have less education and come from low-income families. They are less accustomed to using smartphones and rely less on apps to meet their transportation demands. These users are captive to their mode of transportation because to their susceptibility to the cost of travel, and they are unwilling to shift to another mobility option unless it is more affordable than their current system and is technologically accessible to them. Thus, additional considerations like cleanliness, comfort, privacy, and ecological friendliness are not considered by them while making decisions. As a result, policymakers must ensure that existing forms of public transit and IPT are not undermined while implementing smartphone-oriented mobility systems. Such innovative systems must actually be integrated with the existing transit options to provide passengers with additional options. If provided incentives, such as enhanced smartphone familiarity among users as well as cheaper mobility alternatives, these users may even shift to more contemporary travel platforms.
- Respondents who opt to travel using a variety of transport modes depending on their needs are included in the ***Multimodal Traveller Cluster***. It mostly consists of highly educated younger users from middle- and upper-class families. They have a lot of smartphone experience, and they rely heavily on apps to meet their transportation demands. They frequently compare the various travel options at their disposal, including the mode combinations for their journeys, and they're even open to experimenting with new mobility options. Despite their minor discomfort with the idea of riding with strangers and their concern with the cleanliness of public transportation, they do recognise the importance of public transit and are also opened to using the shared mobility services, which may allow them to enjoy the convenience associated with owning a private vehicle without having to actually own one. Because cost of transport is not a key concern, users in this group can potentially become early adopters and prominent users of the emerging smartphone-based mobility services while also reducing their dependence on private automobiles in favour of other modes of transportation. Given their attitudes towards conventional types of transportation, we may also expect them to (slightly) reduce their usage of public transit by shifting to app-based on-demand alternatives. Campaigns to raise awareness can assist this group in moving away from private transportation while also preventing significant shifts away from the use of public transportation due to environmental sensitivity by focusing on the practical advantages that app-based transport services offer.
- Respondents who rely on private forms of transportation make up the ***Private Vehicle User*** cluster. It consists mostly of middle-aged to elderly users from middle- to high-income households. They have a fair amount of smartphone experience, and depending on the situation, they use apps with a fair amount of dependence. Although some of the users in this category do see the value of public transportation for protecting the environment, they are less likely than multimodal users to experiment with new modes of transportation since they find it so uncomfortable to ride with strangers. In contrast to using public transportation, they are more likely to own a car and only moderately open to trying new services. Cost is not an issue for them, but changing their behaviour is exceedingly challenging with this group. Prior research suggests that new mobility options for these users ought to only be offered as a replacement for current cars when no private option is available (Paundra, Rook, Dalen, & Ketter, 2017).

CONCLUSIONS

The transportation sector is mostly powered by fossil fuels and contributes to environmental consequences such as greenhouse gas emissions. Policymakers are contemplating a wide range of measures, such as technological advancements and policy measures, low-carbon mobility, and technologies that play an important part in this process, primarily using ICT in the sector. Smartphone applications, or "apps," are examples of such innovation, and they have contributed to the development of an ecosystem of smartphone-based mobility services. The market for smartphones and related apps, however, is still growing, and it is unclear how these ongoing changes and developments will affect the user's typical mobility patterns in the future. Examining the association between app usage and mobility can thus offer insight into the potential influence of smartphone app use on people's mobility choices. In this context, this study makes use of latent class cluster analysis to probabilistically group smartphone users in Delhi into three traveller groups (or clusters), each of which is distinguished by similar usage while maximising heterogeneity between groups. Respondents in Cluster 1 had a very high dependence on public transit and intermediate public transportation, a very low dependence on private vehicles, and no usage of taxis/app-based taxis. Cluster 2 respondents, on the other hand, are extensively reliant on various modes of mobility. Finally, cluster 3 respondents depend more significantly on private automobiles.

In addition to grouping travellers into the latent class clusters, an attempt was also made to analyse the variables as factors impacting people' probabilities of belonging to these clusters, especially for multimodal users with high app usage. In comparison to PT and IPT users, male and female users were observed to be less likely to be classified as multimodal travellers. Younger users are more likely to be grouped as multimodal travellers, while older users are less likely to be grouped as private vehicle users. Additionally, those who have greater education are much more likely to be grouped as multimodal travellers. Experience with smartphones has a substantial impact on how people use apps, and users who have used a smartphone for longer than five years are more likely to be grouped as multimodal users. Respondents from households with children are somewhat more likely to be grouped as multimodal travellers. Respondents belonging to households with incomes ranging from INR 20,000 to INR 50,000 per month are much more likely to be grouped as multimodal travellers. Among high-income households, ones with monthly income between INR 50,000 and INR 100,000 are more likely to be grouped as private car users than a multimodal traveller. However, respondents from households earning more over INR 100,000 per month are far more likely to be grouped as multimodal travellers. Vehicle ownership (four- or two-wheeled) implies that the users have a higher probability of being grouped as a user of private cars, and a very high probability of being grouped as a multimodal traveller. The multimodal travellers assess their travel options, choose the mode that best meets their travel requirements, and are also willing to try new transport systems. These users are pro-environment, feel a bit uncomfortable travelling with strangers, and are most likely to minimise automobile reliance if a cheaper option is offered, particularly something that can provide the convenience of private forms of transportation like cars and bikes without owning one.

Encouragement of multimodality as a measure to reduce exclusive car use is seen as a critical component of transportation strategies aiming at decreasing greenhouse gas emissions, such as CO_2 and targeted policies for the various user groups classified under the three clusters can help in achieving low-carbon mobility. Policymakers should ensure that new smartphone-enabled mobility platforms are integrated alongside existing public transit options as an extra option for identified user groups of PT and IPT User Cluster. These users may be willing to switch to modern travel platforms if given the correct incentives, as well as increasing experience with smartphones and cost-saving solutions. The identified Multimodal User Cluster user groups can (slightly) reduce their use of public transportation by shifting to app-based services as early adopters, and travel awareness campaigns could really help this group switch away from private transportation whilst also attempting to avoid significant departures from public transit usage based on environmental sensitivity. It is difficult to induce a behavioural adjustment in the Private Vehicle User Cluster, and research recommends that new mobility alternatives for these users should be presented as an option only in the absence of a private car, rather than as a total vehicle replacement strategy.

However, these initiatives are based on the assumption that increasing multimodality will assist to cut emissions. People, in contrast hand, may struggle with the multiple payment and ticketing systems and applications necessary while utilising the many kinds of transportation that people need in their daily life. When presented with numerous alternatives and sources, accessing, and transferring between various modes of transportation, in addition to locating relevant information, can be daunting. Smartphone-enabled mobility solutions may give an integrated solution to these complex user demands. Although environmental consciousness does not seem to be a necessary aspect of this type of system's adoption and implementation, it may be argued that such systems can provide value to customers by increasing dependability, cutting prices, and promoting multimodal travel. It may also help developing nations establish more sustainable transport systems by making mass transit more attractive and promoting modal shifts.

These new transportation systems and regulations are especially noteworthy since they are tied to Goal 11 of the Sustainable Development Goals – "*Make cities inclusive, safe, resilient, and sustainable*", as a reduction in air pollution from the transportation sector allows for a better quality of life as well as the sustainable growth of urban centres and their residents. Furthermore, in relation to the Paris Agreement's goal of limiting global temperature rise to well below 2 degrees Celsius above 2005 levels, the planned reduction in emissions from the transportation sector because of implementing app-based mobility platforms contributes to Goal 13 of the Sustainable Development Goals – "*Climate Action*", which encourages limiting the impacts of climate change by reducing greenhouse gas emissions.

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The Green Port Strategic initiatives in Emerging Countries to Support Sustainable Maritime Transport

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ABSTRACT

The global ambition to achieve a limit of 1.50C temperature rise has urged many countries to prepare National Determined Contribution as a climate change intervention by implementing a decarbonisation policy. The net-zero strategy of developed nations is expected to be superior to developing countries with technology limitations. The vital role of ports as a nodal supply chain in reducing air pollution, GHG emissions, and carbon emissions from shipping have been recognised. Therefore, this study aims to create green port strategic initiatives in emerging countries based on their readiness to support sustainable maritime transport. For instance, IMO guides maritime operators to implement the 0.5 per cent sulfur limit under MARPOL Annex VI, which forces this company to take operational, technical, and financial measures to collaborate globally. The research uses mixed-method research to explore risk, challenges, and readiness for sustainable port future development. The three sustainability dimensions: economy, environment, and social, contributed as performance indicator criteria. The study will guide the port operator in implementing a strategic framework that encourages green port development in emerging countries. These initiatives aim to reduce carbon emissions and promote unified port waste management, shore power systems, and a cost-efficient operational system that transforms a conventional port into a green port.

Keywords: *sustainable maritime transport, green port, decarbonisation, emerging countries, international trade, climate change*

INTRODUCTION

The global temperature in 2021 increased at an alarming rate, about an average of 1.11 degrees Celsius (World Meteorological Organization, 2022) since the pre-industrial baseline (1850-1900). The revolution industry and its greenhouse gas (GHG) emissions have contributed to global warming. The following gas such are Carbon-dioxide (CO_2), methane (CH4) nitrous oxide (N_2O), methane (CH_4), nitrous oxide (N2O), and chlorofluorocarbons (CFCs) and water vapour (H_2O) (KPMG, 2021). Consequently, the world might experience significant climate change impacts sooner than predicted. By that, the UN Secretary-General described the 2021 IPCC WG1 report as a code red for humanity (PWC, 2021). Global warming exposed hazards, especially in coastal regions with the Sea Level Rise (SLR), which highly impacts the socio-economics aspects of future population and challenges economic growth and performance, including the port and shipping sectors. Higher SLR combined with future extreme storm surges, waves, and tides could result in devastating extreme sea levels (ESL), threatening seaports worldwide (UNCTAD, 2021). Worsen quality of air, water, and ecosystem are some of the implications of climate change, as well as extreme weather, chemical exposure, and decadency in public health quality. Extreme sea level is predicted to occur once a century (could also be once in ten years for some areas) if the global temperature warms to 1.5 degrees Celsius.

The Paris Agreement's decision resulted in all the countries' intent to issue National Determined Contributions (NDC) within the time frame up to 2030. These NDCs reflect the ambition, coverage, condition of the GHG mitigation pledge, and market strategy to achieve those initiatives (UNEP, 2021). Developed nations' climate change mitigation strategy is expected to be superior to developing countries with technology limitations. Emerging countries' strategies to adapt to climate change may differ in meeting the net-zero carbon ambition. Those strategies should be applied specifically for the industry with international impact relations. With more than 80 per cent of the world's trade commodity being carried by sea (UNCTAD, 2021), ports are crucial for global trading development, supply chain, and national economy. During the COVID-19 pandemic, there was a dip in carbon emissions. There are varies for each country; for example, carbon emissions for China rose about 1.3 per cent in 2020; the USA (10 per cent); EU27 (10 per cent); India (6.2 per cent), with a good outcome of carbon emissions dropping about 20 per cent for international transportation for shipping and aviation industry (UNEP, 2021). As the temperature gets warmer, many ports could experience more frequent ESL several times per year (UNCTAD, 2021).

Port is one of the critical elements in the international trading system. Any delays and disruptions at the port, including due to climate change effects, could result in socio-economic importance for the global economy and society. Enhancing the climate resilience of seaports and intermodal transport infrastructure is necessary to achieve sustainable development goals. As the gateway to global trade, the port plays an essential role in the countries' economic sector (Alamoush et al., 2022). Ports are designed with long lifespans assets hence requisite future climate change adaptation measures such as the recurrence of ESL, which would increase the risk of flooding at the facility; appropriate infrastructure design should be considered. Port should be resilient to climate change while contributing to reducing carbon emissions. The objective of this study is to use qualitative analysis to formulate a green port strategy and obtain the financial evaluation for the alternative strategy to develop a green port.

This study aims to provide a recommendation to the port operator for developing a green port. The authors investigate a suitable 'green port' strategy in emerging countries based on their readiness to support sustainable maritime transport. This paper divides into 5 sections; the first is the introduction to why this study is required. Section 2 discusses the challenges of developing green ports in emerging countries; Section 3 discusses the method used in this study; section 4 discusses the formulating strategies for green ports in the view of technology, economy and financial evaluation. Finally, in Section 5, the authors provide the recommendation and conclusion.

Challenges for Developing Green Ports in Emerging Countries

The study will only cover the developing green port in emerging countries as defined by the International Monetary Fund (IMF). IMF categorises the countries belonging to the emerging market based on the country's economy nominal GDP (population and its export market share), market access (country's external debt, global indices, international bonds), and income level (GDP per capita). The final score ranks the countries (Duttagupta, Rupa; Pazarbasioglu, 2021). The five weighted for scoring using the following equation:

Score: 40% x Nominal GDP + 15% x population + 15% x GDP per capita+ 15% x share of world trade + 15% of external world trade

Table 3: Emerging countries list

Continent	Countries
Asia	China, India, Indonesia, Iran, Malaysia, the Philippines, Thailand
America	Argentina, Brazil, Chile, Colombia, Mexico),
Africa	Egypt, South Africa
Europe	Hungary, Poland, Russia (Asia & Europe)
Middle East	Saudi Arabia, United Arab Emirates, Turkey)

Source: (Duttagupta, Rupa; Pazarbasioglu, 2021)

Table 3 shows the countries that fall into the emerging market group. For emerging countries, especially with islands structure, the impact of global warming consists of acidification, losses of coastal ecosystems, food and water security risks, and reducing the potential habitation of small islands (IPCC, 2022). The NDC in G20 members will affect each country's 'green strategy' adopted. This study will only discuss the emerging countries that are considered the most populated countries, such as China (growth rate 0.29 per cent), India (growth rate 0.95 per cent), and Indonesia (growth rate 1.00 per cent).

Table 4 shows Indonesia, China and India's National Determined Contributions (NDC).

Table 4: National Determined Contributions of Indonesia, China and India

Country	Original NDC	New or Updated 2030 NDC
Indonesia	Reduce GHG emissions by 29 per cent and 41 per cent (conditional) relative to business as usual	Reduce GHG emissions by 29 per cent and 41 per cent (conditional) relative to business as usual
China	• The peak of CO2 emissions by 2030 • Reduce CO2 per GDP by 60 – 65 per cent (relative to 2005) • Increase the share of non-fossil fuel for primary energy by 20 per cent • Increase forest stock volume by around 4.5 billion m3 by 2030	• The peak of CO2 emissions before 2030 • Reduce Co2 per GDP by 65 per cent (relative to 2005) • Increase 25 per cent of non-fossil fuel primary energy • Increase forest stock volume by around 6 billion m3 by 2030 • Increase the installed capacity of wind and solar panels to 1200 GW by 2030
India	• Reduce emissions per GDP by 33 – 35 per cent (relative to 2005) • Increase the share of non-fossil fuel for primary energy by 40 per cent (conditional)	N/A

Source: (UNCC, 2022)

As discussed earlier, port and international shipping are vital in global climate change action. The International Maritime Organization (IMO), as the regulatory body of the world's shipping industry, is committed to reducing greenhouse gas emissions (GHG) from international shipping. Many shipping industries' initiatives to limit climate change's impact support the sustainable maritime transportation system. The sustainable maritime transport concept is categorised into three dimensions: economy, social and environment. **Figure 14** illustrates the aspects that influenced sustainable maritime transport for each dimension.

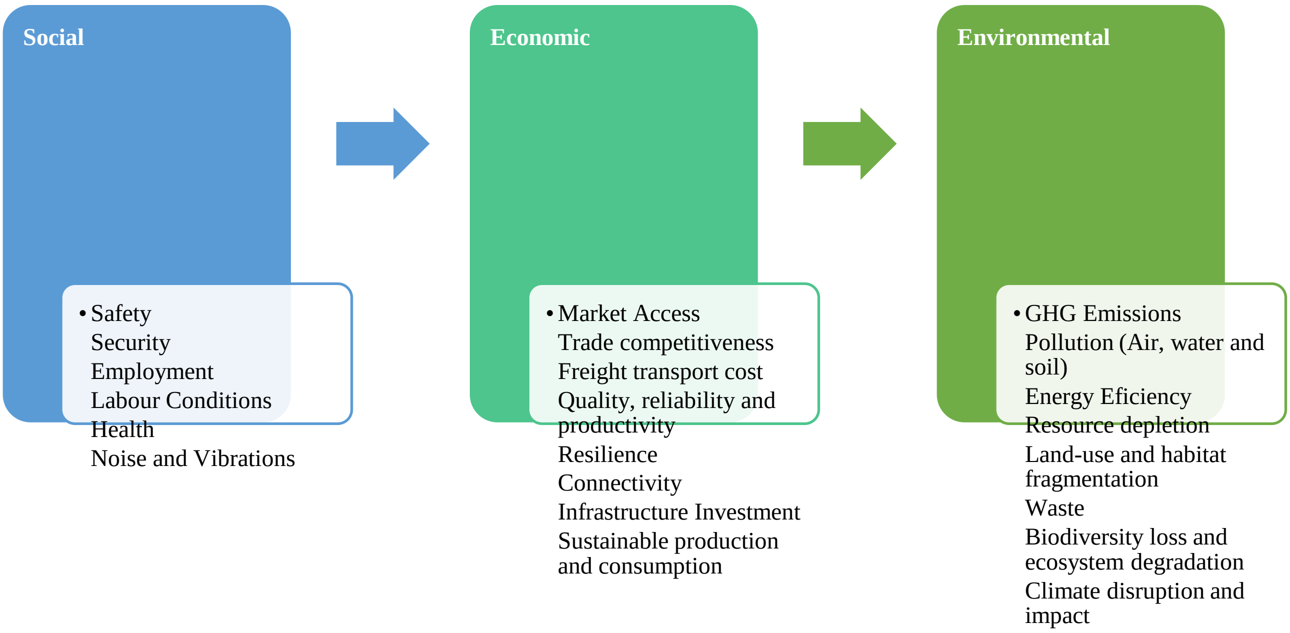

Figure 14: Sustainable maritime transport concept

IMO has set up specific regulations for shipping operators to increase their ships' energy efficiency and reduce carbon emissions from the marine transport ecosystem. There are two existing strategies to achieve green shipping targets, which are (1) implementing Ship Energy Efficiency Management Plan (SEEMP) and (2) moving toward cleaner fuel energy.

SEEMP provides a practical approach for ship operators and management companies to manage operations and fleet efficiency performance over time using the Energy Efficiency Operational Indicator (EEOI) as a monitoring tool. Energy Efficiency Operational Indicator (EEOI) is used as a monitoring measure to examine the ship's efficiency and gauge the effect of any changes in operation, such as improving voyage planning, frequency of propeller cleaning, and technical measures such as waste heat recovery system and a new propeller (Annex 19: Resolution Mepc.203(62), 2011). IMO first implemented the SEEMP and Energy Efficiency Design Index (EEDI) on January 1, 2013, to monitor the amount of CO2 and harmful emissions from ships. The objective of EEDI is to improve the hull design and machinery operations by increasing the ship's overall efficiency to reduce CO2 emissions. IMO 2023 will enforce the stricter rules for (1) all ships of 400 GT and above are required to attain Energy Efficient Existing Ship Index (EEXI) with a specific requirement of improvement; (2) Gas Carrier of 10000 DWT and above are required to improve their technical energy efficiency by 30 per cent from 2013; and (3) stricter improvement for Carbon Intensity Indicator (CII), based on actual fuel consumption and amount of CO_2 produced over distance travelled with 2 per cent incremental improvement and about 11 per cent efficiency achieved at 2026 increased compared to 2019 (IHS Markit, 2022).

The initiative is to replace the heavy fuel carbon with a cleaner energy source to reduce air pollution. For instance, IMO guides maritime operators to implement the 0.5 per cent Sulfur limit under MARPOL Annex VI, which forces this company to take operational, technical, and financial measures to collaborate globally. The enforcement of IMO Sulphur Cap 2020 has boosted demand for low sulphur fuel, modification engines, installation of sulphur scrubbers, and energy efficiency focus. The transition energy for the ship from fossil fuel to the cleaner energy source such as Liquefied Natural Gas (LNG), liquefied biogas (LBG), methanol, hydrogen, hydrotreated vegetables oil (HVO), ethanol and ammonia. The contribution of renewable energy technology, including wind for wind-assisted ship propulsion (WASP) and batteries (KPMG, 2021). The pathway to net-zero carbon in 2050 needs a realisation action to reduce about 40 per cent to 70 per cent of greenhouse gas (GHG) emissions compared to 2008 (IMO, 2021). MARPOL Annex VI, which regulates the procedure to prevent air pollution from ships, has defined specific Emission Control Areas (ECA) with stricter control related to sulphur emission and nitrogen oxides (NOX). The special areas specified by IMO are located within the Baltic Sea, North Sea, North American, Unites and States Caribbean Sea ECA (MEPC.1/Circ.778/Rev.3).

IMO collects a record of fuel oil consumption for vessels above 5.000 GT. The statistical record is used to generate the series of baselines. The sensitivity analysis can determine the fuel oil consumption against the ship's cargo capacity. From the record, we can obtain the carbon intensity indicator (CII) shows its energy efficiency rating. The first annual report on carbon intensity is planned to be done in 2023, while the first rating will be given in 2024. With this baseline in hand, it is expected to achieve a massive 30 per cent more energy efficiency for all new ships than those built-in 2014 or earlier by 2025 (IMO, 2021).

The trade-off for adapting the green port to comply with the legal framework set by IMO includes: (1) during vessel navigation and maneuvring such as a transition to low sulphur fuel, LNG fuels, and biofuels; (2) during vessel at berth by adding cold ironing; those activities provide the opportunity such as increasing demand of low sulphur fuels, creation of better environmental health, boost the innovation in emission abatement technology, with consequences increase the price of low sulphur fuels (Ölçer & Ballini, 2015). All 175 IMO members across the globe are obligated to comply with the IMO's shipping rules and requirements mentioned before.

The 'green port' concept is considered part of sustainable port development. PIANC defines the sustainability port as **"***A concept where the port stakeholders (port authority and port users) cooperate in developing and operating the ports based on economic green growth strategy and long-term vision nature philosophy, where port acting in its privileged position within the logistics chain, assuring that the development will accommodate the needs of future generations, for their benefit and the prosperity of the region that it serves***"** (PIANC Secrétariat Général, 2014). The latest trend of 'green' has become a marketing strategy tool to meet customer needs (shipping lines, shipping agents, industries), port organisation, and legal requirements. The strong foundation of maritime infrastructure will support the development of sustainable maritime transport. The port that able to adapt to climate change and an uncertain future. **Figure 2** shows the component of developing green ports.

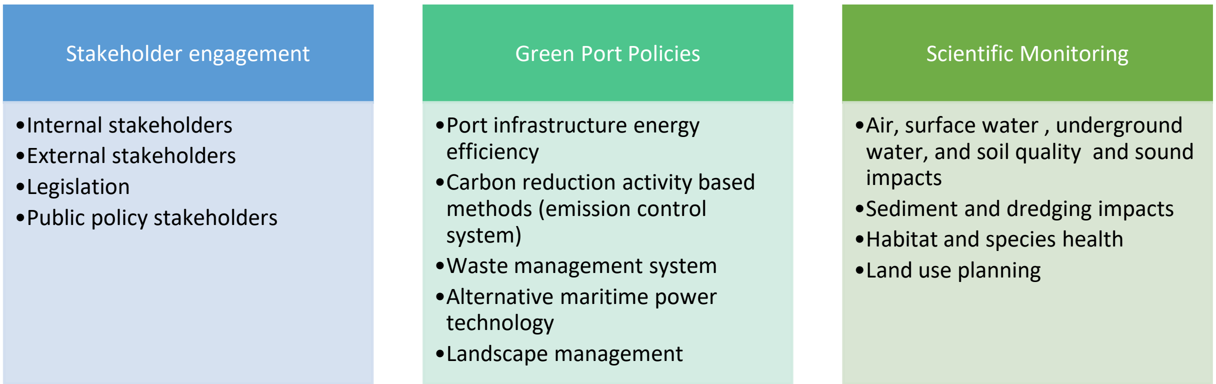

Figure 15: Developing Green Port Concept. Adapted from (Lam & Li, 2019; PIANC Secrétariat Général, 2014)

Some of the international projects have been initiated by the International Association of Port and Harbours (IAPH), which are so-called World Port Climate Initiatives (WPCI), such as (1) Carbon footprint strategy, (2) onshore power supply; (3) environmental ship index; (4) enhancement of intermodal transport system; (5) low emission yard equipment; (6) sustainability in lease agreement; and (7) LNG as fuel (PIANC Secrétariat Général, 2014).

The authors evaluate the suitable strategy to be implemented in the ports in the emerging countries with the most population, such as China, India and Indonesia. The authors used mixed-method research to evaluate the risk and challenges of investing in green ports.

Material and Methods

This study uses a combination of qualitative analysis and quantitative analysis. This study was limited to the container terminal only. The primary research question for this study is: *What is the suitable strategy for developing 'green' container ports in an emerging country?* **Figure 16** below shows the research methodology for this research.

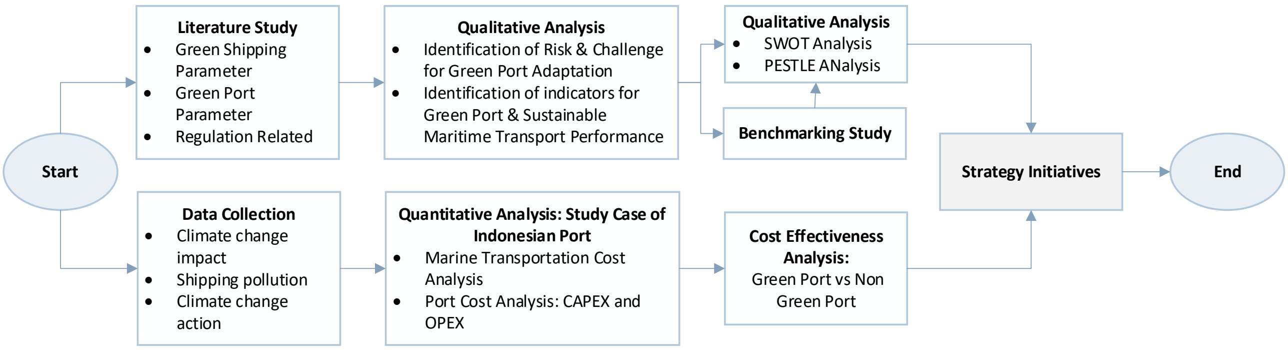

Figure 16: Research methodology

In the qualitative analysis, the authors perform PESTLE analysis and collect information related to 'green' strategies visioned by the port operator in China, India, and Indonesia. On the other hand, the quantitative analysis takes Indonesia as a study case to estimate the cost of pursuing the green port theme. The maritime profile of the countries. **Table 5** shows China, India and Indonesia's maritime profiles based on UNCTAD statistics for 2020.

Table 5: Maritime profile

Description	China	India	Indonesia
Population (millions)	1 439.32	1 380 004	273 524
GDP Growth	2.35%	-7.25%	-2.07%
Coast/area ratio (m/km2)	3.20	5.80	52.50
Container port throughput (TEU)	245 103 781	16 285 806	14 025 449
Ship recycling (GT)	195 486	5 026 416	31 577
Number of port calls	261 269	38 836	166 578
Top 5 port* (Port liner shipping's connectivity index)	Shanghai (120)	Mundra (45)	Priok (35)
	Ningbo (100)	Nhava Sheva (45)	Perak (25)
	Qingdao (75)	Hazira (35)	Tanjung Emas (15)
	Xiamen (65)	Pipavav (25)	Panjang (10)
	Yantian (62)	Chennai (20)	Makasar (10)

Source: (UNCTAD, 2020)

The authors discuss the cost between green and non-green ports in the quantitative analysis. This cost comparison consists of CAPEX, OPEX, and emission costs. The green innovation's feasibility will be evaluated by looking at economic parametric such as NPV and IRR for the proposed improvement strategy.

Result and Discussion

Qualitative Analysis

Developing green ports in emerging countries that still depend on fossil fuel faces higher risks and obstacles than developed countries already advancing towards electrification and renewable energy. Political risk (civil war, corruption, taxation shift, capital movement, and high depreciation) takes a massive toll on the investment of tangible assets. In contrast, financing is structurally complex with a long bureaucracy. Apart from that, in the emerging market, the gas energy infrastructure is only recently trending, which will cause a setback in decarbonisation technology development for about a decade or more than EU countries. PESTEL and SWOT analysis were used to determine the factors influencing emerging countries' 'green' port strategies.

Table 6 shows the PESTLE analysis to examine factors influencing green port development. The factor in the PESTEL influenced the consideration for building the green port strategy.

Table 6: PESTLE analysis for green port development

PESTEL	Internal Factors	External Factors
Political	• Geographical location • Human resources • Operation (OSHA) • Accounting and finance (tax, penalties, break)	• Materials/Product sourcing: Import quotas, tariffs, government support • International regulation
Economical	• Financing limitation • Supply chain issues and tariff • Economic growth	• Joint agreement • Customer demand • Business-to-business services

PESTEL	Internal Factors	External Factors
Social	• Demographics • Port employment and training • Staffing structure • Port Health and Safety	• Port stakeholder engagement • Community awareness of green and sustainability issues
Technology	• Port infrastructure and terminal • Information and technology • Performance monitoring	• Innovation of renewable energy technology • Carbon emission abatement technology
Legal	• Country NDC	• International legislation
Environmental	• Carbon emissions and air pollution • Waste management • Air and water quality	• Coastal ecosystem and biodiversities

Source: Authors' compilation

The authors compiled the green port strategies proposed by the port operators in China, India, and Indonesia, as shown in Table 5. Overall, the strategy focuses focusing on improving the environmental condition in the ports.

Table 7: Green Port Strategies

India	China	Indonesia
Aspect: Port Environment		
– Pollution control: installing port pollution monitoring level – Implementing a program of zero waste to landfill, zero incineration, zero unauthorised disposal, zero effluent discharge – Reduction of water pollution from a shipping company – Recycle and reuse water consumption by 2030 – Provision of rainwater harvesting within port premises – Reuse of port dredging materials – Setting up projects for energy regeneration from renewable energy resources to >60 per cent by 2030	- PRC aimed to reduce carbon intensity and formulation an action plan for carbon emissions to peak before 2030. - Improve management systems, strengthen monitoring and supervision, and promote fuel supply assurance. - Compliant fuel must be used in the inland river control area. - Development of new energy applications in ports and shipping - Noise and vibration reduction in handling activities - Dust control from bulk handling - Ecosystem protection (marine habitat, wetland, and coastal erosion)	– Monitoring air, sound, and water quality – Investing in water waste treatment facilities – Careful consideration for dredging activities (testing of sediment quality – Ensure efficiency of energy consumption – Greening program within the port – Prepare the conservatory area for coastal natural habitat and include it in the Port Master Plan – Efficient usage of air and materials
Aspect: Cargo Operation		
– Usage of energy-efficient equipment – Electrification equipment – Zero waste to unauthorised ship disposal	– Hydrogen-powered automated rail crane – Hydrogen fueled trucks – Hydrogen-powered intelligent terminal – All-electric container shipping application – Invest in dry ports – Invest in hinterland infrastructure – Collaboration with rail operators to develop intermodal services	– Minimising or reducing accidents at port (Lost Time Injury) – Minimise noise pollution during cargo operation – Create a mitigation plan for dangerous goods and hazardous and poisonous materials handling.
Aspect: Ship Operation		
– Implement of sewage treatment plant within the port – Developing shore connection facility for waste from ships – LNG bunkering facilities	- Implement plans and guidelines to control ship emissions and fuel contents. - Onshore power supply	– Implementing port reception facilities and port waste management system – Ensure the availability of dangerous waste treatment facilities – Obtained feasibility study for dredging material disposal system – Onshore power supply
(Indian Port Association, 2022)	(Asian Development Bank, 2021), (Du et al., 2018)	IPC, 2018

Source: Authors' compilation

Port environmental sector: From the table above, it can be seen that Indonesia and India are still trying to improve the existing system by reducing air/water pollution and investing in waste treatment facilities and performing dredging materials treatment. On the other hand, China was already moving toward developing new renewable energy facilities in the port and shipping system.

Cargo Operation sector: Indonesia and India are still improving the efficiency of their cargo operation system and minimising pollution from the cargo operation, while China has moved towards hydrogen-powered energy equipment, electrification equipment, and integrating intermodal services.

Ship Operation sector: India and Indonesia still need to improve their port waste management. All the countries have started to develop onshore power supply and LNG bunkering facilities to support green shipping.

The port operator should address all the environmental and sustainability issues to create strategic planning most suitable for the designated port. The sustainability or green port strategies should be tailor-made to meet stakeholder requirements. Developing green ports to support sustainable maritime transport requires government involvement to formulate suitable green port policies and stakeholders to constantly monitor port environmental and economic thresholds as part of adaptive port planning (APP). The green port policy adaptation in emerging countries should be aligned with the innovation and improvement of green shipping. The policy should support the sustainability goals for maritime transportation sectors.

Quantitative Analysis

The quantitative analysis examines the green port implementation in the sector of cargo services and ship services at the ports. Cargo services in the container terminal consist of (1) stevedoring, (2) cargodoring, and (3) stacking activities at Container Yard (CY). The ship services categories include (4) tug and pilotage and (5) berthing and mooring activities. The additional strategy involves the implementation of (6) renewable energy applications. In the green port scenario concept, the equipment is equipped with an electrification system. At the same time, it will be compared to a non-green port (fossil fuel-powered) and a green port (electrification). The assumption used for the scenario analysis for green and non-green ports shows in **Table *8***.

Table 8: Assumption for Scenario analysis

Variable		Value	Unit
Throughput		350 000	boxes/year
WACC		10%	
Operation Time		24	hours/day
		330	days/year
Operator Salary			
Stevedoring	$	472.33	/month/person
Cargodoring	$	269.90	/month/person
Stacker	$	472.33	/month/person
Salary Factor		13	times/year
Insurance		1%	Capital Cost/year
Maintenance		1.50%	Capital Cost/year

The scenario analysis to evaluate the implementation of green port innovation compared to the conventional port (non-green port such as follow:

<u>Cargo handling at the quayside (stevedoring)</u>

The stevedoring activities in the container terminal refer to the container handling on the quayside. It involves using lifting equipment such as a container crane (STS). The non-green port utilises container cranes using HSD for fuel; on the other hand, the green port occupies electric container cranes. .
Table 9 shows the difference between CAPEX and OPEX from the non-green and green ports in stevedoring services.

Table 9: CAPEX and OPEX for stevedoring services

Non-Green Port					Green Port				
CAPEX					CAPEX				
Variable	**Value**		**Unit**		**Variable**	**Value**		**Unit**	
Container Crane		3	units		Container Crane		3	units	
Productivity		22	box/hour/crane		Productivity		25	box/hour/crane	
		66	box/hour				75	box/hour	
Price	$	4.72	million/crane		Price	$	6.07	million/crane	
	$	14.17	million			$	18.22	million	
Economic Life		25	years		Economic Life		25	years	
WACC		10%			WACC		10%		
CAPEX	**$**	**1.56**	**million/year**		**CAPEX**	**$**	**2.01**	**million/year**	
OPEX					**OPEX**				
Variable	**Value**		**Unit**		**Variable**	**Value**		**Unit**	
Operator					*Operator*				
No. Operator		9	people		No. Operator		9	people	
Salary	$	472.33	month/person		Salary	$	472.33	month/person	
Total Salary	$	0.0553	million/year		Total Salary	$	0.0553	million/year	
Maintenance	$	0.023	million/year		Maintenance	$	0.030	million/year	
Insurance	$	0.016	million/year		Insurance	$	0.020	million/year	
Fuel Cost					*Fuel Cost*				
Fuel Type	HSD				Fuel Type	Electricity			
Price	$	1.34	/litre		Price	$	0.10	/kWh	
Operation Time		5 303	hours/year		Operation Time		4 667	hours/year	
Fuel Consumption		35	ltr/hr		Fuel Consumption		90	kWh	
		185 606	ltr/year				420 000	kWh/year	
Fuel Cost	$	0.25	million/year		Fuel Cost	$	0.04	million/year	
OPEX	**$**	**0.34**	**million/year**		**OPEX**	**$**	**0.15**	**million/year**	

The CAPEX using an electric-powered container crane is higher than an HSD-fueled container crane because the e-crane is more expensive since it is a relatively new technology. In contrast, OPEX for the electric container crane is lower. The OPEX for electric equipment should be relatively stable compared to fossil fuel because the latter has a problem with oil price uncertainty fluctuations.

Transfer from Quayside to Storage (Cargodoring Services)
Cargodoring is the process transfer the container from the quayside to the storage area. The transportation used in cargodoring activity at the non-green port is conventional trailers, while the green port is Automated Terminal Trailer (ATT). Both of the trailers utilise diesel fuel. The difference between trailers and ATT is their level of fuel consumption. The average trailer consumes 6 litres of diesel fuel per hour, while ATT only consumes 4 litres per hour. **Table *10*** shows the difference between CAPEX and OPEX from the non-green port and green port in stevedoring services.

Table 10: CAPEX and OPEX for cargodoring services

Non-Green Port (Conventional Truck)		Green Port (ATT)	
CAPEX	$0.11 million/year	CAPEX	$0.27 million per year
OPEX	$0.17 million/ year	OPEX	$0.16 million per year

The investment of ATT for the green port is twice higher as conventional truck trailers, but the operating cost will be less fuel consumption and fewer carbon emissions.

Container Yard Activities (Stacking)

In the Container Yard (CY), stacking activities is one of the main activities for storing containers effectively. For the scenario analysis, in the non-green port, we use Rubber Tyre Gantry (RTG) with HSD fuel. In contrast, the equipment used in the green port is Automated Stacking Container (ASC) using electricity. Table 11 shows the CAPEX and OPEX differences between the RTG and ASC.

Table 11: CAPEX and OPEX for stacking activities

Non-Green Port				Green Port			
CAPEX				CAPEX			
Variable	**Value**		**Unit**	**Variable**	**Value**		**Unit**
RTG		5	units	ASC		5	units
Productivity		20	box/hour/RTG	Productivity		20	box/hour/ASC
		100	box/hour			100	box/hour
Price	$	1.69	million/RTG	Price	$	1.86	million/ASC
	$	8.43	million		$	9.31	million
Economic Age		20	years	Economic Age		20	years
WACC		10%		WACC		10%	
CAPEX	**$**	**0.99**	**million/year**	**CAPEX**	**$**	**1.09**	**million/year**
OPEX				OPEX			
Variable	**Value**		**Unit**	**Variable**	**Value**		**Unit**
Operator				*Operator*			
No. Operator		15	people	No. Operator		15	people
Salary	$	472	month/person	Salary	$	472	month/person
Total Salary	$	0.09	million/year	Total Salary	$	0.09	million/year
Maintenance	$	0.015	million/year	Maintenance	$	0.016	million/year
Insurance	$	0.010	million/year	Insurance	$	0.011	million/year
Fuel Cost				*Fuel Cost*			
Fuel Type	HSD			Fuel Type	Electricity		
Price	$	1.34	/litre	Price	$	0.10	/kWh

Non-Green Port			
CAPEX			
Variable		**Value**	**Unit**
Operation Time		3 500	hours/year
Fuel Consumption		18	ltr/hr
		63 000	ltr/year
Fuel Cost	$	0.08	million/year
OPEX	**$**	**0.20**	**million/year**

Green Port			
CAPEX			
Variable		**Value**	**Unit**
Operation Time		3 500	hours/year
Fuel Consumption		66	kWh
		231 000	kWh/year
Fuel Cost	$	0.02	million/year
OPEX	**$**	**0.14**	**million/year**

The CAPEX for RTG is $0.99 million per year, while the ASC is $1.09 million per year. The OPEX for the non-green port is $0.20 million per year, while for the green port, about$0,14 million per year. Above scenarios for the cargo services at port, the CAPEX for a green port is always higher than the conventional port. However, the operating cost tends to be lower than the non-green port, and it generates fewer carbon emissions to increase the sustainability of the port in the environmental aspects.

The financing consideration of a green port should examine its economic life for the cargo services, such as stacking and container services. **Figure 4** shows that the green port will show a lower total cost after specific economic life than the non-green port. The green port sector shows the lesser total cost in the year 18th while stacking services in the year 13th from the first use. In the long run, the green port is more sustainable than the non-green port.

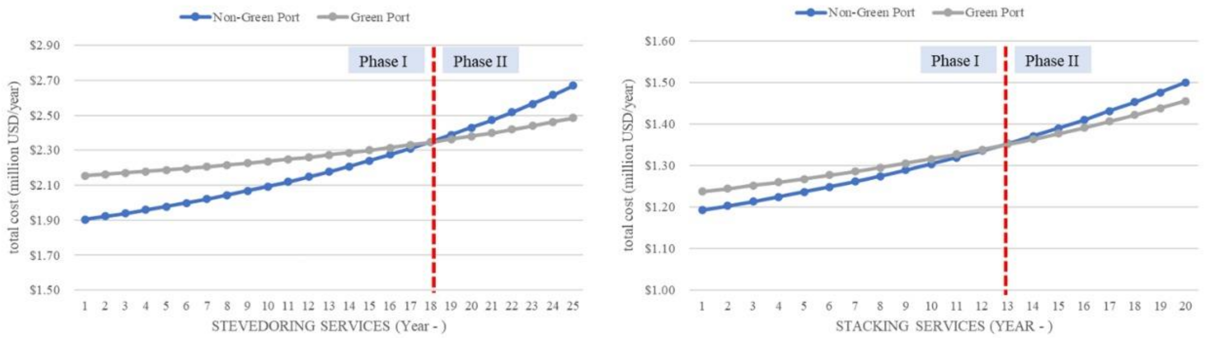

Figure 17: Comparison of the total cost for stevedoring and stacking services.

The sensitivity analysis is performed to analyse the impact of the cargo throughput on the container unit cost (USD/box). Figure 6 shows the breakeven point for the minimum throughput to have the exact unit cost between the green port and the non-green port at a container throughput of 1.4 million boxes per year. For smaller throughput, green port resulted in a higher unit cost of about USD 0.5 per box. The increment in the total throughput will reduce the unit cost for each container box in the green port.

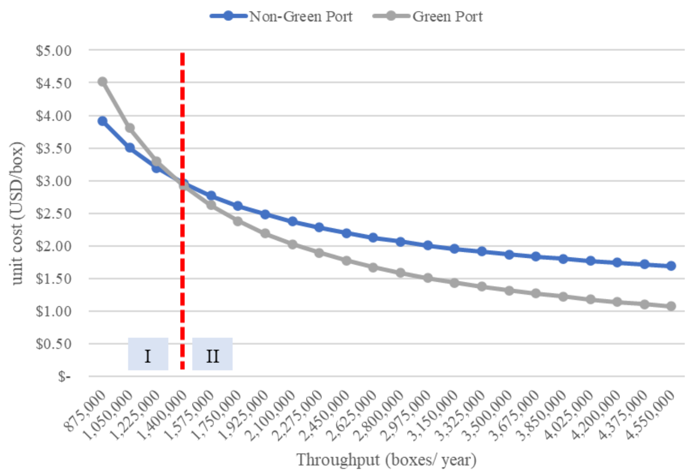

Figure 18: Sensitivity Analysis for Unit Cost Analysis with Container Throughput

<u>Ship Services: Pilotage and tug</u>

In addition to cargo services, a port also provide ship services consisting of pilotage and tug. Green ports utilise tug boats that are the electrically-powered auxiliary engine. Meanwhile, the non-green port uses HSD for its auxiliary engine fuel.

***Table* 12** shows the difference between CAPEX and OPEX from the non-green and green ports in stevedoring services.

Table 12: CAPEX and OPEX for Tug and Pilotage

Non-Green Port		Green Port	
Tugs			
CAPEX	$0.12 million/year	CAPEX	$0.24 million per year
OPEX	$8.04 million/ year	OPEX	$7.04 million per year
Pilotage			
CAPEX	$0.04 million/year	CAPEX	$0.08 million per year
OPEX	$3.87 million/ year	OPEX	$3.49 million per year

Based on sensitivity analysis, the breakeven point for the unit cost of ship services (tug and pilotage) using electric-fueled tugboats at the ship calls 800 per year. Figure 6 shows that below 800 calls. The HSD-fueled tug is more cost-efficient if the call is less than that.

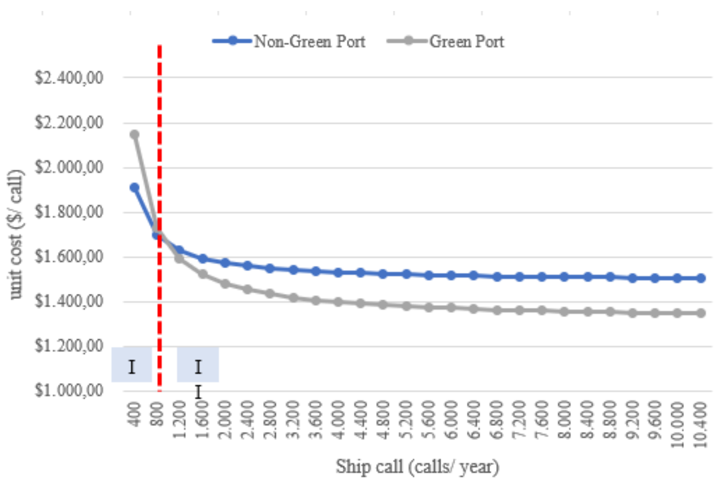

Figure 19: Comparison of unit cost for shipping services

Berthing Services

Another strategy for ship services for a green port is to provide the shore power connection during vessel berthing. A shore power connection (SPC) is a service to reduce exhaust emissions at the port by providing the electricity supply connected from the quayside to the ship when the ship is securely moored at the berth. It allows the vessel to turn off the auxiliary engine while in port. The relationship between power and investment value has a closed correlation or R^2 of 0.95.

Figure 20 shows the relationship between capacity and investment value for shore power connection.

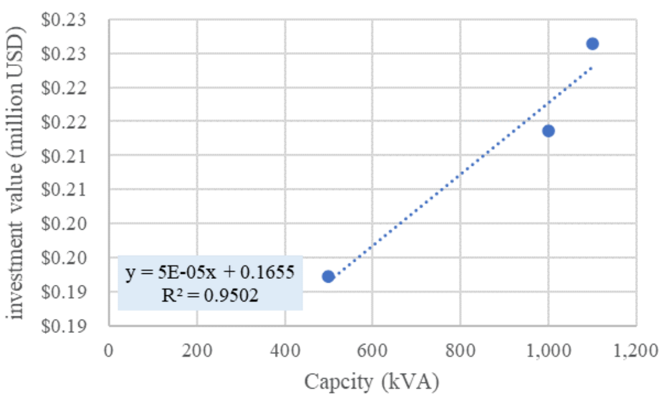

Figure 20: Regression graph between shore power connection capacity and investment value

Figure 8 shows the difference in unit costs between ships using HSD and using electricity by utilising shore power connection services from the port as fuel for the auxiliary engine. It can be seen that the difference is insignificant, but the unit cost is lowered for utilising shore power connection. Regarding shore power connection implementation, the vessel operator should ensure the compatibility between the charging port and the available power capacity of the port.

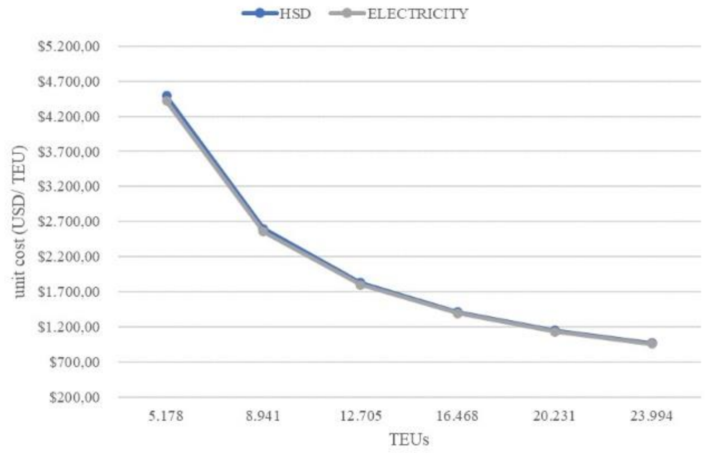

Figure 21: Unit cost for shore power connection usage vs auxiliary engine usage

For a more precise result, we use the study case of the round-trip route between Terminal Teluk Lamong (IND) - Port Klang (MYS) in one (1) year. The authors concluded that the average unit cost difference between ships using HSD fuel and electricity for the auxiliary engine is 1.59 per cent per TEU.

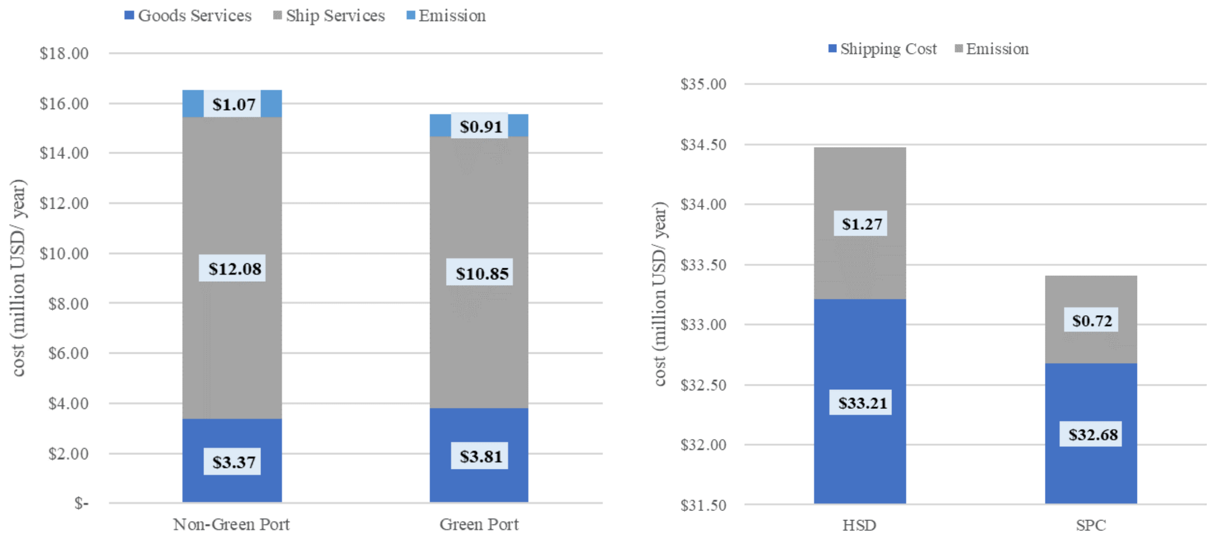

Figure 22: Green Port Cost vs Non-Green Port Cost

The comparison analysis of the application of green ports versus non-green ports can be seen in **Figure 22**. The total cost for non-green ports is $21.52 million per year, while for green ports is $17.59 million per year. This means a savings of $3.93 million per year or 18.27 per cent. Furthermore, the savings received by ship operators when their ships use shore power connection services is 3.11 per cent or $1.07 million per year. If the ship uses HSD, the total cost is $34.48 million per year, and using electricity fuel is only $33.40 million per year for the round-trip route between Terminal Teluk Lamong (IND) - Port Klang (MYS).

Renewable Energy: Solar Power Plants

One of the green port strategies not related to cargo handling or ship services is implementing renewable energy by making solar power plants on the roof of the port buildings and warehouses. In this study, a simulation of the utilisation of the Teluk Lamong Terminal's warehouse roof was carried out, with an area of 10,500 m^2. The total investment required is $1.21 million, generating 2,858,625 kWh of electricity annually. The electricity generated can be used for the port's purposes or shared with the hinterland industries.

Figure 23: The solar panel construction

Based on the total investment required and the electrical power generated, it can be concluded that this project is feasible to implement because it has an NPV value > 0 and an IRR > WACC.

Table 13: The result of the feasibility investment for solar panel construction

Parameter	Unit	Value	Min	Remark
WACC	%	9.40%		
NPV	$	$ 713 741.98	0	YES
IRR	%	16%	9.40%	YES
BEP	year	8		

Figure 11 shows the cash flow of the investment in solar panel construction with the BEP in the 7th year.

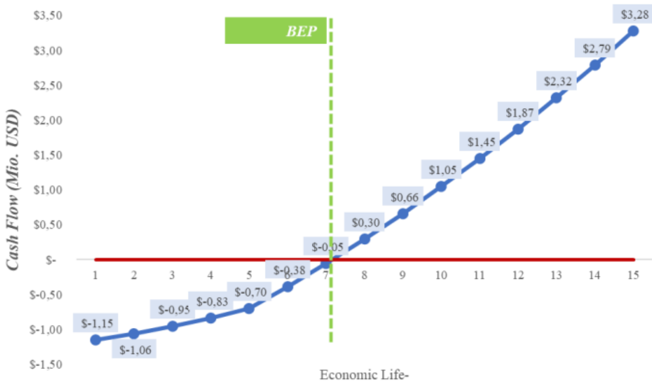

Figure 24: The cash flow of investment for solar panel construction

Recommendation and Conclusion

The quantitative analysis shows that the selection of suitable green port strategies should be examined from the financial feasibility study. Matching the proper green port strategy with port capacity and port demand will be an excellent mindset to follow. Before mapping the green port strategy for each port cluster or hierarchy, the port throughput and ship call should be examined first.

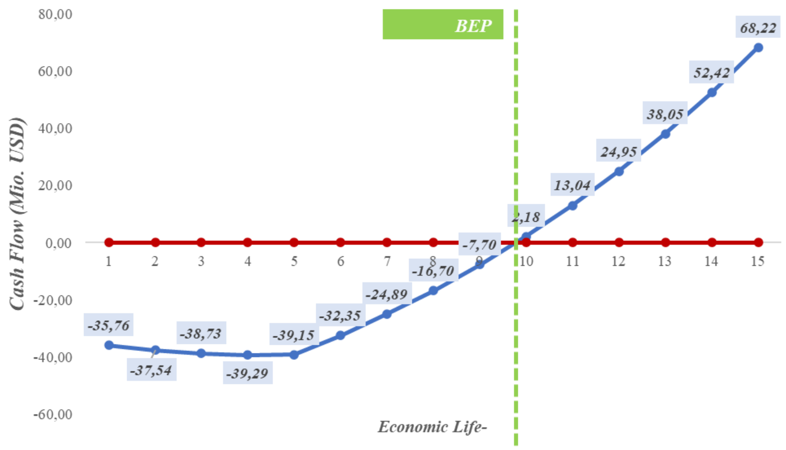

Figure 25: The cash flow of investment for green port

The BEP achieved in the 10th year cash flow shows that there are profits derived from cargo handling services, ship services, and electricity generated from solar panels in the port area.

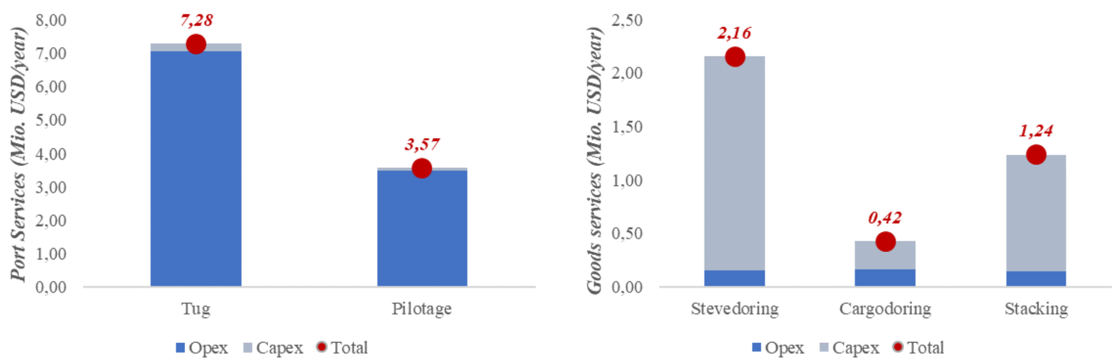

Figure 26: The cost comparison based on the service

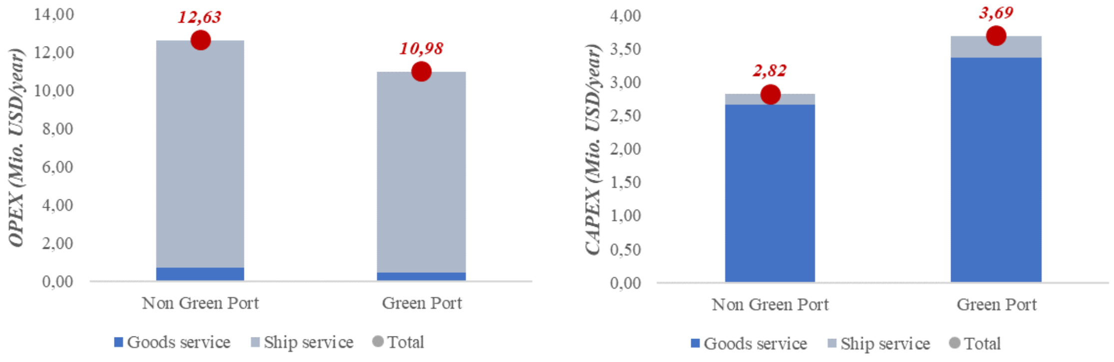

Figure 27: The cost comparison between green and non-green port

The port and shipping industry is moving towards decarbonisation to contribute to National Determined Contribution as climate change action and comply with the IMO regulations. The implementation of the green port should combine the following: (1) activities that comply with environmental regulations and policy set by the government and IMO; (2) initiatives to pursue a sustainable future for port business; (3) operational management with the involvement of all port stakeholders. The green port strategy implemented by emerging countries is considered relatively similar, but the outcome might be different because it requires stakeholder engagement to commit to meeting the target. The port operators should consider the following sequences: (1) improve the port performance of the existing port, (2) plan and review the green strategies that are technically and financially feasible, (3) consider the transition from fossil fuel to electricity-power-based equipment, (5) port waste management system, (6) proper treatment for dredging disposal materials, (7) continuous monitoring of air, water and soil quality to ensure sustainable port environment. Electrification might be a good solution as long as there will be available good capacity grids because it needs the high charging power necessary to be available. Thus, investing the renewable energy application in the port industry is also beneficial to increase the power capacity of the port with cleaner energy fuel.

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Evaluation of Off-Hours Freight Strategy for Sustainable Urban Goods Distribution: A Case of Jaipur City, India

Pankaj Kant, Kushagra Sinha and Sanjay Gupta

ABSTRACT

This study demonstrates the impact of the off-hour freight strategy in Jaipur city on key performance indicators like fleet utilisation, vehicle kilometre travelled, and total deliveries across commodities using a stakeholder interaction model based on the Agent-based Modelling & Simulation (ABMS) framework for evaluating the individual stakeholder's behaviours and interactions in a combined and holistic manner. Two commodities, building hardware and electronics, were chosen for the evaluation of the off-hour strategy. Face-to-face surveys were conducted to gather primary data from stakeholders such as authorities/policymakers, wholesalers, retailers, and transport operators for selected markets in Jaipur city. The goods traffic volumes were observed at the cordon points of wholesale markets for model validation by the GEH statistics method. Model results show that the off-hour delivery strategy has a different impact on fleet utilisation, vehicle kilometres travelled, and total deliveries throughout commodities distribution in urban areas.

Keywords: *Urban Freight; Freight Strategies; Off-Hours Deliveries; Agent-based Modelling & Simulation; Sustainability*

INTRODUCTION

As a result of the causal impacts of urban goods distribution on congestion, externalities, infrastructural fragility, and inconsistency with urban land use, the sustainability of urban goods transportation has become an important policy goal of many nations across the world (OECD, 2003). The same has not been observed in India, where the National Urban Transport Policy (NUTP, 2004; 2012) has put primary emphasis on the provision of passenger transportation in Indian cities, and urban freight has regrettably been neglected in both the policy discourse as well as the proposals for the development of citywide transportation systems (MoUD, 2014). Even the preparation of strategic plans like the Comprehensive Mobility Plan (CMP) and Master Plan, which are undertaken by the local development authorities who lack thorough knowledge of the freight sector (U.S. DoT, 2012), have failed to address the vital issues which have been historically raised by the stakeholders which are directly associated to urban freight like transport operators, wholesale and retail owners, etc. And this is not something unique. The solutions/strategies For Transport Management Plans (TMPs) are frequently chosen without a thorough knowledge of their possible advantages and downsides.

Due to its impact on externalities, economic issues, and social issues, sustainable transportation is crucial for overall sustainable development (Gudmundsson, Hall, Marsden, & Zietsman, 2015). For the decision-making process, travel patterns, physical impacts, environmental impacts, economic implications, strategies, and key performance indicators (KPI) are frequently used (Litman, 2019). To accomplish the goals of sustainable development, decision-makers need and can benefit from freight strategies (Patier & Routhier, 2008). Stakeholder behaviours and characteristics associated with urban freight are recognised as essential research topics (Dablanc, Giuliano, & Holliday, 2013). In the urban freight sector, researchers are still exploring the relationship between policy actions and stakeholder behaviours due to inherent complexities in the urban freight sector (Comi, 2012). Raising awareness of freight issues is necessary, considering all pertinent stakeholders (Ruescha, et al., 2012).

Urban freight transport's impact can be classified into several categories, and each category calls for a particular type of freight strategy (BESTUFS II, 2006). 56 cities from 32 nations had their urban freight data analysed, and various urban freight strategies were then put into place depending on the outcomes. Seven major groups with a total of 48 freight strategies were chosen for examination (Holguín-Veras, Leal, Sánchez-Diaz, & Wojtowicz, 2018). For the sustainable distribution of urban goods, 21 urban freight systems already in use by numerous cities throughout the world were found in the literature (NCFRP 23, 2013). There are numerous categories of building, traffic, and vehicle rules freight strategy (Ogden, 1992). A research study came to the following conclusions: Seven groups of sustainable policy approaches to reduce the detrimental effects of urban freight and impediments in implementing freight plans (Browne & Allen, 2011).

In the development and execution of freight strategies, there is a lack of communication and comprehension between administrators and other urban freight stakeholders (Pronello & Valentinaa, 2017) & (Visser, Binsbergen, & Nemoto, 1999). As stated, urban freight is not very well understood by local authorities or policymakers which makes it difficult to predict the outcomes of freight policies and strategies (Lindholm & Behrends, 2010). The execution of urban freight solutions is hindered by the different goals of shippers and transport operators (Ron Van DUIN, 2018). Sustainable freight transportation requires a framework for the identification and selection of freight initiatives that take stakeholder concerns into account (Sharma, Shelton, & Warner, 2017). Local policymakers in Indian cities lack input from wholesalers, retailers, and transport companies in their policy discourse. In the context of Indian cities, modelling methodologies specifically to concentrate on the important concerns of freight players have not been investigated to come up with acceptable solutions as city logistics measures.

Thus, this study demonstrates the impact of the off-hour freight strategy in Jaipur city on key performance indicators like fleet utilisation, vehicle kilometre travelled, and total deliveries across commodities using a stakeholder interaction model based on the Agent-based Modelling & Simulation (ABMS) framework for evaluating the individual stakeholder's behaviours and interactions in a combined and holistic manner. The null hypothesis for the research study isassumed that urban freight strategies have a similar impact across different commodity distributions.

Literature Review

Off-hour deliveries have a lot of potential as a useful sustainability strategy for the overall enhancement of environmental performance in urban areas. Off-hour delivery should be encouraged as a policy initiative by local policymakers (José Holguín-Verasa C. W., 2014). With widespread industry support, the off-hour strategy is successful in encouraging shift or urban deliveries with a decrease in traffic, pollution, and economic competitiveness (José Holguín-Verasa R. M., 2012). Distribution of deliveries during the day performs the worst due to the high external costs. Urban deliveries at night to supermarkets are found to be the best trade-off between the benefits and drawbacks of night deliveries (K.Mommens, 2018). Results of research studies on off-hour deliveries with and without incentives in the city of Rome indicate that stakeholders have a good tendency toward off-hours deliveries (Gatta, 2017).

Individual-based models and system computational approaches are the two domains in which ABMS application can be found (also known as MAS). By simulating the complex dynamic system and modelling the decision-making behaviours of individual autonomous agents, MAS (multi-agent system) models are used to research collaborative and reactive systems (Evans, 2013). The evaluation of the urban consolidation centre was conducted using an agent-based discrete-event simulation method (UCC). According to study findings, UCC might have an environmental benefit but is unable to maintain itself financially and relies on transport providers to ensure that policies are implemented successfully (W.J.A. van Heeswijk, 2018). To assess the last mile distribution in an urban setting with capacitated vehicle routing problems with time windows (CVRPTW), a multi-agent model was used. According to study findings, the Solomon algorithm can be used to solve the CVRPTW for operational choices involving the distribution of goods in metropolitan areas (M.D. Arango-Serna, 2018).

In the context of Rotterdam City's urban transportation planning, a complete agent-based freight modelling framework (MASS-GT) was utilised to model freight logistics decisions (Tavasszy, 2018). In the area of city logistics, a framework for agent-based modelling was created for a variety of stakeholders. The model incorporates a variety of stakeholders and can be used to examine municipal logistics solutions and domain stakeholder satisfaction measures (Anand, Van Duin, & Tavasszy, 2016). To analyse city logistics policies, a multi-agent modelling approach was employed to take stakeholder behaviour in urban freight distribution into account. According to research findings, banning trucks from entering environmentally sensitive areas and reducing the cost of municipal tolls both directly benefit the environment and produce outcomes that are acceptable to all parties involved (Dai Tamagawaa, 2010). To assess the effect of freight road pricing for e-commerce delivery systems on the test road network, a multi-agent system (MAS) modelling approach was utilised. The early findings point to the possibility of lowering NOx levels in the city (Joel S.E. Teo, 2014).

To cover the transportation of goods between suppliers and retailers in the Tokyo Metropolitan Area, a multi-agent transport model was created (Stefan Schroedera, 2012). The policy initiatives were assessed using an agent-based modelling framework, which can be seen in terms of the cost structure of the transport businesses and the corresponding number and capacity utilisation (Wisinee Wisetjindawata, 2012). On a test road network, a truck ban and tolling as a city logistics measure were assessed using an agent-based modelling framework. According to study findings, these actions did not significantly enhance the circumstances of all stakeholders (Tilman Matteisa, 2016). To represent the varied behaviours and interactions of urban freight players for Toronto city's total logistics cost, an agent-based microsimulation framework was presented (Tanigauchi, 2005). The freight market was simulated using an agent-based framework called the FERMIS model. The use of the agent-based framework made it possible to represent the behaviour of different freight stakeholders if new freight policy measures were implemented (Matthew John Roorda, 2010). As a tool for making decisions, a conceptual agent- based microsimulation model with capacitated vehicle routing problems with time windows (CVRPTW) was created to address daily occurrences that might affect the freight distribution system and freight performance during a working day (M.D. Arango-Serna, 2018).

While user behaviour connected to passenger transport has been extensively studied both worldwide and in developing environments like India, research on urban freight planning- related issues in developing countries is less widespread. On the freight stakeholder behaviour analysis and its relationship with urban goods distribution systems, there is a dearth of literature. According to the literature assessment, little has been studied regarding the use of agent-based modelling in the decision-making of various stakeholders involved in the mobility of urban goods, particularly in developing nations like India. A demonstration of the application of ABMS for building sustainable urban commodities distribution techniques in a developing (countries) context has also not been reported. Modelling the complexity resulting from individual activities and interactions of freight stakeholders explicitly is the most crucial element in implementing the ABMS technique for its potential utility in the urban freight sector. The current study offers much-needed insight into the freight stakeholder behaviour toward adopting an agent-based modelling system (ABMS) to arrive at sustainable urban goods distribution strategies, such as the off-hours strategy in the Indian context.

Materials & Methods

Case City Profile

Jaipur is the capital city of the state of Rajasthan in India. It is a major attraction for both international and domestic tourists, owing to its historical roots preserved in the form of opulent palaces as well as traditional art forms including handicrafts, gemstones, jewellery, textile die and printing, and stone carving. The city is situated 280 kilometres from Delhi in the northeastern region of Rajasthan. As per the available Census of India (the Year 2011), about 3 million people are living in the city. It covers a total area of 2,939 sq. km, of which 17 sq. km is the walled city (historical area), 281 sq. km is the municipal area, and the remaining 2,650 sq. km is under the control of the Jaipur Development Authority as planned areas for future development. The land use distribution is shown in Figure 1.

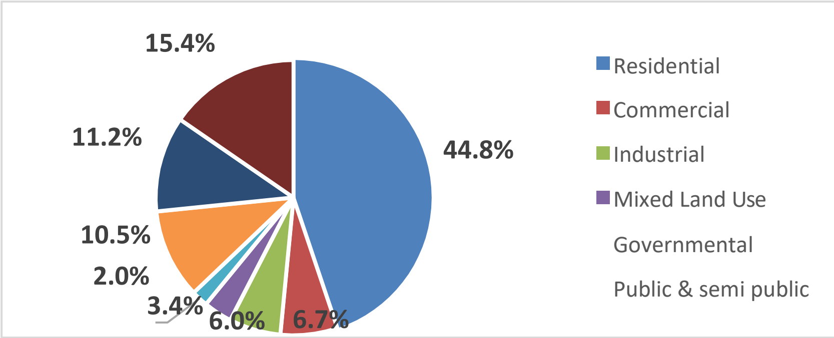

Figure 1. Land Use Distribution of Jaipur

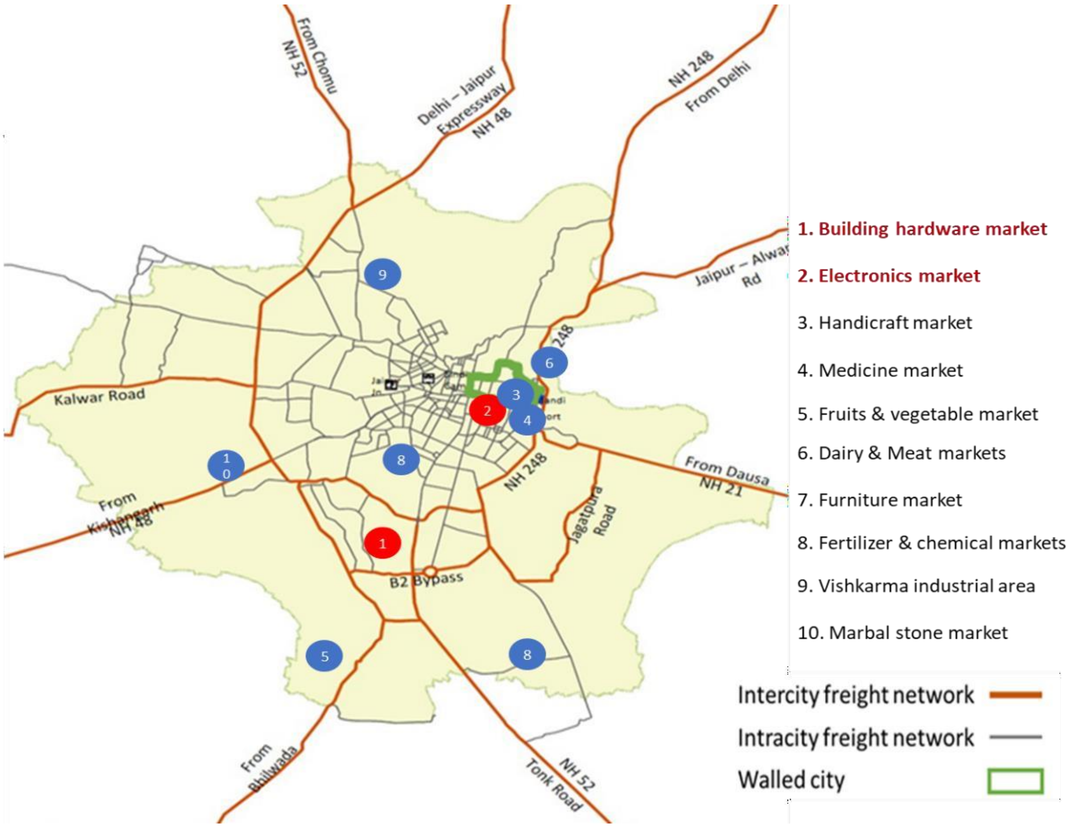

Figure 2. Location of Markets in Jaipur

There are 10 significant wholesale markets in Jaipur (Figure 2). The walled city region is home to markets for electronics, crafts, and medicines. The wholesale market for fruits and vegetables is located near Muhana and Lal Kothi. Wholesale Markets are places for food grains in the Kukasheda and Surajpole regions. Malviya Nagar and the NH11 bypass both sell dairy and meat items. The furniture market is in the Sitapura neighbourhood, construction material market is in Aatish Nagar & Chandpole areas. The market for fertilisers and chemicals in the Durgapaura region. The Viskarma industrial area sells industrial goods.

Commodity Selection

A primary pilot survey of wholesalers and transport operators of five wholesale markets was conducted to assess the salient characteristics of these wholesale markets. A total of 10 samples from each wholesale market were collected for preliminary analysis. Preliminary analyses of these five wholesale markets are shown in Table 1.

Table 1. Results of Pilot Survey for Commodity Selection

Key Performance Indicators (KPIs)	Electronics Market	Bldg. Hardware market	Grain market	Fruits & vegetable market	Furniture market
Avg pay load (tons)	1.8	2.5	2.2	1.2	0.8
Tonnage/sq. mt	0.08	0.28	0.16	0.14	0.04
Trip frequency/sq. mt	0.16	0.17	0.15	0.12	0.11

Source: Primary Survey (Pilot)

It is observed that the weekly tonnage generated per square meter by the building hardware market is the highest followed by the grain market, fruits, and vegetable market. The furniture market is generating the least weekly tonnage per square meter followed by the electronics market due to the inherent nature of the commodity. The fruits & vegetable market and grain market were discarded as there are multiple wholesale markets in various parts of the city, especially grain markets. The furniture market is discarded due to the low tonnage attraction per square meter of the wholesale shops. Finally, the building hardware market and electronics market at Jayanti Nagar in Jaipur have been selected as case markets for this study based.

Research Methodology

The state action charts of its agents are the core building component of ABMS (stakeholders). A state action chart displays the various states and actions an agent might experience throughout a regular day or routine. To examine the effects of the off-hours strategy approach in the case city with the aid of KPIs, the stakeholder interaction model uses the agent-based modelling & simulation (ABMS) framework to evaluate the individual stakeholder's behaviours and interactions in a combined and holistic manner. Figure 3 depicts the suggested ABMS modelling framework for agent (stakeholders) interaction. Unlike other stakeholders whose inputs are more endogenous, the administrator contributes to the model in an exogenous manner. The administrator's main engagement is with the implementation of an off-hours freight strategy. Administrators' key input in developing the prototype ABMS model is time constraints for carriers, shippers, and retailers. The model's time constraints were coded based on the actual circumstances on the ground at the time of data collection. After the model has been calibrated and validated, the off-hours strategy is evaluated.

The suggested framework involves two different types of movement: the flow of information and the flow of actual goods. In the suggested ABMS framework, the solid line represents the flow and sequence of information, while the dotted line represents the flow and sequence of goods movement. The message/call function is used by retailers to place the wholesaler's weekly order. After processing the retailer's order, the wholesaler calls or texts the transport operator that is waiting at a nearby parking area. After receiving the message from the relevant wholesaler, a carrier (agent) goes to the godown of that wholesaler. Once the carrier arrives at the godown, the loaders begin loading it; once loaded, the carrier travels to the appropriate retailer in the city.

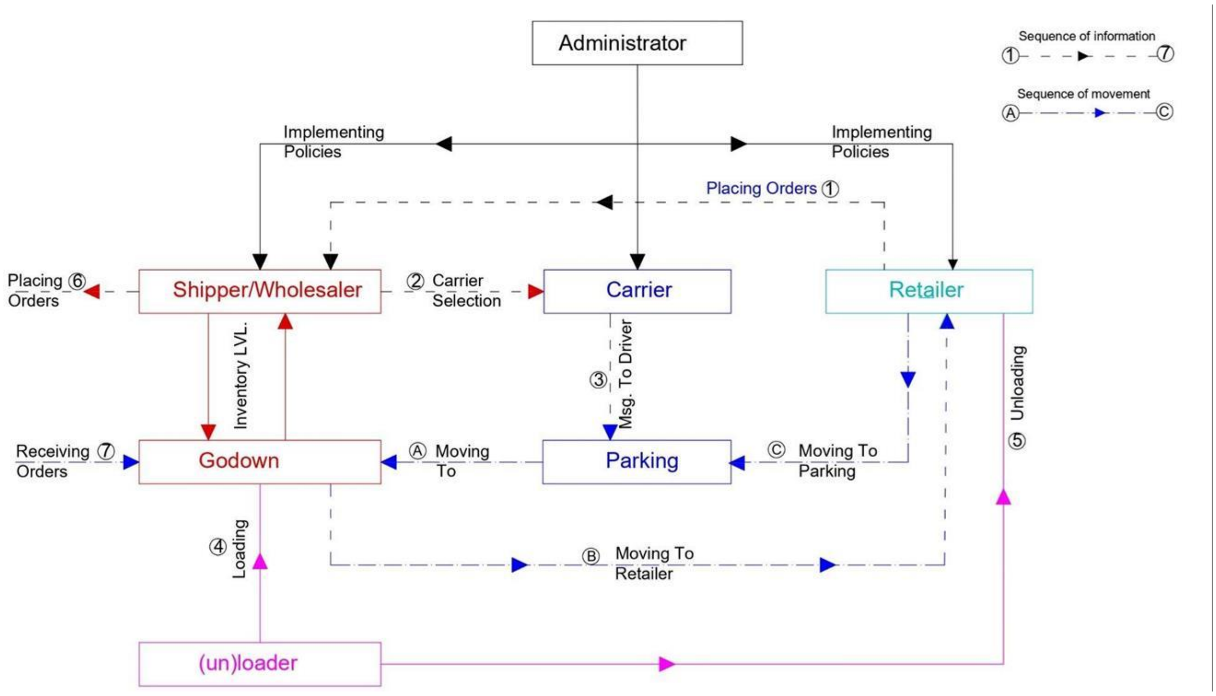

Figure 3. ABMS modelling framework for agents (source: author)

As soon as the carrier arrives at the retailer, the unloading of the items begins. After the goods are delivered to the retailers, the carrier returns to the parking lot to wait for his subsequent delivery from the wholesaler. In the case of the construction hardware wholesale market, the transport carrier parking lot and warehouses are located there, whereas, in the case of the electronic wholesale market, they are located close to the market. Table 2 displays the behaviour and interaction rules of the discovered agents for this research study together with the final model input values.

Table 2. State action transition & functions of agents

Agents	State	Transition Type or triggered by	Function
Retailers	Frequency of Ordering goods (weekly)	Rate	Uniform
	Receiving Goods	Message/call	
	Working hours (10am-9pm) Monday to Saturday	Time out	Boolean
Wholesalers (distributor)	Shipping goods as per received orders	Message/call	Function of retailer orders
	Working hours (10am-6pm) Monday to Saturday	Timeout	Boolean
Trucks/ carriers	Got an Order from the distributor	Msg. from the wholesaler	
	Loading (Hours)	Rate	Triangular
	Going To Client (retailer)	Agent arrival	MSG/call
	Unloading	Rate	Triangular

Going Back to the distributor	Agent arrival	MSG/call
Route Restriction (6 pm to 8 pm)	Time Out	Boolean

(Source: Author)

- The following modelling presumptions are used in the proposed ABMS research framework.
- For this research framework, the Capacitated Vehicle Routing Problem with a Time Window (CVRPTW) is assumed. For the delivery of goods, an infinite number of freight cars with an infinite capacity are constantly accessible.
- All freight vehicles are initially assumed to be located at wholesale markets
- The instance city's comprehensive mobility plan predicts that retailers for both wholesale marketplaces will be located close to the centroid of residential zones (a total of 92 zones). The model results for 92 firms are expanded to include the complete population of construction hardware and electronics goods retailers in Jaipur city.
- The frequency of orders placed by retailers is presumptively distributed uniformly and loading and unloading times are triangularly distributed as observed in the primary analysis.
- Tour routing and planning by transport carriers are not considered in the modelling.
- The model only accounts for the distribution of urban goods (from wholesalers to retailers).
- The model can only forecast the overall volume of freight shipments. Only the average truckload and the current modal share of freight vehicles in the relevant wholesale marketplaces can be used to compute total tonnage movement.
- The ABMS model does not simulate the whole cost of logistics; it simply simulates the transport model.
- The ABMS model's simulation period is 90 days (12 weeks). The simulation experiment's unit of time is the day.
- In the ABMS modelling framework spanning commodities distribution, an additional two- hour time window from 10 pm to 12 pm in addition to everyday business timings has been analysed as off-hour deliveries.
- GEH statistics, model counts, and counts from cordon point traffic volume around the wholesale market were used to validate the ABMS model. the GEH statistic (WEBTAG, 2020), which is a form of the Chi-squared statistic that incorporates both relative and absolute errors, and is defined as follows:

$$GEH= \sqrt{(M - C)^2/(M+C)/2}$$

Where GEH is the GEH statistic, M is the modelled flow C is the observed flow.

For ABMS modelling, AnyLogic 8.4 Java-based software is utilised. The AnyLogic 8.4 student version has a cap on the number of agents that may be modelled, limiting this research study to 100 agents for each commodity distribution.

Data collection

The premises of wholesale markets and retailers were the subjects of the primary establishment surveys. The face-to-face pen and pencil survey method was used for the establishment surveys to collect information from wholesalers, retailers, and origin-destinations surveys from transport operators. At market cordon points of wholesale markets, a manual traffic count of freight vehicles was done to record the overall flow of incoming and exiting freight vehicles. While commodities were being loaded into trucks at the wholesale market, surveys of transport carriers were done there. The sample size for this research project, as determined by various sampling techniques, is displayed in Table 3.

Table 3. Sampling Techniques and Sample Size

	Establishment survey (wholesalers)	**Establishment survey (retailers)**	**Truck driver survey**
Sampling Method	Stratified	Systematic	Stratified
Sample size collected	110	200	550

(Source: Author)

Unlike wholesalers and truck drivers, the locations of retailers were outside the wholesale markets and spread across the city. So, to obtain a locationally diverse sample of retailers, the list of retail shops for each of the two commodities was first sorted location-wise (administrative wards have been considered as locations) and then, and then every fifth retailer in each ward was selected for the systematic survey.

Descriptive Statistics of Data Set

Descriptive statistics of wholesaler's data

Table 4 displays descriptive statistics regarding the attributes of the wholesaler in both markets. In comparison to the building hardware industry, the mean value of the shop area is higher in the electronics market. The electronics market employs more people per 100 square metres than the building hardware market does. In the building hardware market, total tonnage handled, including incoming and outgoing tonnage, is about twice as much as the electronics market per 100 sqm of shop area. The building hardware market has a somewhat lower total tonnage trip frequency, including incoming and outgoing trips per 100 sqm of shop area than the electronics sector. Building hardware has roughly twice as many incoming freight trips as the electronics sector.

Table 4. Descriptive statistics of wholesalers

Indicators	Unit	Electronics Market			Building Hardware Market		
		Mean	Median	SD	Mean	Median	SD
Shop Area	Sq. m	140.2	149.5	67.7	89.1	80	62.5
Employment	Per 100 Sqm	5	4	2.1	3.1	3	1.5
Incoming frequency	weekly	4.1	4	1.4	9	9	2.7
Incoming tonnage	weekly	14.1	15	3.04	27.6	23	15.5
Outgoing trips frequency	weekly	22.1	23	4.1	14.9	15	3.2
Outgoing tonnage	weekly	11.8	12	2.04	24.8	20	13.8
Average Nos. of retailers	Per wholesaler		5.5				8.8

(Source: Primary survey)

The electronics market has more outbound trips compared to the building hardware market. Building hardware has approximately twice as many incoming freight trips compared to the electronics market. The market for electronics has more outbound travel than the market for building hardware. Outgoing trips in the electronics market are higher than building hardware market.

Descriptive statistics of retailer's data

Descriptive statistics for retailers of building hardware and electronics goods retailers are presented in Table 5. The median value of employment is 2 people in most of the retail shops in the building hardware market similar to electronics market retailers. The number of trips attracted (incoming trips frequency) to building hardware retailers has almost half compared to electronics goods retailers. The weekly tonnage attracted to building hardware retailers is much higher than the electronics goods retailers.

Table 5. Descriptive statistics of retailers

		Electronics			**Building hardware**		
Indicators	**Unit**	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
Shop Area	SQM	77.19	70	59.7	94.5	83.6	66
Employment	100/SQM	2.85	2	1.64	3.07	2	1.9

Incoming trip frequency	Trips/week	4.16	4	1.51	2.48	2	1.3
Incomin g tonnage	Tons/week	5.22	5	3.42	8.99	7.5	2.8

(Source: Primary survey)

Descriptive statistics of transport operator's data

Descriptive statistics of transport operator attributes are shown in Table 6. There is a significant difference in haulage time in the case of light commercial vehicle (LCV) & 4-wheel commercial vehicles (4W) modes in both markets, suggesting a significant difference in distribution leads. Loading time is slightly higher than unloading for all modes in both markets. Idle time is almost similar in both markets for 3-wheel commercial vehicles (3W) and 4W, whereas, in the case of LCV, idle time is higher in the building hardware market (BM) compare to the electronics market (EM). Compared to the electronics business, the transportation cost of LCV is higher in the building hardware market. The expenses of loading and unloading for the various freight options are similar in both markets.

Table 6. Descriptive statistics of transport operators

Mode	Commodity	Haulage time (Hr)		Loading time (Hr)		Unloading time (Hr)		Idle time (Hr)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
NMT	EM	0.8	0.4	0.2	0.05	0.18	0.04	0.018	0.03
	BM	0.9	0.3	0.2	0.04	0.19	0.04	0.67	0.13
3W	EM	0.7	0.2	0.3	0.05	0.27	0.06	0.95	0.15
	BM	0.7	0.4	0.6	0.20	0.51	0.07	0.9	0.17
4W	EM	0.7	0.2	0.4	0.08	0.34	0.09	1.15	0.16
	BM	0.8	0.3	0.6	0.17	0.49	0.15	1.13	0.20
LCV	EM	0.9	0.4	0.7	0.07	0.66	0.07	1.4	0.14
	BM	1.4	0.6	0.7	0.12	0.69	0.09	1.85	0.22

(Source: Primary survey)

Cordon point traffic volume counts (TVC)

Traffic volume counts of motorised freight vehicles were observed at the cordon point of the building hardware market for nine hours. A total of 1256 freight vehicles are observed. In the case of the building hardware market, there were 313 3w commercial vehicles, 388 4w commercial vehicles and 555 LCVs respectively observed in the TVC survey. It is seen that LCV has the highest share (44 per cent) followed by 4w commercial vehicles (31 per cent) and (25 per cent) for 3w commercial vehicles respectively. In the case of the electronics market, a total of 1030 freight vehicles are observed in the case of building hardware goods distribution. There were 345 (3w) commercial vehicles, 362 (4w) commercial vehicles and 323 LCVs observed in the TVC survey. The modal share analysis of the TVC survey shows that 4w commercial vehicle has the highest share (35 per cent) followed by 3w commercial vehicle (33 per cent) and (31 per cent) for LCVs. The 3w commercial vehicle consists of both e-rikshaw and auto in modal share calculation.

ABMS Model Validation Results

Table 7 shows the ABMS modelling and validation results for electronics and building hardware goods distribution in Jaipur city.

Table 7. ABMS model results

	Building hardware	Electronics
Trips/Deliveries	Counts	Counts
Nos. of deliveries day extrapolated for all retailers (M)	1 318	940
Trips counts/day from the primary survey (C)	1 256	1 030
Trips Variation	4.9%	- 8.7%
GEH Statistic	2.4	4.5

(Source: Author)

Building Hardware: A total of 1,318 freight trips for all retailers were predicted by the ABMS model in Jaipur city. A total of 1,256 freight trip counts are observed from the cordon survey of the building hardware wholesale market by commercial vehicles (3w, 4w & LCV). There is a variation of 4.9 per cent from modal count (M) and observed count (C) in building hardware distribution. The model is over-predicting the total freight deliveries by 4.9 per cent.

Electronics: For electronics goods distribution the ABMS model predicts 940 freight trips for all retailers in Jaipur city. There is a variation of -8.7 per cent and the model is under-predicting the total freight deliveries by -8.7 per cent. The GEH statistic for model validation has a value of 2.4 in the case of building hardware distribution and 4.5 in electronics goods distribution. GEH value less than 5 is acceptable for validation.

Evaluation of Off-Hour Strategy

Table 8 shows the impact of off-hour deliveries with the business as usual (BAU) scenario evaluated across commodity distribution in the case city.

Table 8. Impact of off-hours strategy on urban goods distribution

	Building Hardware Goods			**Electronics Goods**		
KPI	**BAU**	**Off-Hour**	**% Change**	**BAU**	**Off-Hour**	**% Change**
VKT/Week (Km)	1 737	2 139	23%	1 134	1 131	-0.3%
Travel Time (Hrs.)	58	71	22%	57	57	0.0%
Deliveries (Units)	607	652	7%	438	439	0.2%
Fleet Utilization	58%	65%	7%	49%	47%	-2.0%

(Source: Author)

Building Hardware: In the case of building hardware distribution, there is a 23 per cent increase observed in total vehicle kilometres travelled (VKT) from 1,737 km to 2,139 km with off-hour deliveries compared to the BAU scenario. Similarly, a 22 per cent increase has been observed in total travel time due to an increase in total vehicle kilometres travelled by transport operators in building hardware goods distribution. A total of 7 per cent increase in total business deliveries from 607 to 652 with off-hour deliveries has been observed compared to BAU in building hardware goods distribution. Off-hour deliveries have positive impacts on both wholesalers and transport carriers. In the case of fleet usage, there is a positive increase of 7 per cent is observed with the off- hour delivery strategy vis-a-vis the BAU scenario for building hardware goods distribution.

Electronics: In the case of the electronics good's distribution, there is hardly any difference observed in the total vehicle kilometre travelled from 1,134 km to 1,131 km with off-hour deliveries compared to the BAU scenario. The same has been observed in total travel time by transport carriers involved in the electronics goods distribution due to negligible change in vehicle kilometres travelled. A two per cent decrease is observed in total fleet utilization from 49 per cent to 47 per cent with an off-hour strategy compared with BAU for transport carriers involved in the electronics goods distribution.

There is a positive impact on the economic efficiency of transport carriers with off-hours deliveries as due to increased time duration towards off-peak hours, a greater number of deliveries can be made, especially in those extra off-peak hours daily, which do not usually happen owing to vehicular restrictions in the city. So, due to lesser passenger traffic in off-peak hours, even heavier vehicles can be allowed for moving higher quantities of freight. The positive effects of the off-hour strategy also partially depend upon the ordering frequency of retailers to wholesalers apart from other factors and so, an increase in the ordering frequency of deliveries will impart positive effects by the off-hours strategy. However, although off-hour deliveries are benefiting the transport operators, wholesalers and retailers involved in building hardware goods distribution, it is also increasing the emissions due to increased VKT by goods vehicles. So, to sustain the benefits of off-hour deliveries there should be more thrust towards the enhancement of the usage of the vehicle using cleaner sources of energy (low-emission vehicles) in urban goods distribution.

Conclusion

Urban freight strategies are vital decisions in the sustainability of urban goods distribution. This paper investigated the impacts of the off-hour freight strategy on urban freight stakeholders involved in urban goods distribution across two commodities. The impacts of the off-hour strategy are evaluated in the ABMS modelling framework with the help of key performance indicators of urban goods distribution. The transferability of the model needs to be explored in other similar cities with similar characteristics of freight stakeholders involved in urban goods distribution. The study is limited to two commodities distribution in the case city.

The main finding of the research study confirms that there is a positive impact of off-hour strategy in the case of building hardware goods distribution but a negligible impact on the electronics goods distribution. Research finding confirms that the ordering frequency of goods from retailers to wholesalers is key to the positive impacts of the off-hour strategy on urban goods distribution. An increase in VKT by goods vehicles to improve the economic efficiency of transport operators will also increase the emissions in the urban area which requires the policy intervention to opt for sustainable modes, technology, and fuel type. It can be inferred from the research results that the freight strategies have no similar impacts across commodity distribution and due diligence is required with the scientific investigation before implementing any freight strategy in the context of sustainability of urban freight.

United nation development program has suggested 17 sustainable development goals (SDG) comprehensively for sustainable development (UNDP, 2020). An Off-hour freight strategy in the city logistics domain possibly contributes to some of the SDG goals given by UNDP. Table 9 shows off-hour delivery effects on freight stakeholders and the possible contribution of SDG goals.

Table 9. Impact on freight stakeholders & contribution to SDG goals

Freight strategies/scenario	Wholesalers	Retailers	Transport operators	Policy-Planners
Impact on stakeholders by off-hour deliveries in urban goods distribution	Yes	Yes	Yes	Yes
Contribution to sustainable urban goals	SDG8	SDG8	SDG8	SDG11

(Source: author)

Additionally, strategies for the uptake of vehicles using clean energy for urban freight distribution can help in contributing to SDG9 – Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, specifically towards Goal 9.4 which proposes to reduce total energy and industry-related GHG emissions by gas and sector, expressed as production and demand-based emissions (tCO_2e) as well as mean urban air pollution of particulate matter (PM10 and PM2.5).

Similar studies need to be carried out for a wide spectrum of commodities for distribution in different contexts in urban areas as well as for different kinds of strategies like optimum fleet size, location of freight consolidation centres, warehouses, etc., loading, unloading, and parking facilities, etc. The logistics cost model could be dovetailed in the modelling framework for urban goods distribution. A joint model for shipment size and mode choice could be explored in the ABMS modelling framework for the evaluation of freight strategies.

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GHG Mitigation Policies in Transport Sector for Post COVID-19 Condition based on People's Activity Change

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ABSTRACT

Many efforts to realize low carbon targeting urban transport have been proposed and implemented. These low-carbon efforts reduce not only GHG emissions from individual transport systems but also reduce GHG emissions as a whole by significantly changing people's travel behavior. However, the changes in the travel behavior of individual persons have not been explicitly considered in the transportation demand estimation. Because of that, the GHG emission reduction effect that causes significant changes in travel behavior has not been correctly evaluated. Especially, travel behavior under post-COVID-19 conditions expectedly changes, so it is crucial to estimate traffic demand with consideration of a change in the travel behavior of people.

Therefore, this study applied an activity-based model (ABM) to Jakarta and estimated the impact of transportation policies that contribute to low carbonization by changes in people's travel behavior, such as teleworking activities. Then, this study evaluates how much the mitigation policy contributes to GHG emissions reduction.

Key words: *GHG emission, low carbonization, COVID-19, travel behavior, Activity-based model*

Introduction

According to the SLOCAT report (2021), GHG emissions from the transport sector have increased year after year as motorization has progressed. Many attempts to realize low carbonization due to urban transport were proposed and implemented, particularly in developing countries of the Asian region which are currently experiencing rapid population growth. Many countries tried to deal with this issue by implementing mitigation policies such as transitioning private vehicles into public transport systems in order to reduce GHG emissions in the transportation sector. However, the GHG emissions increase due to the amount of emission has continued to exceed its reduction.

Researchers recognized that reducing GHG emissions only from individual transport systems is futile and that a feasible solution to this problem requires considerably reducing GHG emissions by changing people's travel behavior (e.g., Girod et al., 2013; Golob and Hensher, 1998; Line et al., 2010; Truelove and Parks, 2012). Teleworking policies, for example, are being implemented due to advances in information and communication technology (ICT). These regulations not only fulfill the desires of many company employees for flexible working hours, but they have also changed people's travel behaviors in urban regions. Unexpectedly, COVID-19 spread, and teleworking was abruptly promoted globally because people's opportunities to go out were limited. This event increased the number of people who stayed at home and dramatically affected travel behavior, such as the use of public transportation.

This is clarified in existing studies. Elldér (2020) observed travel behavior during the defined period when telework was practiced, distinguished different telework arrangements, analyzed a wide range of travel behavioral outcomes, and concluded that telework reduces traffic demand and encourages more active transportation modes, as well as congestion relief.

Cerqueira et al. (2020) provided new evidence about the relationship between travel behavior, workplace diversification, and environmental impact in the United Kingdom. They clarified that the impact on the CO_2 emissions due to workplace diversification is often reflected by longer average distances for work trips, which are often associated with more remote residential locations.

As mentioned above, various events affect how people change their travel behavior. However, because changes in people's travel behavior were not explicitly incorporated in traffic demand estimation, the GHG emission reduction effect that causes significant changes in travel behavior was not appropriately evaluated.

Thus, the activity-based model (ABM) was utilized in this study to estimate transportation demand while considering changes in people's travel behavior across urban areas. The ABM was applied in Jakarta Metropolitan Area (JABODETABEK), Indonesia, to assess the impact of transportation policies that contribute to low carbonization through changes in people's travel behavior, such as telework activities. The impact of the mitigation policy on GHG emissions reduction was then assessed.

Literature Review

There is a lot of research and ongoing discussion to come up with mitigation policies to prevent global warming. Accordingly, the literature is reviewed and summarized as follows.

In the global context, the Intergovernmental Panel on Climate Change (IPCC) advised a comprehensive sustainability approach to transportation based on the Avoid-Shift-Improve (ASI) strategy (IPCC, 2014). In this strategy, a hierarchy of actions is used in order to reduce passenger transport emissions. First, avoid – avoiding journeys where possible, through innovative spatial planning and demand management; then, shift – shifting to the more sustainable modes, such as walking, cycling, and public transportation; and lastly, improve – improving the energy and carbon efficiency of the modal choice. This strategy breaks the current dominant policy emphasis on improving private car efficiency, increasing biofuels, and switching to electric-powered cars. The Avoid-Shift-Improve strategy for transportation recognizes that meeting long-term climate goals will require drastic changes in demand, maybe more than technologies or fuels. The IPCC strategy recognizes many other negative externalities besides carbon dioxide emissions in car use, such as road safety, adverse health effects due to commuter physical inactivity, traffic issues, and costs related to land use.

Under these circumstances, scenario planning and emission estimation are being carried out to reduce emissions of greenhouse gases such as CO_2. Some studies discussed the GHG emission in the transport sector in developed/developing countries. For example, Grubler et al. (2018) present a study that includes net zero scenarios that include demand reduction and modal shift based on the Avoid-Shift-Improve approach to discussing demand reduction scenarios. Transportation is one of the major sources of greenhouse gas (GHG) emissions that are causing climate change. As communities work to cut emissions and become more resilient, they are looking to strategies such as the promotion of public transportation and active transportation as a climate action strategy (McGraw et al., 2021). Most developed and developing countries have addressed the contribution of GHG emissions reduction in the transport sector (Anantha et al., 2018; Jing et al., 2022).

Several studies have attempted to analyze greenhouse gas emissions in the transport sector based on the influence of travel patterns and transport system design. Those studies are based on the cause-and-effect relationships of factors such as transportation network topology, transportation cost structure, congestion pricing regimes, traffic control methods, vehicle speed, road environment, design and maintenance of road networks, travel demand structure, and traffic intensity of emission levels (Chiou and Chen, 2010; Nagurney et al., 2010; Nagurney 2000; WBSD, 2004; Yang et al., 2009; Yin and Lawphongphnich, 2006).

According to O´Riodan et al. (2021), due to the need for faster reductions in transport greenhouse-gas emissions, policymakers are increasingly paying attention to the role of reducing mobility demand and shifting towards low carbon transport modes. The author addresses the issue of evaluating public strategies by looking further than modal shift, assessing the trip purpose, especially remote working. Pye et al. (2021) highlight that demand-side measures, such as avoiding the need for travel and modal shift, are usually overlooked. Therefore, the author concludes that there is significant scope for improvements, and models should incorporate techniques that improve the robustness of new strategies (for example, increasing uptake of public transport and active modes or remote working) that would align well with policy goals by policymakers. In that study, a large-scale (nationwide) model is proposed to generate data that could assess policy schemes such as remote working and school bus programs. Transportation demand models can address the scale, magnitude, and dynamics of transportation-related emissions. Linton et al. (2015) explored the modeling tools available for analyzing the emissions of CO_2 from transportation, covering a range of techniques from transport microsimulation to global techno-economic models. That study provided insights into the various advantages and shortcomings of such tools and examined the value of having a broad range of perspectives for analyzing transportation-related emissions. The study concludes by suggesting that the broad range of models creates a rich environment for exploring a spectrum of policy questions around the emissions from transport, and the potential for combining modeling approaches further enhances the understanding that could be attained.

In past literature, GHG emissions could be estimated based on individual travel patterns. According to Davidson et al. (2007), and Stern and Richardson (2005), one of the goals of behavioral research in transport is to understand how travelers use the transport infrastructure in order to better predict their needs and enhance decision-making, thus providing a more holistic view of activities.

The underlying principles and frameworks of behavioral models are greatly influenced by the disciplines of social psychology and behavioral economics (Schaap and van de Riet, 2012). ABM focuses on the underlying motivations behind travel decisions, allowing travel patterns to be more clearly understood and quantify the demands on the mobility system (Axhausen and Gaerling, 1992; McNally and Rindt, 2008). By quantifying the amount of travel within a network through an activity-based approach, emission factors can be applied to estimate the CO_2 emission from road transport. Asakura and Jakkula (2009) presented a methodology considering the relationship between time-flow function and vehicle speed-emission factors to achieve an estimation of local traffic emissions. That study also addresses the use of such emission estimations in the construction of the public policy, in that case, emissions-based road pricing.

The complexity of understanding travel behavior and the framework for data acquisition and modeling is addressed by Sharma et al. (2021). That study reviewed and analyzed recently published works on travel behavior modeling from high-quality publication sources, classifying recent advances in travel behavior modeling based on the type of algorithms, applications, data sources, technologies, behavior analysis, and datasets. Furthermore, the authors discussed emerging research challenges and limitations of recent travel behavior model studies. In order to model and forecast travel behavior, Zarwi et al. (2017) considered several individual aspects, such as demographics, situational, psychological, and sociological. Another perspective addressed by Kim and Parent (2016) is modeling individual travel behavior based on intra-household interactions via datasets of large samples of individual trips. The authors concluded that suitable data collection techniques for this type of travel behavior modeling rely heavily on the individual's familiar sense of the location for both residence and main activity, making it necessary to plan surveys specifically for such an objective, according to the chosen model framework.

In the existing studies, various methods have been developed and analyzed for estimating GHG emissions in the transportation sector. However, the use of ABM to estimate and evaluate GHG emissions and its regulations is still scarce. This paper will focus on the estimation of GHG emissions in the Jakarta Metropolitan Area using ABM as its tool. This paper will also provide the proposal for introducing the teleworking policy in the study area and its effect on reducing traffic and GHG emissions.

Evaluation Method for Estimation of GHG Emissions in Transport Sector

This section outlined the research method to forecast the traffic demand and estimate GHG emissions by ABM. This section provides information about traffic conditions in the study area, required datasets for the estimation, the detailed calculation process, and the estimation of the traffic demand method being proposed. The calculation process was divided into five stages, and the procedures followed in carrying out this study are also included. In addition, the evaluation method of the mitigation policies (decrease in GHG emissions) by ABM was also discussed.

Study Area: Jakarta Metropolitan Area

This paper selected Jakarta Metropolitan Area (JABODETABEK) in Indonesia as the case study area, composed of 9 municipalities (Figure 1), the city has a variety of transport systems for an area populated by 33,918,000 people. Recently, the development of road networks such as bypasses and highways has been prioritized due to the massive number of private transport users. Several policies have also been implemented to control the traffic demand and to reduce GHG emissions by limiting road users, such as the 3-in-1 and odd-even policies.

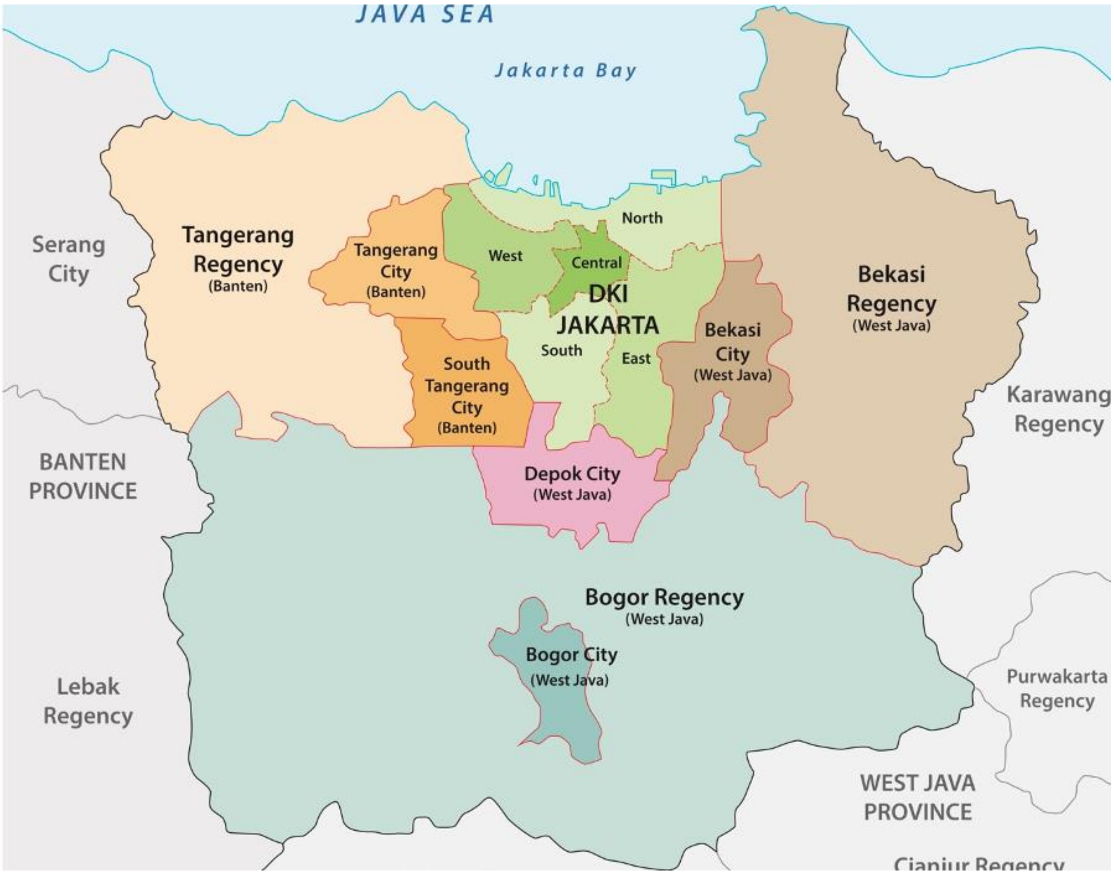

Figure 28: Map of Jakarta Metropolitan Area

A joint project between the government of Indonesia and JICA in 2018-2019 titled JABODETABEK Urban Transportation Policy Integration Project Phase-2 (JUTPI2) was formulated as a revision for the 2001 Jakarta Metropolitan Area's master plan. The final report discussed several long-term issues, including public transport initiatives and TOD development.

Regarding the traffic condition of JABODETABEK, Figure 2 (left) shows the modal share in JABODETABEK in 2002, 2010, and 2018. The use of motorcycles has been growing exponentially, while the use of buses has decreased over time. On the other hand, it is worth noticing that the availability of BRT (TransJakarta) starting in 2010 offers riders different alternatives to taking public transportation. The people have been changing their modes from the traditional bus to both motorcycle and BRT. Also, the number of daily trips in the JABODETABEK was estimated to reach a staggering 55 million trips per day in 2030 by private vehicles Figure 2 (Right). This number corresponds to the trend that was shown in Figure 2 (Left), showing the increase of motorcycle users representing the private vehicle. The governments are expected to do something about it by implementing policies such as ERP (Electronic Road Pricing) policy and even look further into the future, such as introducing a teleworking policy to reduce these congestions (JICA 2015 "Preparatory Survey on Intelligent Transport System Project to mitigate Traffic Congestion in Jakarta (PPP Infrastructure Project) Final Report").

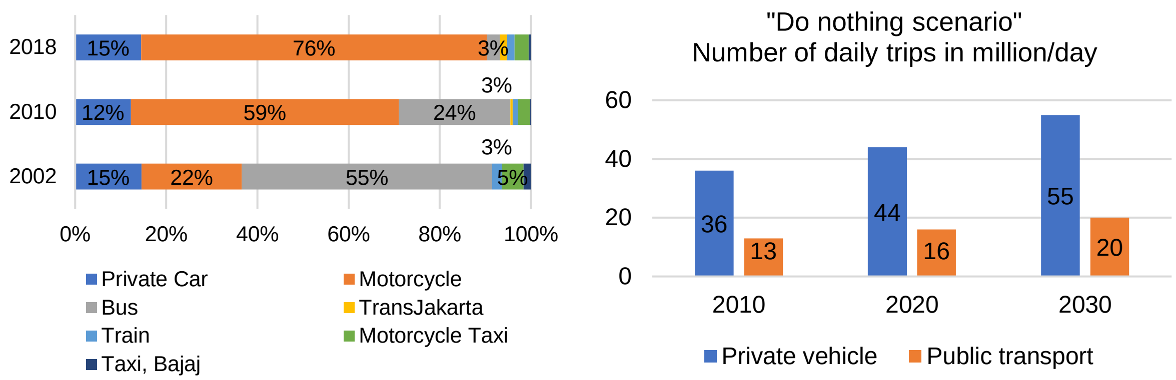

Figure 29: Modal share (Left) and number of daily trips in Jakarta Metropolitan Area (Right) (JICA 2018)

Framework of analysis by ABM

In this study, the Simba.Mobi model (Scherr et al., 2019) was adjusted and applied to the traffic condition in JABODETABEK to estimate daily traffic demand. The model itself is classified as the hybrid approach, which combines the features of utility maximization theory for choice calculation and the rule-based method of considering time and space constraints.

The framework of the calculation process for traffic demand forecasting by ABM is shown in Figure 3 below. The model is divided into five stages which include Stage (1) Generation of synthetic population, Stage (2) Estimation of parameter, Stage (3) Estimation of traffic demand, Stage (4) Traffic assignment, and Stage (5) Policy Evaluation (Stage 5 will be further explained in the next section).

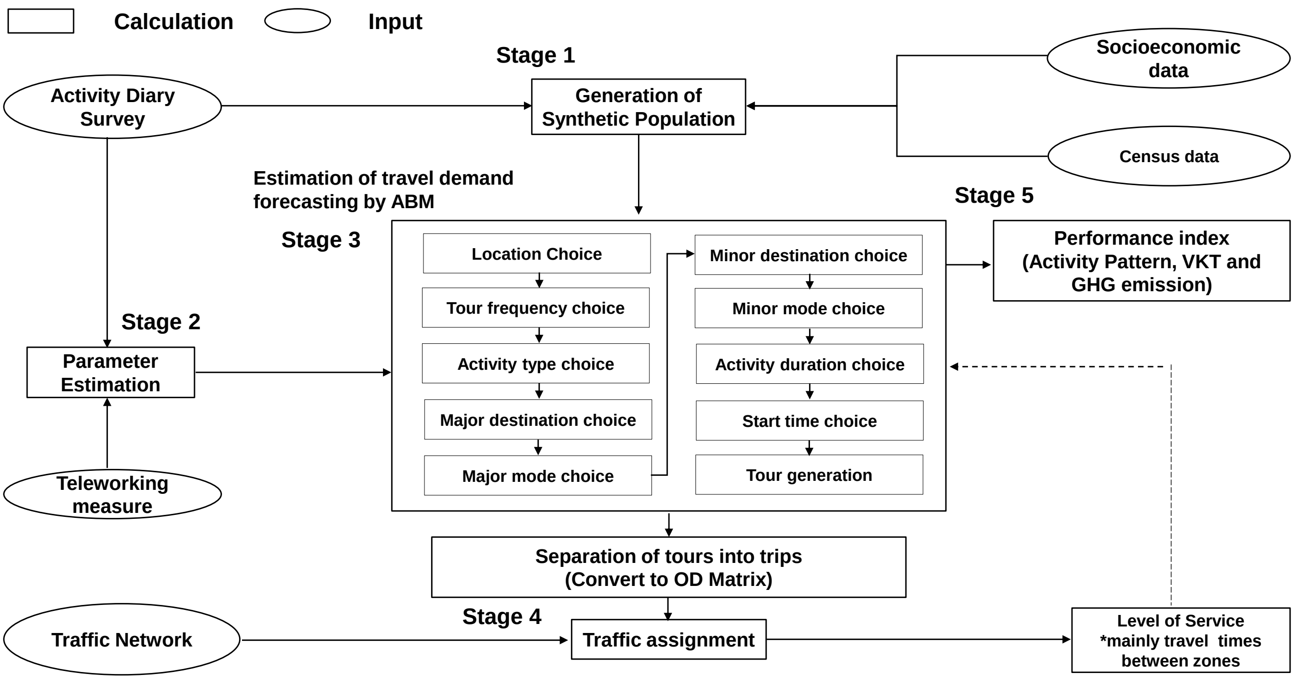

Figure 30: Overall framework of research methodology

Stage 1: Generation of synthetic population

As input in ABM, it is necessary to generate synthetic population data representing all residents, including personal attributes, such as income, age, etc. In the population synthesis stage, it is possible to represent personal information and the relationship within a household. Using the census and Activity Diary Survey (ADS) data, a synthetic population that includes all 33.91 mil-persons and 9.13 mil-households was generated. The synthetic population's generation was computed using an Iterative Proportional Updating (IPU) method (Farooq et al., 2013 and Konduri et al., 2016).

Stage 2: Estimation of required parameter

The required parameters for the discrete choice model inside the ABM were estimated based on the random utility and probability theory, as shown in Equations (1) and (2).

$$u_a = \sum i \beta_{A,i} \cdot x_i \tag{1}$$

$$P_A = \frac{\exp(u_A)}{\sum i \exp(u_{A,i})} \tag{2}$$

Where u_A stands for the utility for choice A, x_i are the attributes of the person, and β is the corresponding parameters. The ADS data was filtered and constructed to estimate the parameters for each sub-models within the ABM. These sub-models include the location choice model, tour frequency choice model, activity type choice model, major and minor destination choice model, major and minor mode choice model, activity duration choice model, and activity start time choice model.

Stage 3: Estimation of daily traffic demand by ABM

Using the estimated parameters and the synthetic population data, the daily traffic demand in the study area was estimated using ABM. By following a specific order, the same discrete choice models were used to calculate each choice for each person by ABM.

Firstly, the location of a primary activity of a person is first selected, then the choice of tour frequency and activity type of every person will be estimated. This process creates an individual activity pattern, such as Home – Work – Home. And once the activity pattern is fully constructed, choices that will affect travel behavior, such as destination and mode, are estimated based on the attraction of each zone and the utility of each mode. As a final step, the activity's duration and start time are computed to complete a whole day tour data for each person. A "Tour" is a combination of trips that includes significant information such as its location, frequency, modes of choice, and other details of an activity. These tour data are then broken down into two categories, one is to express travel behavior (travel time, modal choice, and origin-destination) and 2 to express the activity (activity type, duration, and start time). The tour data was then sliced into multiple trips by utilizing a script in PTV VISUM, resulting in the trips being converted into OD matrix by mode.

Stage 4: Traffic Assignment

The traffic is assigned based on these previously developed OD matrices and transport network data. As a result of this assignment, the travel time of each mode which acts as the level of service, is again re-estimated for the next step of model calibrations. Results such as Vehicle Kilometers Travelled (VKT), Vehicle Hours Travelled (VHT), traffic volumes, activity pattern, and GHG emission will be the output of this stage.

Policy evaluation by ABM

Setting of assumption of teleworking policy

In order to add depth to the research, a scenario was introduced to simulate the effect of a transport policy in reducing GHG emissions. In this study, a teleworking policy was chosen to be further evaluated. Shabanpour (2018) developed an integrated framework to provide the empirical evidence of the potential impacts of home-based teleworking on travel behavior, network congestion, and air quality using POLARIS hybrid approach. In this study, the teleworking policy was integrated into the model by modifying the population data in Stage 1 of ABM. Information regarding teleworking behavior was assumed from a lockdown condition by reading manuscripts from past papers and the latest news in the study area. The results add information on teleworking attributes in the population data and allow the estimation of new demand results.

Specifically, the population data hold work-related variables such as work type and income levels for each person, the script of the population synthesis program was designed such that it generates choices for who will telework or not based on that, these choices were stored in PTV VISUM as an attribute of a person. People with specific work types and income levels will tend not to travel to work based on the teleworking parameter. It is necessary to clarify the actual choice of teleworking in detail. However, a survey related to this condition has not been conducted yet in the study area. Hence, this study will assume the teleworking choice by work type, referring to the past literature and the latest news in Jakarta Metropolitan Area. It is important to mention that the classification of work type shown in this study is based on the actual population census data.

Table 1 summarizes the assumption of which type of work will be able to telework or not under the policy. It is also important to note that the study will enforce a 100 per cent condition of teleworking in the simulated scenario. This issue was due to the lack of information about the actual frequency of teleworking in the study area. A new travel behavior survey regarding the lockdown condition in JABODETABEK is currently being designed to address this issue in the hope of achieving a better result for future studies. Finally, the teleworking condition was evaluated by comparing VKT, VHT, changes in activity patterns, and GHG emissions before and after the policy was introduced.

Table 14: Teleworker assumptions

With Teleworking		**Without Teleworking**	
Craftsman	Expert (lecturer, teacher)	Farmer, fisherman, miner	Goods transport driver
Industry/business owner	Administration staff	Factory works/labor	Public transport driver
Sales, merchant	Technician	Construction laborer	Private driver
Professor, manager, director, etc.		Armed forces/Police	Housemaid, office boy, cleaning service, gardener
		Professionals (doctor, engineer, accountant)	Security Officer
		Waiter, bartender	

Activity patterns

This study aims to propose an idea to refer to and analyze using a rather uncommon yet equally substantial performance indicator, that is, the activity pattern of each person. Kitamura and Fujii (1998) initiated the method of evaluating a transport policy concerning people's activities using what they refer to as an "After-work Travel Pattern", the unit used on their study were the frequency and the time of the patterns. Building on that same concept, Yamada and Fukuda (2019) designed an ABM for the analysis of a change in activities after a traveller leaves the office in Tokyo, activity patterns were defined as a series of behaviors of when a person goes out. Derived from past papers, this study used similar approach in evaluating the changes affected by the teleworking policy. As shown in Table 2, the targeted activity patterns were constructed beforehand. Activity patterns are generated as a result of Stage 5 of ABM. The number of activity patterns generated in the base scenario will be directly compared with the number of activity patterns generated in the teleworking scenario. Compared to the base scenario, changes were done by strictly looking at the difference in the number of patterns in the activity patterns table. Simulation-wise, there are still a wide variety of activity patterns that came as the model results. However, in this study, only 10 activity patterns will be analyzed due to the significance of these patterns associated with the policy being evaluated. Due to that reason, the total number of activity patterns may seem unbalanced in the comparisons.

Table 15: Activity patterns in Jakarta Metropolitan Area

Target	No.	Activity Pattern	Abbreviation
Work related pattern	1	Home → Work → Home	HWH
	2	Home → Work → Shopping → Home	HWSH
	3	Home → Work → Private → Home	HWPH
Education related pattern	4	Home → Education → Home	HEH
	5	Home → Education → Private → Home	HEPH
Secondary activity pattern	6	Home → Shopping → Home	HSH
	7	Home → Private → Home	HPH
	8	Home → Shopping → Private → Home	HSPH
	9	Home → Private → Shopping → Home	HPSH
	10	Home / Telework	H/T

GHG emission evaluation

In order to estimate the GHG emissions, this study uses equations (3) and (4). Equation 3 represents a method for estimating carbon dioxide emissions for individual transport modes. Based on this formula, carbon emissions can be estimated by multiplying the VKT of each link (traffic volume multiplied by the link length) by the emission factor of each transport mode according to its travel speed. By applying them to all links and adding them together, it was possible to calculate the carbon dioxide emission for the entire city.

Additionally, Equation 4 shows the final product of the emissions factors for each transportation system and each travel speed. When calculating the emission factor, it is necessary to estimate the parameters using this formula. However, since the parameters have not been estimated, the values estimated from a past study in Bangkok, Thailand, were used. Table 3 presents the actual emission factors used in the calculation.

$$E_{k,i} = D_k \cdot Q_{k,i} \cdot Ef_{k,i}(v_{k,i}) \quad (3)$$

$$Ef_{k,i}(v_{k,i}) = a_i v^2 + b_i v + c_i \quad (4)$$

Where;
E: Emission (g)
D: Distance (km)
Q: Traffic volume (veh/h)
Ef: Emission factor of travel speed v (g/km)
a/b/c: Parameter
k: Link
i: Mode
v: Balancing speed (km/h)

Table 16: Emission factor for each transportation mode

Mode	a	b	C
Passenger Car	0.0584	-7.4383	335.90
Motorcycle	0.0308	-3.6385	165.98
Bus	0.0378	-4.2744	178.78

Source: *Japan Transport Cooperation Association in Collaboration with Japan Whether Association and Nihon University 2006 "Study for Development of Atmospheric Environmental Impact Assessment Methodology in Bangkok"*

Result of Traffic Demand Forecasting by ABM

Changes in activity pattern and activity executions by teleworking policy

This study set the base year for the traffic demand calculation as 2018. The daily traffic demand forecasting by the developed ABM and the changes in activity pattern by teleworking policy was summarized and represented in Table 4. Work related pattern is targeted at people who have worked as their activity, this might include a worker going to the office or a student going to a part-time job. The values on the 10th row represent the total number of home activity that was completed by each occupational category of workers, students, and others. Additionally, the sum of activity patterns excluding and including home activity was also provided.

Table 17: Activity pattern results

Target	No.	Activity Pattern	Base (in patterns)	Teleworking (in patterns)
Work related pattern	1	HWH	18,425,682	26,730
	2	HWSH	17,028	19,305
	3	HWPH	22,572	25,542
Education related pattern	4	HEH	6,787,935	6,709,644
	5	HEPH	1,864,566	1,187,209
Secondary activity pattern	6	HSH	1,386	1,188
	7	HPH	1,089	495
	8	HSPH	495	594
	9	HPSH	891	1,683
	10	H/T	5,652,207	21,068,161
SUM		Excluding H/T	27,121,644	8,072,390
Total		Generated Pattern	32,773,851	29,140,551

The expected result of introducing a teleworking policy was to see the number of home activities increases as work activities decreases; though some portion of the results corresponded to the initial hypotheses, other portions have also shown some interesting outcome. Table 4 shows how the number of main work-related patterns of (H – W – H) decreased significantly while staying at the home pattern (H/T) increased by a staggering number of 199 per cent and 118 per cent, respectively. Due to the nature of the model trying to replicate the lockdown condition during a pandemic, the reason behind the increase of patterns such as (H – W – S – H) and (H – W – P – H) by 13 per cent and 12 per cent respectively could be justified by the fact that people who had to go to the office will definitely spare their inbound trip time to do maintenance activity such as shopping. The decreasing number of activity patterns (H – S – H) by 15 per cent can be explained when the structure of the family/household is being considered, in which a worker might currently live with a non-worker. It is conceivable that the workers will do the shopping activity instead of the non-worker people. Additionally, the increase in secondary activity patterns such as (H – S – P – H) and (H – P – S – H) by 18 per cent and 62 per cent, respectively, was theorized in a past study by Shabanpour (2018), where people working from home will consequently have more flexibility to conduct secondary activities. In this study, only workers were targeted to be the subject of the impacts of teleworking policy evaluation. Therefore, for students, there is no significant difference in the number of activity patterns under the usual condition and the teleworking policy.

Moreover, Figure 4 shows the percentage of the share number of activities being executed from both scenarios. The drastic increase in home activity and the decrease in work activity can be seen in the columns shown in the chart. Furthermore, the increase in secondary activities such as private and shopping can also be seen in the teleworking case.

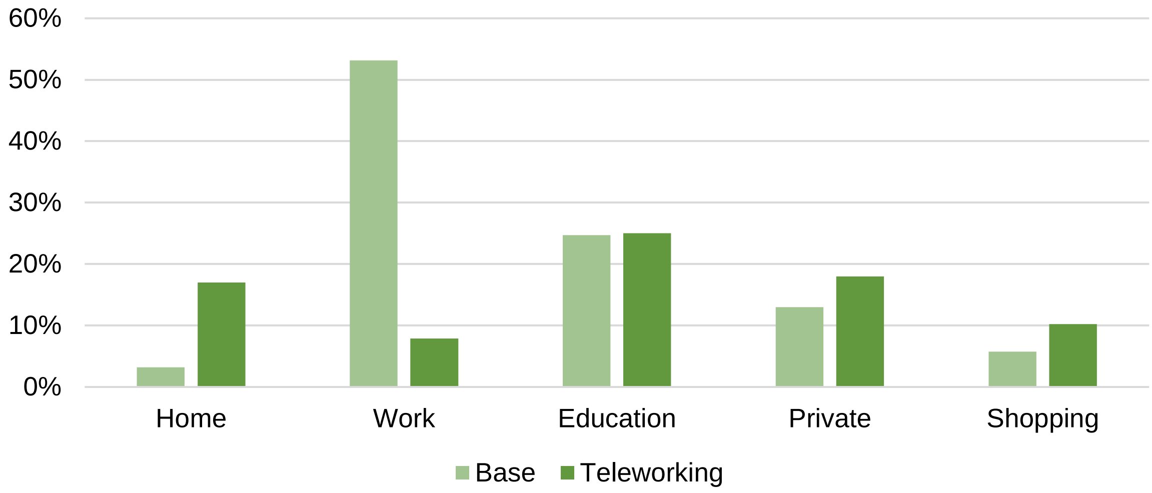

Figure 31: Comparison of number of activities executed

Changes in traffic situation by teleworking policy

Based on the generation of each individual's activity pattern in the previous section, The model was simulated using a transport modeling software called PTV VISUM, the graphical representations of the assignment and the result of applying traffic volume allocation are shown in Figure 5 (left: steady state, right: when teleworking policy is applied). It can be seen that in the case of teleworking scenario, the speed of vehicles in the overall network is significantly higher than the usual condition in many road sections, including the road section in the city center area.

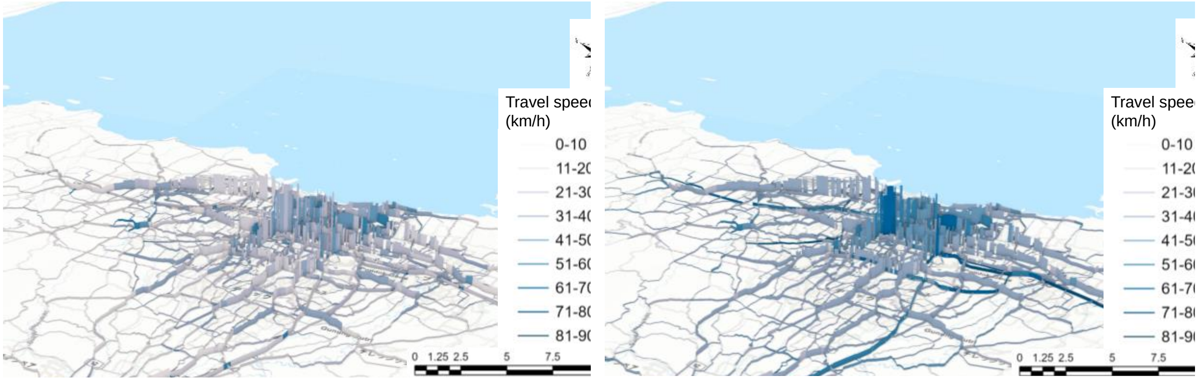

Figure 32: Traffic situation of each scenario (Left: Base, Right: With teleworking policy)

In addition to that, Figure 6 also represents the changes in modal share after the introduction of teleworking policy. The mode types being considered in the model include private cars, motorcycles, and public transportation. The increased motorcycle share was caused by the decreased number of long hauling trips generated in teleworking case. According to the census data, 35.99 per cent of the households in JABODETABEK own more than two motorcycles. Justifying the fact that people will go shopping or do other leisure activities by riding a motorcycle.

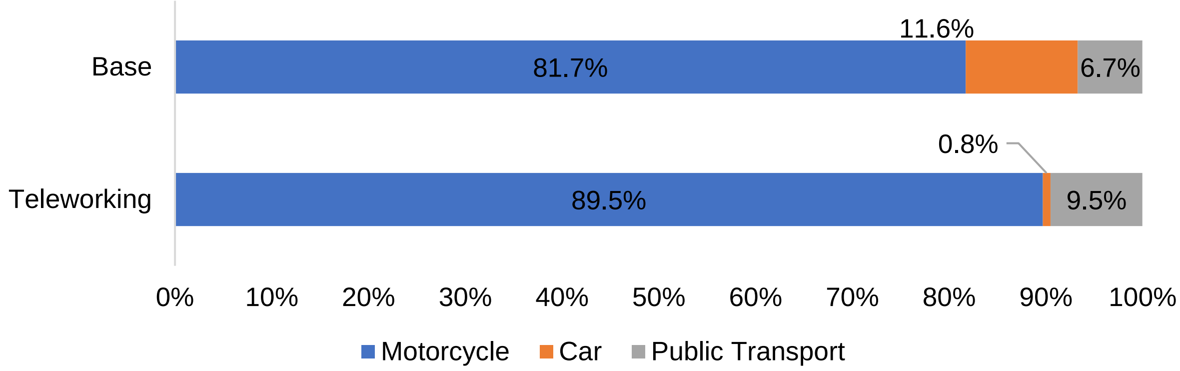

Figure 33: Modal share results

In total, the VKT and VHT results for each scenario were summarized and validated. As mentioned before, the base year for the model was set as the year 2018, which was the year the ADS was conducted. The estimated results in Table 5 show that over 1 billion Vehicle Kilometers were traveled and over 46 million vehicle hours were traveled. The deviation with the model referred from the JUTPI2 project by JICA were 6.4 per cent and 0.2 per cent, respectively.

Table 18: Validation of VKT and VHT

	Estimated	JUTPI2 Model	Deviation
VKT (veh.km)	1,081,276,448	1,016,254,104	6.4%
VHT (veh.h)	46,477,837	46,373,863	0.2%

Table 6 demonstrates how teleworking policy affected the VKT, VHT, and traffic volume of the network. As expected, the introduction of the policy has significantly decreased all aspects of traffic indices due to the lesser number of tours being generated. These results also provide an indication of how effective the teleworking policy scenario is in reducing congestion in the study area. Activity pattern analysis results show that the teleworking scenario successfully lowered the VKT value and the VHT values by some margin (VKT: 375,848,940 veh.km; VHT: 22,856,961 veh.h).

Table 19: Comparison with VKT, VHT, and Volume

	Base	Teleworking
VKT (veh.km)	1,081,276,448	705,427,508
VHT (veh.h)	46,477,837	23,620,876
Volume (PCU)	2,400,173,272	1,598,407,043

GHG emissions

Figure 7 shows the results of the estimation of GHG emissions in the network, both for the usual condition and in the teleworking condition. The results were formatted as a pie chart to represent better the division between gasses emitted by each travel mode. It is very interesting to see the huge difference between the two conditions due to the effect of introducing the teleworking policy. In total, the amount of GHG emission (specifically, CO_2) emitted under the usual condition and under the teleworking policy were 151,268 t-CO_2 and 23,240 t-CO_2, respectively. It is important to point out that under the teleworking policy, the percentage of the share being held by motorcycles increases by more than 10 percent. Through the analysis of activity patterns, it was understood that some people who telework tend to travel more frequently yet at shorter distances, giving travelers a choice to opt for a simpler means of transport, which is riding a motorcycle instead of driving private cars. These results also correspond to the results shown in Figure 6 of modal share.

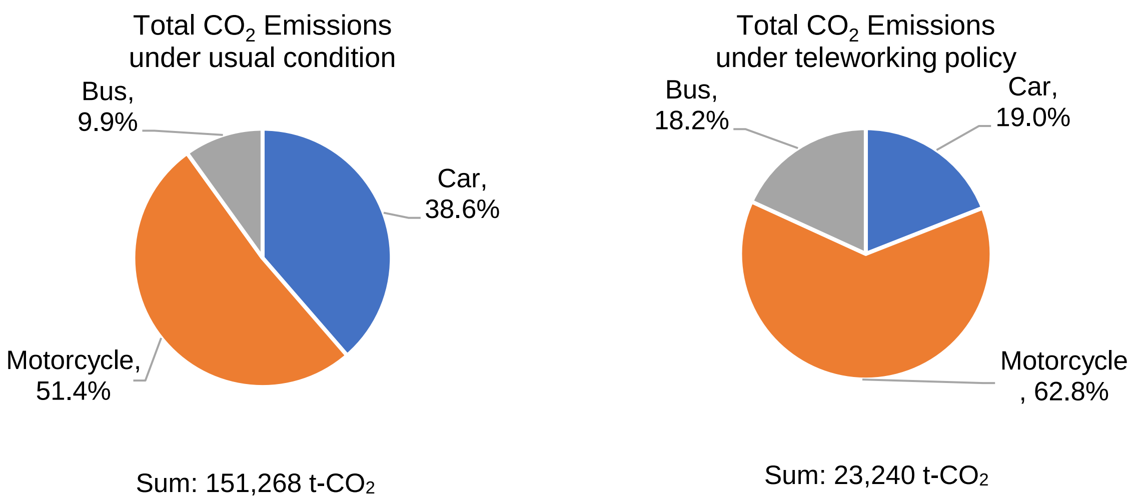

Figure 34: GHG emissions comparison

Conclusion

In this study, ABM, which can explicitly deal with the fact that transportation policies bring about significant changes in people's transportation behavior, was used. An approach was presented to analyze the impact of policy implementation on transportation demand. Then, the proposed approach was applied to the evaluation of the introduction of the telecommuting policy in the Jakarta metropolitan area, and a trial calculation was made of how much GHG emissions would be reduced by the introduction of the telecommuting policy. So far, many analyzes have been conducted on the reduction of greenhouse gas emissions through changes in the choice of transportation modes and the choice of travel routes due to the implementation of transportation policies, but the changes in people's activity patterns themselves have not been sufficiently investigated. In this respect, the approach of traffic demand estimation using ABM proposed in this research is a very effective means. From the analysis of this research, the following three points were clarified.

1. It was understood that the number of activity patterns generated in the model is heavily influenced by the information stored in the population data and the state of constraints that were set up during the policy implementation. Table 4 shows how the number of work-related and staying-at-home patterns were affected by the introduction of teleworking policy.
2. In terms of the traffic condition, the introduction of teleworking policy has managed to reduce congestion. Vehicles are able to drive at a faster-constrained speed in the network. By the analysis of the activity pattern, the reasoning behind this occurrence was able to be analyzed.
3. The GHG emissions under the usual condition and the teleworking condition were estimated to be 151,268 t-CO_2 and 23,240 t-CO_2, respectively. Teleworking policy has had a huge impact in regard to the total emission, and it was also clarified that teleworkers travel by motorcycles instead of private cars to finish their secondary activities, increasing the share

for both modal and CO_2 emissions.

Hence, in this study, it was concluded that the analysis of activity patterns could provide additional information for decision-makers to consider in implementing a policy. The policy that was evaluated was focused on gearing up the transportation sector to shift following the ICT transformation. Teleworking policy was believed to be a solution to reducing congestion as well as GHG emissions in the future. Moreover, the use of ABM also established a foundation in modeling travel behavior using much more detailed data, information such as census data and person trip data can be substituted into big data, it is expected that an extensive data analysis will be the norm in the future. By focusing on assessing the trip purpose and reducing the need to travel, it was proven that GHG emissions could be significantly reduced. In the result section, the drastic decrease in CO_2 emission caused by the change in people's travel behavior was clarified in more detail due to the utilization of ABM.

In a further study, an activity survey will be needed to create a proper condition for the teleworking policy in the model. This kind of survey will eliminate the shortcoming of this paper by giving the authors much more detailed information about the actual situation of teleworking policy in the study area, such as the frequency of teleworking, the duration of teleworking, and the activity scheduling choices due to the policy. Based on the survey, parameters will be estimated to represent new constraints in the model. As for the estimation of GHG emissions, it is also crucial to use an emission factor for the appropriate study area instead of using alternatives. This can be done by referring to supplementary literature or obtaining it by conducting a survey.

Acknowledgment

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Collaborative Development of Sustainable Transport Sector in the Mekong Countries

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ABSTRACT

Non-state actors have as much role to play in sustainable policy and governance initiatives in the transport sector in the Mekong countries as the state actors. Activities of concerned private sector associations aimed at reducing emissions in the transport sector are considered as important in achieving the objective of emission reduction. Overall, non-state actors such as international organizations, non-government organizations and private sector associations also play significant roles in public awareness raising and providing support during the policy formulation and governance. Effectiveness of such initiatives increases when state actors are also able to provide an enabling environment for promoting a sustainable transport sector. The current paper aims to study: (i) the manner in which the Mekong countries are developing their sustainable freight transport sector, (ii) sustainable freight transport policies that are being implemented and/or being formulated collaboratively (between state and non-state, national and regional actors) in the Mekong countries, and (iii) roles played by various non-state actors in developing the sustainable transport sector by mapping initiatives undertaken by non-state actors. Drawing upon the concepts of global public policy and governance, transnational/international public administration and transnational networks, the paper will formulate its recommendations based on new institutionalism and network governance perspectives.

Key Words: *collaborative development, freight transport, global public policy and governance, new institutionalism, non-state actors*

INTRODUCTION

Countries in Mekong region comprising of Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam or also refer to as CLMVT countries, are located in the South Eastern part of Asia. All countries, except Myanmar and Viet Nam, share their borders. Home for nearly 250 million inhabitants, the subregion gains its importance for regional and global supply chain due to its strategic location and, shared borders with China and India.

In the last decade, intra-regional trade in the Mekong region recorded the average annual growth rate at 11 per cent[15]. Trade between countries in the Mekong region has increased in the past decade due to the openness of countries to trade and being a part of development cooperation programs among the Mekong countries as explained below. The freight and logistics sector too have expanded significantly in the last two decades, largely due to rapid increases in exports in the Mekong region as a whole.

However, the logistics industry in the Mekong region is plagued with a range of issues. In spite of higher investments in infrastructure and trade, logistics costs in the Mekong region continues to be higher than many other parts of the world—about 17 per cent of the gross domestic product (GDP) in Thailand and 25 per cent of GDP in Viet Nam, in contrast to less than 10 per cent in most countries of the Organization for Economic Co-operation and Development (OECD) (ADB 2015b). The transport infrastructure in the GMS has spurred an increase in transport and traffic and a corresponding increase in Greenhouse Gas (GHG) emissions. Within a decade (2010-2020) the number of vehicles registered has almost doubled

[15] Authors' own calculation based on GMS Intra-Regional Trade data, available at www.greatermekong.org/gms-intra-regional-trade percentC2 percentA0-us-billion

and transport sector responsible for 20 per cent of GHG emissions[16]. In addition, fuel cost accounts for 40-60 per cent of road transport companies total operating cost (ADB 2015b). High logistics costs and inefficient fuel use altogether impact competitiveness and hence reduce profitability of the logistics industry in the GMS, especially the freight truck service companies.

There is a growing interest in having collaborative development of the logistics sector in the Mekong region by ensuring stakeholder participation in decision making processes to ensure their interests, in particular those of non-state actors (such as businesses, business associations, non-government organizations etc). National governments, and regional and international organizations are seeking to include such non-state actors in policymaking as well as implementation of policies.

OBJECTIVES

Against the above backdrop, the objectives of this paper are: (i) the manner in which the Mekong countries are developing their sustainable freight transport sector, (ii) sustainable freight transport policies that are being implemented and/or being formulated collaboratively (between state and non-state, national and regional actors) in the Mekong countries, and (iii) roles played by various non-state actors in developing the sustainable transport sector by mapping initiatives undertaken by non-state actors.

GLOBAL PUBLIC POLICY, GOVERNANCE, INSTITUTIONALISM AND COLLABORATION

The current paper analyses the involvement of non-state actors in policy making on sustainable transport in the Mekong countries, within the concepts of global public policy making, governance and institutionalism. We begin the discussion by explaining such underlying concepts to provide a structural framework to the analysis. Studies of public policy and administration have treated the nation-state as the unit of analysis at most. It means that state agencies and policies, or its sub-national units, are examined. Or, alternatively the sovereign public administrations of states are compared. This approach is well-known as ‘methodological nationalism’ (Stone and Ladi, 2015; Bauer et al, 2018). However, the state typically works with or is influenced by other states, or non-state institutions.

With the blurring of state exclusive domains to create policy, the result is a rise of global policy and its governance. Global (Public) Policy (GPP) refers to a set of overlapping but disjointed processes of public–private deliberation and cooperation among both official state-based and international organizations and non-state actors around establishing common norms and policy agendas for securing the delivery of global public goods or ameliorating transnational problems (Stone and Ladi, 2015).

In many countries and policy areas there is a long tradition for private sector involvement in the formulation and implementation of policy, especially at the level of national policy making. The inclusion of relevant and affected groups and organizations in governance networks help to overcome problems in terms of societal fragmentation and resistance to policy change, and thus tends to make the governing processes more effective (Mayntz, 1993). At the same time, the participation of a plurality of stakeholders in the decision-making process tends to enhance the democratic legitimacy of the public policy and governance (Scharpf, 1997). These practical and scientifically justified insights recommend the use of governance networks at the local, national, and even the transnational level (EU, 2001). More recently, non-state actors have played important roles in climate change policies and implementation in different countries. Hsu et al (2018) speak about important contributions provided by non-state and subnational actors to climate action such as building confidence in governments concerning climate policy and push for more ambitious national goals, providing space for experimentation or act as orchestrators in coordination with national governments for climate policy implementation and so on.

There has been increasing but varied involvement of non-state actors in decision making and implementation in the Mekong region as well. Breslin & Nesadurai (2017) point out though there is a strong commitment to state sovereignty in the ASEAN in general and the Mekong region in particular, various forms of transnational governance have emerged where non-state actors (business firms, NGOs, foundations, experts) engage in or contribute directly to the development of norms, standards,

[16] https://data.aseanstats.org/indicator/ASE.TRP.ROD.B.005

rules and practices in these countries, which also points out the failure of national, regional and/or global institutions to provide effective governance.

An issue that government and regulatory agencies face is how to make decisions when the decision making is complex with the involvement of a number of stakeholders – state and non-state. Arras & Brown (2017) found that in the European Union (EU), stakeholders can contribute to agencies' accountability and oversight but they also fulfil certain agency needs especially for expertise. There are discussions and debates on improving and/or finetuning methodologies and approaches of stakeholder engagement and consultations in such instances (e.g., Barfod 2017, Giorgutti 2020, Ignaccolo et al 2018, Bjorgen et al 2019).

Since late 1990s, the debate on sustainable development at the United Nations (UN) has been increasingly emphasizing the importance of collaboration, including through the creation of new partnerships involving private sector participation (UNGC & IRTU 2015). Indeed, strengthening the means of implementation and revitalize the Global Partnership for Sustainable Development is goal number 17 of the UN Sustainable Development Goals (SDGs).

More recently, UN Economic and Social Commission for Asia Pacific (ESCAP) has identified, seven core elements that need to be present for a strong institutional basis on dry ports including defining a role and involvement of the private sector in the policy consultation process (UNESCAP 2022c).

There are also several examples of transnational collaboration and collaboration between intergovernmental organizations. For example, "Observatory on border crossing status due to COVID-19" launched by UN Economic Commission for Europe (ECE) with support of a few other UN agencies and other international partners to gather updated information from different sources regarding border crossing limitations and measures taken in the countries around the worldwide due to COVID-19 outbreak.

Institutional theory provides a structure for promoting non-state actors' involvement in decision making by theory capturing the rather long series of scholarship on co-production, multiple stakeholders, public-private partnerships, privatization and contracting. Institutionalism also includes core ideas about results, performance, outcomes, and purposefulness. It discusses on how institutions behave and how they perform and simplify assumptions of rational self-interest or competitive markets (or more rely on collective action) (Lynn, 1996).

SUSTAINABLE FREIGHT TRANSPORT DEVELOPMENT IN MEKONG REGION

Interest in green transportation logistics in the Mekong region has grown in recent years due to increased emphasis by both private industry and policymakers to make transportation more environmentally friendly. As members of the Association of South East Asian Nations (ASEAN), the Mekong countries adhere to the ASEAN Transport Strategic Plan (TSP) 2016-2025. In TSP the ASEAN member countries agreed to pursue sustainable transport and development of 'Avoid', 'Shift' and 'Improve' strategies at the regional and Member States level with actions mainly related to energy and environmental topics (Bakker et al 2017a, Bakker et al 2017b). It recognizes the benefits of cooperation and consultation with stakeholders in decision making processes related to the transport sector (ASEAN 2019).

The Mekong region has also experienced a growing number of regional and subregional cooperation initiatives which involve all or some countries in the region. The transport sector is a common area of the cooperation in some of these cooperation initiatives as highlighted in the Greater Mekong Subregion (GMS) Transport Sector Strategy (TSS) 2030 (ADB 2018).

The objective of ensuring green performance of the overall transportation supply chain and thus logistics is likely to be a central goal for both industry and policymakers in the years ahead. It is also manifested in the TSS 2030 vision of a "seamless, efficient, reliable and sustainable Greater Mekong Subregion transport system", while the previous TSS did not include environmental concerns.

All Mekong countries have signed and ratified the Paris Agreement on Climate Change. Hence, the countries are required to release and update their Nationally Determined Contribution (NDC) via UNFCCC website to identify their targets for adaptation and mitigation activities aiming at reducing the accumulation of GHG emissions. The transportation sector is one of the major emitters in the region. However, the countries' policy toward sustainable transport are varied as reflected in their NDC updates.

This section analyses initiatives in which non-state actors have been involved in the Mekong countries specifically in the development of the transport sector but also generally in decision making and implementation. Mostly non-state actors' involvement in the Mekong countries have been in form of consultations in case-to-case basis or specific to projects and programs. No mechanism exists either at the ASEAN or any other subregional mechanisms levels to involve non-state actors in decision making for sustainable transport. There are practices of holding meetings of business chambers (e.g., ASEAN Business Advisory Council, GMS Business Council) and civil society organizations but these focus broader areas and not specifically sustainable transport (e.g. organized by ADB) (ASEAN, n.d.; GMS-BC, n.d.; ADB, 2021b). Multilateral organizations such as the UNESCAP and ADB conduct consultations with national and sub-national governments, and non-state stakeholders in the countries as part of their regular processes (such as for Facilitating Cross-Border Paperless Trade by the UNESCAP) (e.g., UNESCAP, 2019 & 2020).

Table 1 summarizes the issues in developing sustainable transport in individual Mekong countries and the type of collaborative initiatives that have been adopted. Whereas all the countries have focused on development of sustainable transport in recent years and have undertaken consultations with non-state actors to certain degrees, these have not been without issues. In some cases, such as in Viet Nam and Thailand, the focus of consultations has been inter-agency or sub-national consultations given the involvement of a multiplicity of agencies in the transport sector and lack of capacities on sustainable transport issues. In case of Myanmar, there have been several issues plaguing its transport sector which have led to underinvestment in the sector. While Cambodia and Lao People's Democratic Republic still have issues, they have undertaken initiatives and consultations to develop their sustainable transport sector.

Table 1: Sustainable Transport and Collaboration in Mekong Countries

Country	Issues Facing Sustainable Transport Sector	Collaborative Initiatives on Sustainable Transport
Cambodia	Unsafe and sustainable infrastructure; lack of data	Consultations by government e.g., for Logistics Master Plan and multilateral agencies such the Climate Investment Fund and ADB
Lao People's Democratic Republic	Transport vulnerable to climate change, lack of financing	Consultations by government e.g., for Vientiane Sustainable Urban Transport Project, and multilateral agencies such as Global Green Growth Institute and ADB; Limited private sector role
Myanmar	Underinvestment in transport sector; adverse effect of COVID-19	Consultations by government e.g., for inland water port terminals and for SASEC Vision Document and multilateral agencies such as the World Bank and ADB Collaborative action with private sector mainly in form of Public-Private Partnerships
Viet Nam	Transport vulnerable to climate change; fine balancing of economic growth and climate change objectives	Consultations by government e.g., for electric transport development plan for Ho Chi Minh City and multilateral agencies such as the World Bank; issues reported in public consultations such as partial addressing of relevant issues through such consultations
Thailand	Transport large emitter of GHG; multiplicity of agencies	Consultations by government such as for such in urban infrastructure in Bangkok or electric mobility, multilateral agencies such as Global Climate Fund and other development partners such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ); issues in such consultations reported such as because of decision making and highly technical nature of such discussions

Source: Authors' Compilation (2022)

Cambodia – Even though it is developing fast, Cambodia's transport sector continues to face a number of challenges including that of having unsafe and sustainable infrastructure (ADB, 2019). Transport sector is considered as one sector which the climate related-information and data are still lacking. Cambodia has been an active participant in the annual Asian Regional Environmentally Sustainable Transport (EST) Forum, which aims to promote environmentally sustainable policies and strategies in the sector (ADB, 2009).

The recent update of Cambodia NDC was released in 2020. In the update, Cambodia freight transport mitigation activities are directed toward shifting long distance freight movement from trucks to train. The mitigation action includes enhanced maintenance and inspection of vehicles (piloting maintenance and emission inspections of vehicles) aiming at (i) reduction of maintenance cost/saving cost, (ii) reduction of traffic accidents, injury and fatality, (iii) reduction of air pollution and, (iv) reduction of GHG emission.

Collaborative development with private sector engagement with non-state actor such as private sector is deemed important to accelerate the mitigation activities. One such example of public consultation is that conducted by the Government of Cambodia in preparation of the Cambodian Logistics Master Plan for US$50-billion transport/logistics projects aimed at boosting its economy growth (Portcalls, 2022; Kunaka, 2018; Beresford, 2021))

Cambodia Road Connectivity Improvement Project (CRCIP) intends to support the improvement of climate resilient road accessibility in targeted provinces. To this end, a Stakeholder Engagement Plan has been prepared by the Ministry of Public Works and Transport (MPWT) and the Ministry of Rural Development (MRD)(MPWT & MRD 2020).

Among the other examples are the Climate Investment Fund (CIF) support received by Cambodia between 2010 and 2018 including on climate resilience that included transport as one of the sectors, which had stakeholder engagement as one of the integral elements of the programs that run under it (LLC, 2019). National Road Safety Committee established in 2005, includes a wide range of stakeholders. At the moment NRSC is drafting a National Plan for the Decade of Action for Road Safety 2021-2030 (GBN 2020, Kunthear 2022).

Among international collaboration, notable is collaboration of Cambodian government departments with multilateral agencies such as the Asian Development Bank (ABD). One such example is transport sector assessments, strategies, and road maps (ASRs) for Cambodia prepared ADB in 2019 in consultation with the MPWT and the Ministry of Rural Development and development partners working in the transport sector. This is an integral part of project planning to ensure coordination between Cambodia’s priorities and those of ADB’s Strategy 2030 and the ADB Sustainable Transport Initiative. A specific initiative on sustainable transport in the ASRs is increasing travel share of urban sustainable transport modes from 19 per cent in 2014 to 25 per cent in 2023 (ADB, 2019a). In spite of several issues plaguing the sector, future prospects of sustainable transport of Cambodia are bright because of different factors such as the emergence of new technologies and a long-term global shift to sustainable investments (Beresford, 2021)

Lao People’s Democratic Republic is one of the world’s most vulnerable countries from the point of view of climate change because of high socioeconomic dependence on climate-sensitive sectors, such as agriculture and water resources. ADB conducted ASRs for the transport sector for Lao PDR as well through consultations with government departments, such as the Ministry of Public Works and Transport, and Lao PDR has been a member of its EST Forum since 2004 (ADB, 2010; ADB, 2011). The country’s vision for transport in 2030 is for the transport sector to be “highly effective and efficient with integrated sustainable transport (Phounsavath, 2019).

In the long run, the national sustainable transport and mobility policies will focus on the support for better coordination between transport and territorial planning and the application of advance technology that enables mobility services (MPWT, 2021). The key vision in transport is pertaining to the capital-Vientiane’s- urban development by 2030 is to make Vientiane an eco-friendly, liveable, and sustainable city (Vongpraseuth, 2022). The country released its recent NDC update in 2021. Freight transport measures include Lao-China railway which expected to increase the use of train for land transportation, and hence reducing the carbon emission. Another measure is biofuels to meet 10 per cent of transport fuels. The baseline information in 2019 estimate the share of biofuel in transport fuels as between 0.5 per cent and 1 per cent (Lao PDR Nationally Determined Contribution, 2021).

Participation of non-state actors particularly private sector is instrumental in the implementation of the NDC. However, it is hard to secure private sector financing so the primary source of funding would be from ODA or other development assistance. The private sector role in collaborative development of sustainable transport sector still limited at coordinating activity to co-oversee of the NDC implementation.

Through NDC Support Program for Lao PDR, UNDP is working closely with the government and other partners on complementary projects to strengthen outputs and ensure comprehensive responses to government needs. Other areas of collaboration are being explored such as with the private sector and communities to raise awareness for more inclusive NDC enhancement (UNDP n.d.).

Global Green Growth Institute conducted public consultations to prepare a Green Growth Potential Assessment (GGPA) during 2016-2017 to assist the Government of the Lao PDR in formulating its national green growth strategy and support the national administration in policy design and implementation. Urban development and transport were identified as one of the entry points for green growth interventions by the assessment.

Among other examples is Enhancing Systematic Land Registration Project of Ministry of Environment and Natural Resources, which was financed by the World Bank and drafted a stakeholder analysis and engagement plan as part of the WB's Environmental and Social Framework (ESF) (MONRE 2021). Recent examples from Lao PDR of stakeholder engagement include a workshop held by UNESCAP in June 2022 on the theme "National Workshop on Transitioning to Electric Mobility in Lao People's Democratic Republic", which included both state and non-state actors (UNESCAP 2022a). ADB too has conducted stakeholder consultation for its sustainable transport projects for Lao PDR (e.g., ADB 2017). One such example is consultations held, including at village levels for Vientiane Sustainable Urban Transport Project for the different project components and to take into environmental issues/concerns raised by the stakeholders (ADB, 2021a).

Myanmar – Despite Myanmar's strategic location between the three major economies of China, India, and the ASEAN, the country's quality of transport infrastructure is lower than its regional peers and income group (World Bank, 2022). Multilateral organizations such as the ADB and World Bank have provided suggestions for development of a sustainable transport system in Myanmar even as the sector in Myanmar continue to face vulnerabilities arising out of its internal political situation, the fallout of COVID-19 and underinvestment in the sector (World Bank, 2022; ADB, 2016). Myanmar's National Transport Master Plan 2014 was developed to provide guidance for a long-term investment program of transport sector in general that will help the Government to achieve its economic growth targets by 2030 (Swe, 2018). More recently Myanmar started discussions on the development of sustainable urban transport (UNESCAP, 2016).

In 2021 Myanmar updated its NDC. There is no policy to phase out fossil fuel vehicles currently. With regard to reconditioned vehicles, only vehicles up to 3 years old can be imported and for new vehicles, only vehicles that meet Euro 4 standards will be allowed. Annual emissions testing for commercial vehicles is mandatory. However, emissions testing facilities are limited as less than 50 per cent of national Road Transport offices have multi-testing system facilities.

Collaborative actions with private sector are mainly in form of Public-Private Partnership projects implemented in energy sector i.e. hydro power and landfill methane recovery (Institute for Global Environmental Strategies, 2022). The private sector engagement in freight transport sector is expected wider to support vehicle efficiency and standards to decrease fossil fuel consumption.

The World Bank as per its normal practice has components of stakeholder engagement in its projects for Myanmar (e.g., see World Bank, 2020a). In similar fashion, Strategic Environmental Assessment of the Hydropower Sector in Myanmar conducted by International Finance Corporation in 2017 included a component on stakeholder engagement (IFC, 2017).

Evidence of a more direct non-state stakeholder engagement can be found in ADB's project titled "Maximizing Transport Benefits through Community Engagement Project: Guidance Report on Kayin and Mon States - Context, Stakeholders and Engagement" conducted in 2015 (ADB 2015c). More recently, the Myanmar government conducted consultations with regional authorities to initiate six new inland water port terminals, four on the Ayeyarwaddy River and two on the Chindwin River. The consultations were part of the implementation of Myanmar's National Transport Master Plan (Mizzima, 2017).

Myanmar is also a member of South Asia Subregional Economic Cooperation (SASEC) and it conducted consultations with the governments departments and private sector in 2018 as part of adoption of the SASEC Vision Document that includes development of the transport and communication sector including the development of subregional gateways and hubs (SASEC, 2018).

Viet Nam – Viet Nam is one of the countries that are most vulnerable to the impacts of climate change. The government has been taking measures to keep in pace with the requirements of an economy that is one of the fastest growing in the world, while balancing both sustainability and financial aspects. The government addressed the impact of climate change as a key issue by approving the National Target Program in 2008. ADB conducted ASRs for Viet Nam as well in consultation with relevant government departments of Viet Nam in 2012. The Assessment along with Viet Nam Transport Strategy 2020 laid down a forward strategy to improve planning, implementation, and operational efficiency throughout the sector, including for mainstreaming climate change mitigation and adaptation (ADB, 2012; ACPCI, 2000). In 2020, the Ministry of Transport, Viet Nam unveiled its 2030 master plan for transport infrastructure that could be worth as much as $65 billion and relies on private sector solutions (Guild, 2021).

As per the NDC update of Viet Nam 2020, transport sector is one of the priority sectors with several mitigation measures including modal shift from freight transport by road to freight transport by inland waterway, seaway and railway, and fossil fuel changing in freight transportation (Viet Nam National Green Growth Strategy 2021-2050). Transport sector in Viet Nam is dominated by small and medium-sized companies own small number of vehicles, and also a large number of one-man truck owner.

Private sector engagement is mostly in form of Public-Private Partnership projects in hydro power and waste to energy sector. There is a lack of policies to encourage transport companies to invest in green technologies as well as to improve the quality of SME-owned vehicles.

There has been a tradition of holding consultations on the transport sector in Viet Nam. In 2000 the Vietnam National Transport Strategy Study conducted under a multisectoral steering committee headed by the Vice Minister of the Ministry of Transport and with extensive involvement of the government departments and institutes through task force meetings, a series of seminars/workshops, learning sessions, training course on transport planning, and consultation meetings with donors (ACPCI, 2000). Public consultations (mostly with officials of provincial government departments and other representatives from provinces) were held for Mekong Transport and Flood Protection Project - environmental assessment in Viet Nam in 2000. Activities of the project included minimizing air pollution by checking all trucks, vehicles, or construction machines on air emission and covering vehicles transporting construction materials (APECO 2000).

More recently consultations were held to prepare a study on electric transport development plan for Ho Chi Minh City. The plan, part of the NDCs project backed by the German government, has an aim to help Viet Nam enhance capacity and legal framework facilitating transportation development in line with low-carbon solutions and GHG reduction (Viet Nam Plus, 2022). In Hanoi, uptake of e-mobility solutions is being enhanced through stakeholder engagement. It is a last-mile connectivity demonstration project is a part of Hanoi City’s work with a private sector enterprise (Zhang 2021). Among other initiatives, World Bank drafted recommendations for engaging private sector in the logistics sector in 2015 in a report titled “Engaging the private sector in transport and logistics planning and policy making: options for Viet Nam” and more recently drafted Stakeholder Engagement Plan for a Project titled “Viet Nam COVID Emergency Response Project” (World Bank, 2015, World Bank, 2020b).

There have been issues with such public consultations. World Bank-Australia Safeguards Partnership Phase II project titled “Viet Nam: Assessment of Environmental and Social Management Practice in Transport and Urban Development” included components of stakeholder engagement. The assessment report found that national principles of public information disclosure, community consultation and complaint redress are only partly implemented in practice in Viet Nam either in urban or rural areas (Saint-Pierre et al 2020). Clarke & Vu (2021) found that stakeholders’ perception is that Environmental Impact Assessments (EIA) that are carried out in Viet Nam for countless projects fall short of EIA goals.

Thailand – The Thai Government has pledged a 20 per cent reduction in GHG emissions by 2030 as transport is responsible for one third of its GHG emissions. Two major challenges for a shift towards sustainable transport in Thai cities are: a low-quality public transport service based on old vehicles and a rapid increase in private motorization. Additionally, city administrations lack financial and technical capacities as well as general knowledge on sustainable urban transport (GIZ, 2021).

Thailand's Environmentally Sustainable Transport Master Plan 2013-2030 and Transport and Traffic Development Master Plan 2011-2020 aim to reduce GHG and transportation emissions through Avoid, Shift and Improve approach. One of the strategies of the Master Plan is to promote public awareness about environmental issues by holding public relations activities (MOT, 2013). ADB developed ASRs for Thailand's transport sector that focuses on air transport, rail and road in 2011 after consultations with government agencies and development partners (ADB, 2011)

Thailand updated its NDC in 2020 while Low Carbon Tax policy as market-based instrument has already been introduced in 2016. As other countries in Mekong region, the freight transport sector is dominated by SMEs. Thailand encourages multimodal transport system aiming at reducing road transport while encouraging rail and ship. This is clearly reflected has in the National Transport Infrastructure Development Strategy 2015-2022 to support its vision in becoming the regional hub as well as anticipating the future demands in transportation.

The private sector involvement is reflected as the representatives of working group members by providing advisory during the policy formulation process. The supports are needed in the following areas: (i) capacity building to integrate mitigation actions into enterprises' plans, (ii) instruments, incentives, mechanisms and approaches to engage the private sector in the shift to green investment, (iii) research development and deployment (RD&D) in technologies related to carbon neutrality e.g., hydrogen, bio-hydrogenated diesel, etc (Low Greenhouse Gas Emission Development Strategy, 2021)

There have been a few initiatives in which stakeholders' engagement have been effectively applied such as in urban infrastructure in Bangkok or electric mobility (see Ratnaburi et al 2021, UNESCAP 2022b). In 2018 the Ministry of Transport, Thailand developed Thailand's "NDC Action Plan for the Transport Sector" through a comprehensive stakeholder consultation and modelling process with the focus on an expansion of public transport (urban and inter-urban), energy efficiency measures for the growing car fleet and biofuels (Nanthachatchavankul, n.d.).

Several stakeholders' engagement initiatives have been driven by international organizations or agencies. Green Climate Fund (GCF) has developed Thailand Country Program on climate change, which is a "tool and an overarching reference document for engaging with a broad range of domestic and international stakeholders". Transport is a priority area in the program (GCF 2017). German Agency for Technical Cooperation (GIZ) is supporting the Thai government through 2012 to 2022 for setting up Thai Clean Mobility Programme that supports city administrations in planning and implementing sustainable urban measures and projects to reduce greenhouse gas emissions in transport. An inter-ministerial group has been set up to jointly work on the design of the program. The project follows a multi-stakeholder approach and empowers local governments to identify, plan and deliver optimal solutions to the issues they face (GIZ, 2019; GIZ, 2022).

However the effectiveness of such stakeholder participation has been limited in some cases: Kantamaturapoj et al 2018 found that stakeholders' perception on public participation in Thai Environmental and Health Impact Assessments is that their effectiveness has been limited for the following reasons: 1. the important decisions are made before the public can get involved, 2. government officers and non-governmental organizations are able to influence outcomes of public hearings more than the project-affected people due to the highly technical nature of the discussions. A key problem for decision making in transport sector in Thailand is the lack of effective coordination, consultation and control, and agencies with overlapping jurisdictions (Pomlaktong et al, 2011; GIZ, 2014).

COLLABORATIVE GOVERNANCE: A CASE OF GREEN FREIGHT ASIA (GFA)

Green Freight Asia (GFA) is a non-profit association of industry players, which collaborates with industry companies, NGOs, and governments to improve the energy efficiency, fuel efficiency, reduce CO_2 emissions, and to lower operational costs across the entire supply chain (https://www.greenfreightasia.org/). Any organization in any industry/sector can become a member if they want to work on decarbonization and applicable solutions regardless of their industry, size, or type. GFA helps organizations to optimize their operations for better efficiency through 6 different programmes namely: (i) Measurement, Reporting, and Verification (MRV) Programme, (ii) Partnership Impact Programme, (iii) Labelling and Certification Programme, (iv) Eco-driving Programme, (v) Carbon Offsetting Programme, (vi) Sustainability Insights Programme.

In freight transport sector, GFA focus on eco-driving and labelling and certification to all carriers and shippers across Asia Pacific to reduce the trucking service industry’s emissions, to build up a green ecosystem for the industry players along the supply chain, and hence aiming to decarbonise the economy. The programmes are expected lowering the fuel cost as the cost account for 40-60 per cent of the total operating cost in the region as well as allowing shippers to contract carriers with lower carbon footprints, while carriers focus on lowering their own emissions in order to increase the chance of becoming subcontractor during the bidding process.

In Mekong region, the eco-driving, and labelling and certification programmes have been introduced to freight transport SMEs through at least two regional initiatives including the EU funded project on “Sustainable Freight Transport and Logistics in the Mekong Region” (2016-2019), and “Green Freight and Logistics Development in the Mekong Countries” (2017-2020) funded by Mekong-Republic of Korea Cooperation Fund (MKCF). The support from GIZ during the initiation phase has paid attention by the SMEs of transport sector about the importance of eco-driving and its impact to fuel saving.

With regard to the certification program, the ranking of GFA certification comprise of: Minimum (Leaf 1), Enhanced (Leaf 2), Strong (Leaf 3), and Outstanding (Leaf 4) which allows carriers to inform their progress towards sustainable freight. At the same time, shippers can log into the GFA database and decide to select a carrier based on its GFA ranking. A carrier who obtains Leaf 1 certification has demonstrated minimum commitment adopting green freight practices, while Leaf 4 indicate the carrier commitment to report annual progress on its CO_2 reduction. The shippers set up their commitments to inform the carriers about GFA certification and to include the environmental criteria as an important indicator in bidding process.

The GFA initiative reflect the global (public) policy which involve non-state actor’s collaboration in setting up common norms using the market governance approach. However, the collaboration could be more effective if the governance is scaled up to network governance by involving the state actors/governments in facilitating proper policies which enable the carriers acquire the green technologies e.g., reducing the import duty for green technologies, a mandatory certification for certain company size, etc.

The market structure of the freight transport services is also playing a significant role in rolling out this initiative. Given a limited number of reputable carriers, it is hard for the shippers to enforce the sustainability criteria in their bidding document. At the end, they will try to negotiate the criteria from mandatory to voluntarily.

CONCLUSIONS

From new institutionalism perspective, the involvement of non-state actors to address environmental issues in transport sector is viewed as the paradigm shift to acknowledge the importance of collective action in delivering public goods e.g., clean air, and mitigating the impact of climate change. While recognizing the importance of market governance as highlighted in the case study of a private sector initiative, the efforts would be more effective if the governance is enlarged by increasing the role of state actors in supporting the initiatives alike. For future study, clear accountability system for both actors could be further explored to include incentives and disincentives mechanism as the controlling measures.

A survey of initiatives and projects in the five Mekong countries, including but not limited to those on sustainable transport reveals a mixed picture: all the countries face issues with climate change and high GHG emissions of their transport sector but Lao PDR and Myanmar, and to some extent Cambodia have some way to go to have more firmed-up policies on sustainable transport as well as processes for non-state stakeholders’ participation to develop their sustainable transport. Definite, long-term strategies for collaboration with non-state actors are absent in all the countries. Mostly such collaborative initiatives are project-specific and in most cases, these are conducted by or at the behest of multilateral agencies or international organizations. More information exists for public consultations in Viet Nam and Thailand than other countries. Such information shows that such involvements have been imperfect: in many cases consultations with non-state actors have fallen short of their goals or the processes adopted were faulty.

At the regional and subregional levels, a number of cooperation programs have adopted approaches to include non -state actors in decision making and implementation such as ASEAN TSP 2016-2025, GMS TSS 2030, and several other subregional cooperation programs. Multiplicity of such programs and overlaps in their areas of work, put stress among relevant agencies and other stakeholders in the Mekong countries, which in turn leads to a dilution of their priorities and objectives. Further no formal mechanism exists to involve non-state actors in systematic basis by any of the regional or subregional programs.

The other issues are because of limited capacity and understanding among stakeholders, in particular community representatives, of technical issues, the possibility of dependence of government agencies on non-state actors for obtaining technical expertise, methodological issues (i.e. whether the approaches adopted for stakeholder or non-state actors' engagement are the right ones), overall issues related to the transport sector (e.g. rapid growth, high GHG emissions, underinvestment) and so on.

The paper would recommend that a mechanism is set up at the subregional level for the Mekong countries to involve non-state actors in decision making on the development of sustainable transport in these countries. In order to make such a mechanism effective, a mapping of relevant and interested non-state actors, followed by awareness generation and capacity building activities for non-state actors should be organized in each country and at subregional level. Finally, to optimize such a mechanism methodology of involvement of non-state actors, keeping in mind the specificities of the Mekong countries (such as wide differences between the countries in terms of development of transport sector, differences in political and regulatory systems and situations), should be developed. The methodology may be tested at national, sub-national and subregional levels and suitably refined and adopted.

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