

Enhancing the Resilience of Urban Transport in Asian Cities after COVID-19: Synthesis of Academic Study Results and General Recommendations

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Background Paper for the Regional Workshop on
Sustainable, Inclusive and Resilient Urban Passenger Transport:
Preparing for Post-Pandemic Mobility in Asia

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Executive Summary

In Asian cities, the COVID-19 pandemic may be accelerating the longer-term trend towards greater use and ownership of private cars and motorcycles, while reducing the use of and trust in public transport and shared taxi and car-pool services and generating structural financial difficulties for public transport operators. It may also induce more active travel – walking, cycling and micro-mobility – and substitution of physical mobility by online activity. With the exception of the effects on active travel and online activity, these trends contravene the United Nation’s commitments to sustainable, equitable and resilient urban development as laid down in the *Sustainable Development Goals*, the *2030 Agenda for Sustainable Development*, and the *New Urban Agenda*.

This Study Background Report discusses how Asian cities might reconfigure the trends of accelerated growth in private motorised mobility and diminishing use and financial viability of public transport and shared taxi and car-pool services. To this end, it uses the Sustainable Urban Transport Index developed by UN ESCAP, proposes a framework for understanding and promoting resilience in urban transport, and reviews the academic literature published until July 2021 on the short- and long-term impacts of the COVID-19 pandemic on urban transport in Asian cities. It also offers a series of recommendations for enhancing the resilience of urban transport systems in the short (0-2 years after the pandemic), medium term (2-5 years) and long term (5-20 years) in Asian cities.

The Report concludes that the SUTI offers a useful framework for assessing the effects of COVID-19 on transport in Asian cities because it considers the modal share; access, quality, reliability and affordability; and operational costs of, and investments in, public transport. It confirms that the empirical findings in the academic literature on the impact of the pandemic on urban mobility are largely consistent with the suggested impacts on public transport, private car and motorcycle ownership, active travel and online activity.

Two approaches to understanding resilience in relation to urban transport are identified. The 'engineering resilience' approach concentrates on the capacity of a transport system to resist and absorb the impacts of a disturbance in order to maintain an acceptable level of service (robustness), to recover and bounce back to pre-disturbance functioning ('bouncebackability'), and/or to transform to a different stage of operation (adaptability). The 'socio-ecological engineering' approach is primarily concerned with the capacity of a transport system to adapt continuously in light of both expected changes (flexibility) and unanticipated changes (agility) in its environment.

If urban transport in Asian cities is to become more sustainable and equitable after the pandemic, then both forms of resilience need to be enhanced. Key to greater engineering resilience is restoring public confidence in public transport and in spending time in busy public spaces and high-density settings in the short term. This can trigger a virtuous cycle in the medium and long term: greater use will increase fare box ratios, which will facilitate and legitimise large investments in network expansion and new technology, which can further increase use, etcetera.

The flexibility and agility of public, shared and active transport systems in Asian cities can be enhanced by extending the infrastructures and upgrading technologies for those forms of transport and online activity; embedding the transformation of urban transport systems in Asian cities in medium- and long-term changes in urban systems for land use, public health, social care and economic affairs; and capacity building among transport system operators and local government actors.

1 Introduction

The COVID-19 pandemic continues to cause havoc around the world. Vaccination rates are now going up – albeit in a deeply uneven manner across the planet – but infections are still ripping through countries and cities, causing widespread illness and mortality. People who have not been ill or have recovered are also affected in myriad other ways. For instance, non-medical responses to the pandemic such as social distancing, stay-at-home orders and lockdowns have affected livelihoods, businesses, education, mental health and social relationships for unprecedented numbers of people, again in ways that are socially and spatially deeply uneven. The transport sector is one of the most affected, with aviation and public transport within urban areas arguably hit hardest in Asia and elsewhere (Earley and Newman, 2021; Rothengatter et al., 2021).

The effects of the COVID-19 crisis on transport in Asian cities are likely to outlast the pandemic itself by a considerable margin. Different future trajectories for urban transport systems across Asia are open. Nonetheless, it is not unreasonable to expect that, in the coming decade, the pandemic will:

- a) accelerate the longer-term trends towards greater use and ownership of private cars and motorcycles;
- b) reduce use of, and public trust in, public transport and shared taxi and car-pool services;
- c) cause structural financial difficulty for public transport operators; and
- d) induce more demand for walking, cycling and micro-mobility.

With the exception of d), these trends would contravene the United Nation's commitments to sustainable, equitable and resilient urban development as laid down in the *Sustainable Development Goals*, the *2030 Agenda for Sustainable Development*, and the *New Urban Agenda*. They would also aggravate a series of challenges urban transport and cities in Asia are already facing, including rapidly increasing greenhouse gas (GHG) emissions, rampant air quality problems, extensive road congestion and associated productivity loss, extensive harm from traffic accidents, and stark social inequalities in mobility capabilities – individuals' potential to undertake trips and participate in activities at destinations across the city in a safe, affordable, convenient and efficient manner.

This Background Study Report argues that the COVID-19 pandemic may indeed result in the above trends in Asian cities, but that proactive and comprehensive policy and governance focused on enhancing the resilience of urban transport systems in the

short term (0-2 years after the pandemic), medium-term (2-5 years) and long-term (5-20 years) can help those cities to 'build back better' transport that also contributes to greater sustainability and equity.

In support of this claim, the Report seeks to realise the following objectives:

- a) provide a framework for understanding and promoting resilience in urban transport that is informed by different strands of academic literature;
- b) review the academic literature published until July 2021 on the short- and long-term impacts of the COVID-19 pandemic on urban transport in Asian cities; and
- c) offer a series of suggestions about how short-, medium- and long-term policy and governance can enhance the resilience of urban transport in Asian cities in ways that contribute to greater sustainability and equity.

Throughout the Report urban transport is understood as a 'system of systems' that are configured around particular modes of transport. These systems are conceived of as socio-technical and complex; they are configurations of different elements – i.e., technology, infrastructure, policy and regulation, cultural values and meanings, user practices, and knowledges – that change, typically in non-linear and difficult-to-predict ways, due to internal dynamics and external pressures and (sudden) shocks (Geels, 2012; Geels et al., 2017). With its multiple waves of infection and government-mandated lockdowns and social distancing, the COVID-19 pandemic is an obvious example of a series of interconnected shocks, while internal dynamics are exemplified by a city government's policies to make public transport more resilient, sustainable and equitable with a view to the post-pandemic future.

The remainder of the Report begins with a brief overview of the Sustainable Urban Transport Index (SUTI) developed by UN ESCAP (Regmi, 2020) in Section 2, before discussing the resilience concept in Section 3. The SUTI framework is introduced because it has informed the review of academic literature on the impacts of the COVID-19 pandemic on urban transport in Asian cities in Section 4, and the thinking in Section 5 on ways in which the resilience of urban transport in those cities can be enhanced. The concluding section summarises the Report's main findings and recommendations.

2 Sustainable Urban Transport Index

Although the specific circumstances will vary from city to city, urban areas in Asia have been facing broadly similar challenges regarding transport for some time (Regmi, 2020). These include rapid urbanisation, rapid motorisation, increasing average incomes, and local institutions that are unable to provide or enable new affordable, safe and convenient transport infrastructures and services on a scale that keeps pace with the growth in the demand for passenger transport. As a result, transport systems in Asian cities are often plagued by high levels of road congestion, widespread accessibility problems, significant traffic extensive air pollution, and rapidly increasing greenhouse gas (GHG) emissions – with due adverse consequences for the (local) economy, the environment, public health and quality of life. In addition, the costs and benefits of these trends tend to be socially and spatially unequally distributed, which intensifies socio-spatial inequalities and transport injustice (Verlinghieri and Schwanen, 2020). In absolute numbers, urban transport challenges tend to be biggest in the largest cities which are often also country capitals; however, once city size is controlled, the issues are as least as big in intermediate cities where institutional capacities to respond to urbanisation and motorisation are often more limited (Poiani and Stead, 2015).

Irrespective of how the challenges play out across Asian cities, it is clear that long-term trends in urban transport in Asia – and indeed across the planet at large – are in tension with the realisation of the Sustainable Development Goals. The SDGs were adopted in 2015 by the UN General Assembly for realisation by 2030, and they remain the prevailing framework for thinking about, and (global) action seeking to achieve, sustainable development – even if the COVID-19 pandemic has enhanced doubts and debates in academia about their realisability and affordability (*Nature*, 2020; Sachs et al., 2020).

UN ESCAP recognises the importance of effective governance to addresses the transport challenges that Asian cities face and seeks to support the enhancement of local institutional capabilities in various ways. One of these is the provision of a comprehensive yet relatively easy to administer tool that cities can utilise to assess the sustainability of their (passenger) transport system (Gudmundsson and Regmi, 2017; Regmi, 2020; Regmi and Swamy, 2020). This tool, the Sustainable Urban Transport Index (SUTI), can be used to benchmark the sustainability of the local transport system cross-sectionally by comparing a given city with others elsewhere, or – perhaps more

helpfully – longitudinally track changes for a single city between different moments in time.

The SUTI reflects the geometric mean of standardised scores, each in the [0, 100] range, on the ten indicators included in Table 1 (see Regmi, 2020, for further details). The selection and specification of the SUTI indicators have been informed by the SDGs. This is evident from the multiple references in Table 1 to SDG11 ('Make cities and human settlements inclusive, safe, resilient, and sustainable') and SDG9 ('Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation') and links to SDG3 ('To ensure healthy lives and promote well-being for all at all ages') and SDG13 ('Take urgent action to combat climate change and its impacts').

Second, the SUTI is informed by a strong understanding of sustainability that privileges the 'Shift/maintain' over the 'Improve' components of the well-known A-S-I (Avoid-Shift-Improve) framework. The focus is on shifting trips to public transport and 'active transport' – here understood as walking and cycling – or at least maintaining the position of these modes of transport, rather than on electrification or increased fuel efficiency. The latter 'improve' strategies may help to reduce the environmental burden transport creates but do little to reduce road congestion, social inequality, or concerns over traffic safety. Given the relatively high population densities in many Asian cities, a focus on 'Shift/maintain' and away from (private) car use is sensible, appropriate and important.

Third, the SUTI index also addresses important dimensions of social sustainability, particularly through the focus on convenient access to, and affordability, of public transport and traffic safety. Nonetheless, there is no direct measure of structural inequalities in transport or accessibility according to, for instance, gender, socioeconomic status or disability. Information on such structural inequalities is welcome as both urban policies and the COVID-19 pandemic tend to influence and benefit the mobility of social groups in different ways.

Table 1 also assesses the likely influence of the COVID-19 pandemic on the indicators during the pandemic itself and afterwards. As discussed in Section 5, it is difficult to say when the pandemic will end across Asian cities. The end date may vary according to country and city and last until 2023. The assessment is informed by the literature reviewed in Section 4 and will inform the recommendations offered in Section 5. *In the short term, the modal share of public transport and active modes, quality and reliability of public transport and operational costs of public transport tend to be affected most profoundly, while the effects on air pollution and GHG is strongly dependent on stay-*

at-home and lockdown policies to be in place. It is reasonable to expect that *in the longer term the indicators related to public transport will be affected most clearly*. Given the varied scores of the cities included in Table 2 on those indicators, the longer-term impacts of the pandemic are *likely to be quite complicated and differ between cities in Asia*. However, as will become clear in Section 5, the nature and magnitude of those effects can be influenced by policies that city-level – and national – governments can put in place.

Table 1: Indicators in the Sustainable Urban Transport Index (SUTI), link to Sustainable Development Goals (SDGs) and susceptibility to COVID-19 impacts

	Indicator	Operationalisation	Link to SDGs	Likely impact of COVID-19 pandemic	
				During the pandemic	Afterwards
1	The extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes	Extent to which most recent comprehensive plan considers walking networks, cycling networks, intermodal transfer facilities, and low emissions (electric) vehicles for public transport, each scored on a five-category ordinal scale [0, 4], then summed to total score [0, 16]	Direct reference to Target 11.2 ^a and relevant to Target 9.1 ^b	None (0)	None (0)
2	Modal share of active and public transport in commuting	Percentage of trips for work and education by walking, cycling, public bus (including minibus), Bus Rapid Transit, tram, rail or scheduled ferry.	Direct reference to Target 11.2	Strong (3)	Mild (2)
3	Convenient access to public transport service	Percentage of the resident population living 500 meters or less from a public transport stop with minimum 20-minute service	Used by UN bodies to monitor Target 11.2	Mild (2) but with large variations across time and location	Mild (2)
4	Public transport quality and reliability	Percentage of all public transport users that is satisfied with quality or reliability, based on a survey	Helpful in support of Targets 11.2 and 9.1	Strong (3) or very strong (4)	Mild (2) or strong (3)
5	Traffic fatalities per 100,000 inhabitants	Number of persons killed per 100,000 inhabitants	Adopted by UN bodies to monitor Target 3.6 ^c	Slight (1)	Slight (1)
6	Affordability – travel costs as part of income	Cost of monthly public transport ticket in average monthly income for poorest quartile of the city's population	Helpful in support of Target 11.2	None (0)	Mild (2)

7	Operational costs of the public transport system	Ratio of fare revenue to operating costs for public transport systems ('Fare box ratio')	Relates to Target 11.2	Very strong (4)	Mild (2) to strong (3)
8	Investment in public transport systems	Share of all transport investments in the city that is directed towards public transport, averaged over 5 years	Relates to Target 11.2	Mild (2) but with large variations across time and location	Strong (3)
9	Air quality	Annual mean levels ($\mu\text{g}/\text{m}^3$) of fine particulate matter (PM_{10}) in the air (population weighted) compared to the health threshold	Adopted by UN bodies to monitor Target 11.6 ^d	Strong (3) but with large variations across time	None
10	Greenhouse gas emissions from transport	CO_2 equivalent emissions from transport by urban residents per annum per capita	Relevant for SDG 13 ^e	Strong (3) but with large variations across time	None

a "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all"

b "Develop quality, reliable, sustainable and resilient infrastructure"

c "By 2020, halve the number of global deaths and injuries from road traffic accidents"

d "By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management"

e "Take urgent action to combat climate change and its impacts"

Source: based on Regmi and Swamy (2020)

Table 2: Standardised scores on SUTI for selected Asian cities

	Colombo (2017)	Greater Jakarta (2017)	Hanoi (2017)	Kathmandu (2017)	Bangkok (2019)	Yangon (2019)
1 The extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes	69.0	75.0	43.8	43.8	62.5	43.8
2 Modal share of active and public transport in commuting	81.8	35.1	0.8	74.7	34.5	53.8
3 Convenient access to public transport service	30.0	46.9	50.0	81.3	69.6	49.5
4 Public transport quality and reliability	0.2	59.3	76.9	5.1	58.3	68.5
5 Traffic fatalities per 100,000 inhabitants	57.3	94.4	77.9	81.9	1.0	12.7
6 Affordability – travel costs as part of income	70.4	67.9	93.0	75.9	99.9	85.4
7 Operational costs of the public transport system	46.9	28.4	19.6	52.6	100.0	92.9
8 Investment in public transport systems	49.0	100.0	3.9	35.7	100.0	33.0
9 Air quality	74.3	53.6	28.4	44.3	77.9	67.6
10 Greenhouse gas emissions from transport	77.1	71.3	88.2	88.3	26.4	45.1
SUTI score	32.7	52.5	32.2	47.8	42.2	49.4

Source: Regmi (2020), Sidhara (2020) and Thein (2020)

3 Understanding Resilience

Resilience is a polysemic concept: it means different things to different people and in different contexts. This is why careful definition and conceptualisation are important. Conceptualisations of resilience have been classified in various ways in the academic transport and planning literatures (e.g., Davoudi et al., 2013; Hayes et al., 2019). In this Report a distinction will be made between engineering and socio-ecological resilience. These offer two approaches to change and disruption in transport systems.

3.1 Two approaches to resilience

In the transport context the category of 'engineering resilience' gathers the most common understandings of resilience, in part because of its roots in the disciplines and research fields of engineering, operations research and disaster management studies. Here resilience is understood as the capacity of a transport system to (see also Davoudi et al., 2013; Gonçalves and Ribeiro, 2020):

- a) resist and absorb the impacts of a disturbance caused by a shock, interruption or disaster in order to maintain an acceptable level of service (= *robustness*);
- b) recover and bounce back to the pre-shock steady state of regular and balanced functioning (= '*bouncebackability*'); and/or
- c) transform to a different stage of operation (= *adaptability*)

At the core of engineering resilience sits the idea that disruption is a threat to system functioning (Hayes et al., 2019). Engineering resilience further assumes that transport systems are usually in a default or 'normal' state and sometimes – often due to a significant disturbance – can shift to a 'new normal'. Engineering resilience is therefore premised on equilibrium thinking, with the assumption of a single equilibrium often dominant. This also means that systems are taken to be relatively stable and predictable. The focus is on the magnitude and impacts of risks with known, or at least knowable, probabilities that are associated with (potential) disturbances (Chester et al., 2021). On a more fundamental level, the engineering resilience perspective is based on broader philosophical understandings of reality as *complicated*, where changes in the interplay between transport systems and their environments can be known and meaningfully examined with the help of 'tools' such as linear cause-effect relationships and probability theory.

Socio-ecological understandings of resilience are rarer in the transport context (Hayes et al., 2019) but can complement the insights afforded by engineering resilience in useful and significant ways. The socio-ecological resilience approach has been developed at the interface of the science of ecology (especially the work of C.S. Holling) and the social sciences. Here disruption is seen as an opportunity and as triggering renewal, innovation and system transformation. While they may have multiple, locally stable equilibria, systems are often in dynamic disequilibrium. Change is therefore seen as the default and the future of a system is understood to be (largely) unpredictable.

The starting point of socio-ecological perspectives is that reality is *complex* (Chester et al. 2021): the interplay between transport systems and their environments are at best partially knowable because they are characterised by non-linear feedback loops, processes of (local) self-organisation, and interdependencies. It is also difficult to isolate transport systems from other complex systems – e.g., for energy, land use, and IT – because these are closely interconnected, meaning that disturbances and changes cascade and multiply through and across them, causing multiple direct and indirect effects (Markolf et al., 2019). Consider, for instance, how climatic change can lead to more irregular and intense bursts of precipitation in certain places, thereby not only flooding and potentially washing away roads and tracks but also affecting power cables over- and underground and taking out power stations, with due consequences for electric vehicle charging and a city's light rail or electric BRT system, as well as the operation of the IT systems that regulate traffic management and signalling (*ibid.*).

Within this context, resilience is understood as a system characteristic that captures the potential for continuous adaptation in light of ever-changing circumstances. The focus is thus on adaptability rather than robustness, and a useful distinction can be made between (Markolf et al., 2019):

- a) *flexibility* – the ability to reconfigure a system's parameters in light of expected changes, and
- b) *agility* – a system's ability to adapt and evolve in an environment that is characterised by continuous and unanticipated change.

In socio-ecological perspectives, knowledge about resilience and system change is generated with the help of a broader range of methods than under engineering resilience. Quantification and modelling of relationships remain important but are taken to be more challenging and often seen as less meaningful. Since the focus is on uncertainty rather than risk and on possibility rather than probability, there are clear limits to what insights quantification and modelling allow. As a result, a much greater role is assigned to interpretivist and narrative methods, including qualitative scenario analysis. Moreover, where engineering resilience approaches are strongly expert

driven and characterised by starkly hierarchical relationships between knowledge production by scientists and consumption by policymakers, transport service operators and others, there is much more emphasis placed on participation by, and deliberation with, stakeholders in socioecological approaches to resilience. In the latter knowledge production is in many ways a collective, interactive and iterative processes of meaning-making (Chester et al., 2021).

3.2 Implications for intervention

The distinction between engineering and socioecological resilience is not merely academic. It has practical value as both lead to different insights about how best to intervene in existing transport systems.

Engineering perspectives on resilience tend to predispose practitioners, including policymakers and transport operators, towards particular types of interventions. Attention is often directed towards physical components within a transport system that are deemed critically important, such as specific stretches of road, particular stations, or a given type of vehicles. Engineering adaptations that are based on projected conditions are proposed and pursued with a view to minimise the vulnerability and maximise the robustness of individual components (Hayes et al., 2019).

Consider, for instance, plans to replace dark-coloured, asphalt on key arteries in a city's road-network with light-coloured concrete to deal with expected rises in summer daytime temperatures because of climate crisis. This intervention may be very effective in reducing urban heat island effects and enhancing the thermal comfort of road users on hot days. However, it may also create unanticipated adverse effects during other shocks or under pressures (i.e., frictions that build up gradually over time) because those conditions had not been considered during the projection stage. The specifics of those unanticipated effects will depend on the mix of circumstances and events in a particular place at a given moment. They may, however, include enhancing road safety risks during increasingly irregular and intense bursts of precipitation or greater need for costly maintenance at times that available financial budgets are very tight.

Socio-ecological perspectives on resilience tend to direct attention to both the whole system and the connectivity and modularity of the components of which it exists (Chester et al., 2021). This offers the opportunity for greater focus on the 'softer' components of transport systems. For instance, real-time and place-specific provision of information on potential disruptions and tailored to specific groups of road users

can enhance the flexibility of road-based transport systems on short notice, whereas the use of modular lanes on motorways can increase both flexibility and agility across different time-scales. They can help to deal with diurnal, weekly and seasonal fluctuations in the level of bus/coach or HGV traffic, while also accommodating uncertainty about the speed of diffusion of fully autonomous vehicles or the number of years that 'autonomous' (SAE-levels 3-5) and 'conventional' (SAE-levels 0-2) have to share the same road space.

At the same time, the kinds of interventions that can be derived from socio-ecological perspectives are often rather generic and often play out at a strategic level; many steps of translation and particularisation are typically required before concrete interventions in transport systems can be implemented.

3.3 Conclusion

The previous subsections highlight that engineering and socioecological resilience differ from each other on multiple dimensions, including the qualities associated resilience, the underpinning worldviews and understandings of how transport systems change, the ways in which knowledge about resilience is generated, and the kinds of intervention in transport systems they enable. Despite their different philosophical basis, it is important to understand engineering and socioecological resilience as complementary to each and to avoid privileging one over the other. Both have a role to play in relation to the longer-term impacts of the COVID-19 pandemic, and lead to different but complementary policy recommendations.

4 Impacts of COVID-19 on Transport in Asian Cities

4.1 Introduction

The peer-reviewed academic literature on transport and COVID-19 has burgeoned since the Spring of 2020. Many papers have focused on how transport has facilitated the spread of the SARS-CoV-2 virus between and within countries through aviation and public transport, and how curbs on transport activity can slow down that spread. However, the number of publications on the consequences of the pandemic for transport, especially within urban areas, is now at least as large. A substantial share of this second category is focused on cities in Asia, and attention will be directed towards this set of studies, complemented with publications focused on other world regions where relevant. A distinction will be made between short-term impacts, defined as changes to people's mobility, their attitudes and perceptions, the operation and management of urban transport systems, and levels of air pollution and CO₂ emission during waves of infection and government-mandated stay-at-home orders, lockdowns and social distancing, and longer-term impacts likely to outlast the COVID-19 pandemic.

The sub-sections below are loosely structured on the basis of the indicators in the SUTI (Section 2) although not all indicators have been covered in the academic literature published until late July 2021.

4.2 Short-term impacts

4.2.1 *Mobility, attitudes and perceptions*

There is abundant evidence that overall levels of mobility in physical space dropped significantly during waves of infection and government-mandated lockdowns. Reduced numbers of physical trips have been reported for all trip purposes (Barbieri et al., 2021; Hasselwander et al., 2021 for Metro Manila) but especially for social, recreational and leisure activities (Anwari et al., 2021 for Bangladesh; Shakibaei et al., 2021, for Istanbul). Online activity has replaced many of the foregone trips (*ibid.*; Zhang et al., 2021).

While quantitative evidence is limited, clear social and spatial differences have occurred in mobility reduction and substitution by online activity (Gutiérrez et al., 2021; Hasselwander et al., 2021). Online survey studies have shown that in Pakistan and Istanbul women engaged more in telecommuting than men, with men in Bangladesh also taking more out-of-home trips for shopping during the first wave of infections (Anwari et al., 2021; Shakibaei et al., 2021). A study in the Netherlands also showed that older adults reduced trip levels more than other age groups, presumably reflecting greater perceived risks of serious illness, hospitalisation and mortality among older adults (De Haas et al., 2020). Multiple studies have suggested that the effects of government-mandated lockdown on mobility levels have been much smaller in informal settlements and cities with extensive informal sectors (Gutiérrez et al., 2021; Anwari et al., 2021; Sharifi and Khavarian-Garmsir, 2021). Digital divides – differences in access to, and use of, the digital technologies that make online activity possible – constitute another axis along which inequalities in mobility are likely to have increased, but robust evidence about how they have affected trip-making during the (early stages of the) pandemic is very limited.

Transport mode use has been affected more strongly than trip frequencies, with mixed consequences from a sustainability perspective. Online survey research has shown away a universal shift away from public transport (Anwari et al., 2021; Hasselwander et al., 2021; Shakibaei et al. 2021; Zhang et al., 2021), although the magnitude of this change varies across and within cities and social groups. A smaller shift away has also been reported away from taxi and ride-share services (Rothengatter et al., 2021; Shakibaei et al. 2021) and, in Bangladesh, from paratransit (Anwari et al., 2021). At the same time, increases in private vehicle use, motorcycle use and cycling and walking have been reported (Anwari et al., 2021; Zhang et al., 2021). Pulled rickshaw use also increased according to a study in Bangladesh (Anwari et al., 2021). The increase in cycling and walking is less universal than the decline in public transport; for instance, it was not observed in the early stages of the first wave of infections in Istanbul (Shakibaei et al., 2021).

A focus on mode use in general hides important variations according to trips purpose. The study by Anwari and colleagues (2021) in Bangladesh indicates that the magnitude of changes depended on why trips were undertaken. Paratransit use, for example, was reduced substantially for accessing employment, greengrocers and markets, but increased for short-distance recreation and medical services. The study by Shakibaei et al. (2021) in Istanbul shows how changes in mode use depended not only on trip purpose but also on study participants' gender, age, income and car ownership. The

study also demonstrates how these relationships between mode use, trip purpose and social group changed over the course of the first wave of infections.

Attitudes and risk perceptions were associated with some of the observed changes. Attitudes have rarely been measured directly, although De Haas et al.'s (2020) nationally representative study in the Netherlands did demonstrate that those towards public transport had become more negative during the first months of the pandemic. In a related vein, Barbieri et al. (2021) use online survey data from 10 countries, including India and Iran (Islamic Republic of), to show that the risk of contracting COVID-19 was perceived as much higher for bus and tram/metro than for walking, cycling and single occupancy car use, with shared car use taking an intermediate position. The differences were particularly pronounced for the Iranian sample.

4.2.2 Infrastructure, operation and fare box ratio

Many cities in Asia have seen partial or full closure of public transport services or at least a significant reduction in seating capacity (25-50%) at times of high infection levels (Earley and Newman, 2021; Zhang et al., 2021), with due consequences for the recouping of operational costs. These costs are often higher than before the pandemic given the need for extra cleaning and hygiene practices. In Bangladesh, for instance, the fare box ratio has been under pressure because of the government stipulation that seating capacity had to be reduced by 50% (Anwari et al., 2021), and in Delhi the metro is estimated to have lost some RS 1.609 crore in the period March-September 2020 (Rothengatter et al., 2021). While public transport operators have been compensated by government, many planned investments in network and service upgrades or expansion have been postponed, reduced or cancelled in the past 18 months (Earley and Newman, 2021).

At the same time, infrastructure and operation have adapted. Documentation of initiatives in the academic literature is scarce and fragmented (although the database introduced in Combs and Pardo, 2021, summarises a few examples from Asian cities). Hasselwander and colleagues (2021) mention the pop-up networks of cycling and bus rapid transit (BRT) lanes that have been created in Metro Manila.

4.2.3 Air pollution and GHG emissions

There is now a substantial number of studies analysing the effects of government-mandated lockdowns on air pollution levels, mostly in environmental science journals. Methodologies and air pollutants considered – CO, NO, NO₂, PM₁₀, PM_{2.5}, O₃ and/or SO₂ – differ, and (large) Indian cities are given most attention, possibly reflecting the

severe air quality problems these cities tend to experience. Gouda et al. (2021), for instance, report significant reductions in measured levels of NO (-63%), NO₂ (-48%), PM_{2.5} (-48%), O₃ (-18%) and SO₂ (-23%) for Bengaluru in January-March of 2020 compared to the same months in 2019; reductions from before to during lockdown are of a similar magnitude. Other studies focused on Indian cities also show large reductions in pollutions although the magnitude varies between and within cities and according to pollutant (R. Khan et al. 2021; Kolluru et al., 2021; Kumar et al., 2021; Mandel et al., 2021; Rahaman et al., 2021; Vega et al. 2021). A study focused on Lahore also shows significant reductions owing to the lockdown (Pervaiz et al., 2021), but Sangkham et al. (2021) show a more mixed picture for the Bangkok Metropolitan Area with a 45% reduction in NO during lockdown vis-à-vis the same period in 2019, against similar levels of O₃ and PM₁₀ and increases for PM_{2.5} (+18%), NO₂ (+39%) and SO₂ (+42%).

A comparative study by Benchriff et al. (2021) shows not only variation between cities but also different trajectories for individual cities over time (Table 3). During lockdown NO₂ and PM_{2.5} levels were significantly lower than before in all cities in Table 3 bar Jakarta. However, not all of the reductions shown can be attributed to lockdowns per se because differences with previous years are generally smaller; seasonal factors also play a role. After the lifting of lockdowns, pollution levels increased again in Baghdad, Jakarta and Ulanbataar, but declined further in Kathmandu and Dhaka, while remaining similar in New Delhi.

The results demonstrate that caution should be exercised with generalisations about how air quality has been affected by pandemic-related lockdowns in Asian cities. Moreover, not all changes can be attributed to changes in traffic levels because emissions from other sectors (heating/cooling, manufacturing, etc.) were affected by government-mandated lockdowns. None of the studies reviewed here has sought to attribute changes in air pollution to specific sectors.

Focusing on CO₂ emissions in India, Parida et al. (2021) show a reduction of 28.5% for India in the period from January to mid-June in 2020 compared to mean levels for 2017-2019 for transport excluding aviation. This substantial reduction amounts to approximately 0.55 MtCO₂/day generated less by the transport sector in the first 5.5 months of 2020.

4.3 Longer-term impacts

4.3.1 A new normal?

A large majority of participants in a global online survey among transport experts in early 2020 agreed or fully agreed that, after the pandemic, a 'new normal' would emerge in which online working will be popular, online shopping will be the most popular shopping activity, and car dependence will increase because of public concern of crowding on public transport (Zhang et al., 2021; Table 4). At the same time, support for the idea of online education as the standard model of education was much lower, and only one-fifth agreed that the pandemic would result in extensive urban decentralisation (away from the city centre) or de-urbanisation (away from large cities). Levels of agreement among experts in India and Asia outside India, China, Japan and South Korea were mostly above those for the global sample, especially for the statements on online shopping and greater car dependence. The latter result is particularly salient in light of the relatively high levels of public transport usage in Asian cities before the pandemic. However, the data were collected at the beginning of the pandemic and expert views may have shifted since then; results from the second wave of the global online survey of transport experts have not yet been published.

4.3.1 Modal shifts

A suite of other studies has also suggested a longer-term move away from public transport that will likely outlast the pandemic (Beck et al., 2020; De Haas et al., 2020; Gutiérrez et al., 2020; Raunak et al., 2020; Barbieri et al., 2021; Rothengatter et al., 2021; Zafri et al., 2021a). Evidence for this claim is limited as it is typically inferred from empirical research on expectations held by members of the public during the first wave of the pandemic (De Haas et al., 2020; Raunak et al., 2020; Barbieri et al., 2021), stated responses under a scenario of low infections but before mass vaccination (Zafri et al., 2021a), or revealed behaviour after lockdown(s) have been lifted (Beck et al., 2020; Rothengatter et al., 2021). Moreover, online samples are unlikely to be representative of full populations and this discrepancy is likely larger in countries and cities with bigger digital divides, greater poverty and/or more people in informal housing or employment. In other words, findings and conclusions in the literature need to be interpreted with caution, even if there is consensus and the arguments are intuitively agreeable.

Table 3: PM_{2.5} (µg/m³) and NO₂ levels (1E15 molecules/cm³) in 2020 compared to averages for 2018-2019 for selected cities

	Dates of lockdown	Before lockdown						During lockdown						After lockdown					
		Average		Difference		Change		Average		Difference		Change		Average		Difference		Change	
		PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂	PM _{2.5}	NO ₂
Baghdad	17/3-14/6	49.8	5.2	16.3	0.5	49%	11%	39.8	2.8	11.0	-0.4	38%	12%	78.0	3.8	42.3	0.2	54%	7%
Dhaka	26/3-14/6	151.4	7.1	-5.8	0.0	0%	0%	51.3	2.9	3.9	1.1	-7%	27%	29.5	2.0	-1.2	-0.7	-4%	27%
New Delhi	25/3-30/6	115.3	6.0	16.0	-0.1	12%	-2%	44.3	3.5	27.1	-1.6	38%	31%	n.a	3.5	n.a.	0.4	n.a.	-9%
Kolkata	25/3-30/6	121.3	4.3	15.3	-0.1	11%	-2%	21.7	2.4	15.3	-0.5	41%	17%	n.a	2.1	n.a.	0.2	n.a.	9%
Ulaanbaatar	10/3-60/6	131.1	1.0	14.1	0.1	10%	8%	20.3	0.9	-6.9	-0.1	25%	-5%	n.a	1.3	n.a.	0.04	n.a.	3%
Kathmandu	24/3-14/6	66.2	1.6	19.7	-0.4	23%	20%	31.6	2.0	27.4	-0.5	46%	20%	9.3	1.4	21.7	-0.3	70%	16%
Jakarta	30/3-5/6	41.1	1.6	15.6	-0.2	62%	12%	48.8	1.6	8.6	0.8	21%	33%	63.8	2.2	19.0	-0.5	52%	17%

Source: Benchriff et al. (2021, Tables 2 and A2)

Table 4: Agreement with statement among long-term changes after the pandemic among transport experts (percent agreed or fully agreed)

Statements in online survey	Experts in India (n=28)	Experts in Asia outside India, China, Japan & South-Korea (n=33)	All experts (n=284)
Online working (working at home, neighbourhood satellite offices, cafes, etc.) will become popular	85.7%	66.7%	77.9%
Online shopping will become the most popular shopping activity	89.3%	78.8%	60.9%
Online education will be a standard model of education	25.0%	57.6%	34.3%
Car dependence will become more obvious due to adverse reactions to crowded public transport during the pandemic	75.0%	69.7%	63.0%
More and more people will out-migrate from populated cities	25.0%	27.3%	22.2%
More and more people will choose to live far from the city centre	28.6%	21.1%	20.5%

Source: Zhang et al. (2021, page 77)

The ultimate test lies in what will happen once large-scale vaccination has been achieved in most cities across Asia, and the risk of new variant of the variant triggering the nth wave of infections has subsided.

Paralleling a shift away from public transport, changes are expected towards greater car dependence (Shakibaei et al., 2021, for Istanbul; see Table 4 for India), more walking and cycling (Zafri et al., 2021a) and also – particularly salient in the context of Asian cities – motorcycle use (Raunak et al., 2020; Zafri et al., 2021b). Based on an online survey conducted in May and June 2020 among 1,202 individuals from across India, Raunak et al. (2020) suggest growing use of both two- and four-wheelers, including motorcycling and private cars, after the first lockdown in the Spring of 2020; however, they suggest that the pandemic is most likely to induce increases in car ownership among middle-income households among whom car ownership is lower than their higher-income counterparts, and who are able to afford this purchase, unlike lower-income households.

Also using online surveys, Zafri and colleagues (2021a) have shown how in times of low infection rates but before mass vaccination has been achieved in Bangladesh the inclination to walk and cycle more is likely to be greater among those individuals who pre-COVID travelled on public rather than private transport, already walked or cycled more, and who did not think that available physical infrastructure constrained their cycling, among other factors. In another online survey study among Dhaka residents, Zafri et al. (2021b) show that the first wave of the COVID pandemic has, on balance, strengthened participants' intention to purchase a motorcycle for daily travel, especially if they held positive attitudes towards motorcycles, had some experience of using them, and identified as male or owned a bicycle.

The academic literature has devoted little attention to the long-term effects of the COVID-19 pandemic on platform-enabled shared taxis and car-pool services, and almost none to informal transport modes. Both terms need careful unpacking because they cover a wide range of services. Of the 804 Bangladeshi in Zafri et al.'s (2021a) study, some 45% said they would use 'shared transport', which included both rideshare and rickshaws, less than before the pandemic, against approximately 25% saying they would travel more with modes in this category and 30% indicating they would not change their frequency when infection rates had gone down. These statistics are less dramatic than for public transport but still substantial: 60% said they would reduce public transport use after rates had gone down, 20% they would increase transport use and 20% would not change their behaviour. Nonetheless, services with many captive riders, such as motorcycle and minibus taxis, may see a quicker and fuller recovery after the pandemic than those that rely on patronage by users with greater discretion over the service(s) they use to fulfil their mobility needs.

At the same time, operators of shared taxi and carpool services enabled by digital platforms have shown significant adaptability during the first wave of the pandemic by moving away from ferrying persons towards activity in (non-COVID) patient transport to/from medical service centres, food delivery, logistics and micro-mobility (Combs and Pardo, 2021; Shokouhyar et al., 2021). Also, a Delphi study among 18 mobility experts worldwide indicated the extent to which shared mobility services can re-establish trust among (potential) users as one of the key factors that will decide how platform-enabled mobility services will fare after the pandemic (Shokouhyar et al., 2021). Other such factors include public attitudes towards mobility and eco-friendly transport and city-level decisions about investments in transport infrastructures and about if and how urban planning moves beyond favouring private car use (*ibid.*).

4.3.2 *Digitalisation*

There is a consensus in the academic literature that the pandemic is a 'game changer' for the digitalisation of mobility. It is widely expected that after the pandemic there will be significantly more business meetings and working from home, although a partial return to working at the workplace after mandated restrictions or waves of infections have ended has been expected and empirically validated (Beck et al., 2020; De Haas et al., 2020; Irawan et al., 2020; Shakibaei et al., 2021; Zhang et al., 2021).

Expectations regarding online shopping are more equivocal. As outlined in Table 1, the experts in Zhang et al.'s (2021) survey expect a fundamental shift towards online shopping, but the expectations of 834 participants in an online survey in May 2020 in Indonesia showed a more nuanced picture. While roughly a third expected to undertake less out-of-home grocery and non-grocery shopping after lockdown and the first wave of infections, half expected to return to pre-pandemic routines and a minority (18% for grocery and 11% for non-grocery shopping) expected to engage in out-of-home shopping more often. Moreover, all else equal, those who had engaged in non-grocery shopping online during the first wave expected to be shopping at least as much as they did before the pandemic. The specific embodied experiences that offline shopping for consumer goods enables may not dissipate as quickly because of the pandemic as is sometimes thought.

4.3.3 *Infrastructure development, air pollution and GHG emissions*

The long-term consequences of the pandemic for city-level transport infrastructure development have so remained severely underexamined in the academic literature. The likelihood of delays in investment has been acknowledged for Asian cities in general (Earley and Newman, 2021) and for the metro in Delhi more specifically (Rothengatter et al., 2021). However, empirical evidence to back up claims has not been provided, even if the conjectures are intuitively agreeable.

Academic studies about the long-term impacts of pandemic-related changes in urban transport in Asian cities could not be identified. Such impacts will depend to large degree on how modal shifts away from public transport and towards (private) car use and the substitution of physical trips by online activity will unfold, provided that the pandemic has little effect on the pace of electrification of urban transport across Asian cities.

4.4 Conclusions

A substantial number of academic studies seeking to understand pandemic-related changes to mobility in Asian cities and more widely have now been published. As this Section indicates, this literature has – understandably – focused more on short- than long-term changes to mobility in Asian cities. With regard to longer-term changes, the literature is reasonably unanimous and, in many ways, does not diverge much from wider professional discourse:

- a) public transport will struggle to recover although it is difficult to say how much; if it does, then this will take some time although it is unclear how long;
- b) platform-enabled shared taxi and car-pool services will also be affected in the longer term, though perhaps less than normal public transport because riders have less choice and providers remain in, or shift towards, other forms of transport service provision;
- c) the rise of private car use and ownership, and to a lesser extent motorcycle use and ownership, is likely to be accelerated by the pandemic, though again it is unclear by how much;
- d) walking, cycling and micro-mobility may be increasing in importance, but effects seem to be less robust than for public transport and private car use and more variable across, and possibly within cities;
- e) the replacement of physical mobility by online activity has been accelerated as well but the pace and extent of change varies across activity type, city and social group;
- f) long-term impacts on informal transport services have been examined the least of all, but may be modest if these attract mostly captive users with little discretion over which form(s) of transport they use;
- g) increased social and spatial inequalities in realised mobility and accessibility between and within cities are a realistic prospect in light of pre-existing digital divides and especially if the fares of public, shared and informal transport services increase, services are rationalised and investment in infrastructure development are reduced, and/or tailored to the most profitable services and routes;
- h) public policy at both national and city levels has a very large impact on shaping how transport systems in Asian cities evolve and the extent to which the mobility needs of all social groups in the city will be met.

At the same time, it is clear that the academic literature on the effects of the pandemic on urban transport suffers from many limitations. Any study of the long-term consequences of processes that have yet to unfold depends on inherently time- and place-specific expectations, hopes and fears. Whether experts or members of the general public are surveyed, the results say more about perceptions and attitudes at

the time and place(s) at which participants respond to questions than about what will happen when the pandemic has subsided or is over.

Readers should also be aware that the inevitable time gap between data collection and publication in a peer-reviewed academic journals means that currently available studies do not consider how second (and subsequent) waves of infection have shifted understandings, perceptions and attitudes regarding everyday mobility in Asian cities and indeed elsewhere.

Another major limitation is that studies of revealed or expected behaviour during and after the pandemic are overwhelmingly based on online surveys, which are not representative of wider urban populations. They are even less likely than government-sponsored surveys at non-pandemic times to adequately cover the most vulnerable social groups suffering from multiple forms of deprivation and with the least discretion over how they move through the city. Examples include – but are by no means limited to – inhabitants of informal settlements and neighbourhoods, the chronically ill and disabled, children and the oldest old, and low-income single mothers. Groups such as these may ultimately have most to benefit from great resilience in urban transport systems after the pandemic.

5 Towards Resilient Urban Transport after COVID-19

5.1 Introduction

A silver lining to the COVID-19 pandemic is that it allows for a resetting of the fundamental parameters within which transport planning and policy at city and national levels operate. The pandemic has demonstrated not only the need to enhance resilience of urban transport systems but also the willingness and capability of governments to intervene in urban transport a manner that, before 2020, was widely deemed unrealistic – also beyond the advanced liberal democracies of the global North.

As Section 3 has indicated, enhancing the resilience of urban transport systems in Asian cities requires engagement with both the engineering and socioecological approaches to resilience. This section will discuss the insights that can be derived from grounding policy interventions in both approaches. It is, therefore, premised on the idea that Asian cities, insofar as they wish to ‘build back better’ transport on the back of the pandemic, should focus on *both system consolidation and system transformation*: they should make public transport more robust and adaptable, whilst enabling deep changes towards low-carbon and socially just urban mobility.

Throughout this section a distinction is made between short-, medium- and long-term interventions. It is difficult to link chronological qualifiers to these terms, but a reasonable heuristic categorisation would be 0-2 years post-pandemic for the short term, 2-5 years post-pandemic for the medium term, and 5-20 years post-pandemic for the long term. What constitutes ‘post-pandemic’ is of course difficult to define. Rather than a unilateral declaration by a national government or the WHO, a combination of vaccination of the (vast) majority of the population, low probability of national and/or local governments considering further/new lock-down or social distancing policies, and low risks of infection at population level seems to constitute a reasonable set of criteria. However, at the time of writing this Study Background Report, it is unclear when these criteria will be met across Asian cities. Given current uncertainties about vaccination speed and the possible emergence of new virus variants, this moment will likely vary across Asian countries and fall in 2022 or 2023.

Underpinning this section is also the idea that enhancing resilience of urban transport systems without paying attention to transport justice is ill-advised and, if it intensifies social tensions, potentially counter-productive. Justice needs to be understood broadly in this context, to consider (e.g., Verlinghieri and Schwanen, 2021):

- a) the distribution of benefits and costs or harms (distributional justice);
- b) the decision-making processes regarding enhancing resilience are made, who influences those and how (procedural justice); and
- c) the extent to which, and ways in which, the needs, values, knowledges, customs and capabilities of different groups are recognised and respected (justice as recognition).

Concerns over justice in system consolidation and system transformation are addressed more easily if transport planning makes the traditional focus on efficient traffic flows subservient to a long-term orientation towards the satisfaction of the (dynamic) needs of all residents and visitors in a city. This is much easier if the core objective of long-term transport planning is recentred onto the enhancement of people's mobility capabilities – their potential to undertake trips and reach destinations, and thus their freedom to undertake the activities they value – in a manner that does not diminish the mobility capabilities of others (Schwanen, 2021). This framing of long-term transport planning's core objective recognises that the need for transport is in most cases derived from the need to undertake or participate in activities that are distributed across space and time. It also encourages policymakers and other professionals to take transport planning out of its institutional silo and to integrate it with and into urban planning, public health, social care, economic affairs and other siloed policy domains (Zhang, 2020).

5.2 System consolidation through greater engineering resilience

Sustainable urban transport systems cannot be achieved without strong, efficient public transport systems that enhance the mobility capabilities of *all* city residents and visitors by virtue of being convenient, reliable, accessible and affordable.

For the short term, enhancing *bouncebackability* when the COVID-19 pandemic subsides is essential. Rapidly restoring public confidence to pre-pandemic levels must be at the heart of efforts to make public transport recover quickly: enduring lack of trust will diminish individuals' mobility capabilities, depress ridership and harm public transport's fare box ratios in the medium term – at a time when operators' financial resources will have severely depleted, if not completely exhausted. Concrete short-term interventions helping to restore public confidence include post-pandemic

continuation of the hygiene practices that were mandated or voluntarily adopted during the COVID-19 crisis, such as the visible and frequent (deep) cleaning vehicles and provision of sanitisers (Raunak et al., 2020; Hasselwander et al., 2021; Shakibaei et al., 2021). Acceleration of the transition towards digital payment systems may also help, as do real-time provision of information on passenger and crowding levels on vehicles and in stations (*ibid.*). The latter intervention in particular will also help to enhance robustness and adaptability.

At the same time, restoring confidence in public transport alone will not be sufficient. It is at least as important to restore trust in living in high population/activity density settings and spending time in busy public spaces. The long-term (economic) benefits of agglomeration that cities enable (e.g., Glaeser, 2011) have not dissipated, and high densities of people and activities are critical to the viability of strong public transport, shared mobility and cycling and walking systems, and the mobility capabilities associated with these systems. Transport policymakers should work together with professionals in urban planning and public health to explore collectively how, for instance, Internet- and app-based interventions – known to help reduce agoraphobia and related panic disorders (Domhardt et al., 2020) – and marketing campaigns can be used to restore public trust in high-density settings and busy public spaces.

For the medium and long term, a greater focus on modularity in system design and operation can enhance the robustness of public transport systems. One possibility is to use more but smaller vehicles (bus systems) or compartments (urban rail) instead of larger or longer ones (e.g., articulated buses and open, interconnected rolling stock through which people can walk from front to back). The latter may be more efficient but also allow viruses to spread more easily and may make individuals more vulnerable to infection.

A wide range of interventions can enhance the engineering resilience of public transport systems when new epidemics happen in the future. A useful framework for thinking about such interventions is provided by Zhang's (2020) PASS approach. This offers a normative perspective on the responsibilities of government, transport operators and transport system users in enhancing the robustness, bouncebackability and adaptability of (urban) transport systems during future epidemics. The approach encompasses four increasingly far-reaching steps to be taken in sequence:

- a) *Prepare – protect – provide*: the preparation of emergency plans and the transport capacity of health services; protection of transport operators and users and vulnerable populations more generally; and provision of guidance and information, financial support and anti-virus services to transport operators and users;

- b) *Avoid – adjust*: avoidance of inconsistent and non-scientific policymaking, crowded platforms and vehicles, and unnecessary and non-urgent trips; and adjustment of policy processes, service provision and demand management, activity-travel patterns and logistic supply chains to minimise overall transport activity;
- c) *Shift – share*: encouraging modal shift to walking, cycling, and (shared) micro-mobility; sharing of operational resources (e.g., using vehicles for transport passengers to move and distribute goods and parcels) and information; and
- d) *Substitute – stop*: Substitution of physical transport and in-person activities with online activities; termination of services where social distancing is not possible and institution of stay-at-home orders and business closures.

Zhang's PASS approach is comprehensive and systematic; many, but not all, proposed measures have been implemented in cities across Asia in the current pandemic. However, the approach is also generic and must be tailored to both the level of cities and the particular conditions in each individual city. It also presupposes the existence of strong capabilities and extensive resources in (local) government and a centralised, or at least coordinated approach, to the provision of transport services. Neither may hold for specific cities, and in particular for those where informal transport services plays an important role in the satisfaction of many people's mobility needs.

5.3 System transformation with the help of socio-ecological resilience

Increasing the engineering resilience of (public) transport systems in Asian cities is important but, on its own, insufficient. A wider, long-term transformation of urban transport is required to pre-empt a further transition towards full hegemony of the private car transport system across Asian cities. Enhancing the flexibility and agility of public, shared taxi and car-pool services, cycling, walking and micro-mobility systems can help cities to avoid that transition. This is particularly so if policies are put in place that seek to diminish the adaptability of the private car transport system (Schwanen, 2016; Geels et al., 2017).

5.3.1 Cultivating flexibility and agility

There are multiple complementary ways in which flexibility and agility of urban transport systems in Asian cities can be strengthened. The most important focus on:

- a) Upgrading and extending the infrastructures and technologies for low-carbon transport and online activity;
- b) Linking transport interventions to land use planning; and

- c) Enhancing resources, skills and capabilities of users, service operators and local government.

5.3.1.1 Infrastructures and technologies for transport and online activity

In the short term, the widely introduced pop-up infrastructures for walking, cycling and micro-mobility, as well as in some cities BRT (Section 3), should be consolidated, spatially extended and be accompanied by complementary infrastructure, for instance for bicycle parking and storage (Hasselwander et al., 2021; Nikitas et al., 2021; Zafri et al., 2021a). For the short- and medium-term, it would also be good to extend or introduce bicycle and e-bike hire and e-scooter schemes at locations that are easily accessible and with rates that are affordable to all social strata across the whole urban area – not just for already privileged middle-classes in dense, well-to-do neighbourhoods. Shared bikes, e-bikes and e-scooters are no silver bullets but can, under certain conditions, make short-distance trips and first/last-mile trips to public transport stops flexible, fast and efficient. Those conditions include safe road infrastructure and parking/storage, clear regulation, affordable prices and payment methods that are also accessible to low-income groups. Micro-mobility schemes need to be developed in consultation with rickshaw or motor taxi drivers to minimise competition and ensure that a substantial number of those drivers can be employed in the operation of new micro-mobility schemes. More generally, those micro-mobility schemes should privilege social sustainability over maximising market share and profitability.

Additional road space for active travel – walking, cycling and micro-mobility – is essential, and this involves reallocating road space away from private cars (Earley and Newman, 2021; Nikitas et al., 2021; Zafri et al., 2021a). From a user point of view, segregated physical infrastructures such as dedicated sidewalks and bike paths will be preferable, but modular road designs whereby road space can be allocated more flexibly to different uses also merit careful attention as medium and long-term changes to current planning and design practice. Modular road designs can be particularly useful if (changing) climatic conditions prohibit walking, cycling or micro-mobility during daytime during certain months each year. Flexibility and agility in light of changing climatic conditions must be built into any medium- and long-term plan for the upgrading and extension of any infrastructure for sustainability transport (see also Schwartz and Regmi, 2020), including active travel. This also means enhancing capacity in maintenance and repair of active travel infrastructures, another area where the skills and experience of informal transport workers can be valuable and capitalised on by employing them in relevant occupations. With all these interventions it will be important to place public acceptability and ensuring procedural justice centre stage

(see also Nikitas et al., 2021), and adopt participatory, deliberative and iterative planning and implementation processes that will enhance both.

New, extra and better transport technologies and infrastructure for active travel need to be complemented with substantial investment in public transport technologies and infrastructure. In the medium term, rapid electrification as well as further digitalisation in service operation, real-time customer information provision and payment systems – alongside the modular design discussed earlier – can enhance flexibility and agility as well as increase patronage (see also Earley and Newman, 2021). Given the blows dealt to fare box ratios and finance resources by the pandemic, financial support through government subsidies and other financial support would be helpful in the short and medium term (Anwari et al., 2021; Rothengatter et al., 2021). Such support can also pre-empt operators raising fares and be tied to conditions that disallow fare increases. While understandable given the current financial situation, higher fares will likely further disadvantage low-income workers and neighbourhoods (Gutiérrez et al., 2020) and intensify existing transport inequalities.

Investment in digital infrastructure will also enhance the flexibility and agility of urban transport systems, if it gives users across all social strata and locations within the urban area – including informal settlements – greater discretion over whether to undertake physical trips or engage in online activities. Here the importance of enhancing the capabilities of transport system users comes to the fore: they can only benefit directly from improved digital infrastructure if they have the skills and can afford online activity participation. Enhancing IT literacy and overcoming digital divides must be tightly coupled to transport policy (Anwari et al., 2021).

More generally, enhancing mobility capabilities across all social strata and groups in a city is critical to the flexibility and agility of low-carbon transport systems in Asian cities in the short, medium and long terms. Creating high-quality physical infrastructures for cycling and micro-mobility is not enough to guarantee use across all strata and groups. Cultivating cycling-related skills, confidence and aspiration through cycling lessons in primary and secondary education, through dedicated workshops and via smartphone apps is important too, especially in disadvantaged groups (Schwanen and Nixon, 2020). Confidence and aspiration are also cultivated by positive reinforcement, including the celebration of successes (Nikitas et al., 2021), and awareness raising through campaigns that in the first instance target 'low hanging fruit' – individuals and groups who are most likely to use micro-mobilities or new opportunities to cycle (see also Anwari et al., 2021). The latter strategy can generate role models that others want to follow and imitate.

5.3.1.2 *Linking transport interventions to land use planning*

Expectations about what can be achieved with more and better infrastructure for active and public transport or online activity need to be realistic. Yet, the benefits of such infrastructural interventions can be multiplied through long-term policy strategies at the transport-land use interface that can replace a common orientation towards – and fascination with – mega-projects unduly favouring transport infrastructure (e.g., metro, light rail, BRT) over other aspects of urban development and the wellbeing of all in the city. Two such strategies have particular potential in enhancing the flexibility and agility of urban transport systems other than the private car: the compact city and the 15-minute city. They too need to be tailored to a particular city's context and history and the heterogeneous and at times conflicting needs of *all* its residents. Participatory, deliberate and planning and implementation processes can make an important contribution in this regard, if designed and carried out in a careful and appropriate manner.

The compact city has been around for decades, at least in Europe, and is related to the US approaches of Transit-Oriented Design and Smart Growth. It involves the concentration of new housing, office, retail and leisure developments in high-density, mixed-used areas around nodes in the public transport network and restrictions on new developments in open or green spaces in order to reduce urban sprawl. Based on studies focused on countries and cities which have for long periods implemented compact city policies (e.g., Schwanen et al., 2004; Geurs and Van Wee, 2006), it can plausibly be argued that this strategy can generate a virtuous cycle: public transport accessibility, usage and profitability improve, which generates financial resources and (political) momentum for network extension, upgrading of technology, and experimentation with new service models and (modular) designs, all which increase accessibility and usage further. Importantly, densification and mixed-use development with appropriate street designs that do not privilege car use can boost the viability walking, cycling, micro-mobility and shared mobility.

The 15-minute city concept is much younger, and perhaps known best for its recent adoption in Paris. It is more explicitly focused on improving the quality of city life and is linked to ideas about the smart city (Moreno et al., 2021). Increasing the viability, flexibility and agility of mobility by modes other than the private car is perhaps more a by-product of shorter distances to services and employment, greater social cohesion and strong neighbourhood-level economies than an explicit goal. Whether the concept is as transformative for the actual *uptake* sustainable urban mobility as protagonists claim remains to be seen and demonstrated (and past studies on the impacts of jobs-housing balance on commuting patterns provide some reasons for

that caution in this regard – see e.g., Cervero, 1996; Peng, 1997). Nonetheless, if implemented in ways that avoid deepening patterns of segregation along lines of class or race/ethnicity within cities, the concept may enhance the ability of walking, cycling and (shared) micro-mobility – and possibly local public transport and car sharing – systems to adapt to foreseen and unforeseen changes and shocks.

More broadly, the medium- and long-term changes to transport and land use planning advocated could be placed under a broader umbrella of transitioning towards smart cities in the medium and long term. The term ‘smart city’ is understood in many different ways, both in the academic literature and in the realm of practice (e.g., Mora et al., 2019, 2021). Here it is *not* understood as a one-size-fits-all, technologically deterministic, top-down solution to urban ills that is focused on efficiency, optimisation and control, and sold to cities by global tech companies. Rather it is imagined in a manner that is much better aligned with to the UN’s 2030 Agenda for Sustainable Development and the New Urban Agenda – i.e., as a socio-technical constellation that

- a) cuts across sectors and domains such as transport, housing, energy, et cetera;
- b) works towards and embodies sustainability, equity (distributional justice) and resilience; and
- c) is tailored to historically emerged, place-specific yet also trans-locally dependent social, cultural, political, institutional, economic, technological and physical conditions and processes.

Thus, the smart city is envisaged as a constellation in which transport and other urban systems are co-designed and co-created by government actors, businesses, research organisations as well as citizens and civil society as open processes for collective learning and adaptation in a wider world where the climate crisis, future epidemics and other foreseeable and unforeseeable sequences of events will affect Asian cities and their transport systems in myriad ways.

5.3.1.3 Enhancing the capabilities of transport system operators and local government

It is also important to enhance the capabilities of transport system operators and local government actors. Financial support to public transport operators has been discussed already, but informal transport providers also merit attention. Professionalisation and consolidation of informal transport provision, through training and service contracting, can – if done in a manner that attends to their needs, customs and capabilities (justice as recognition) – can generate greater operational efficiency and financial stability at both operator and system levels (Hasselwander et al., 2021). However, this requires

genuinely open engagement rather than top-down programmes on the terms of (local) government agencies.

In a similar vein, within a multilevel governance structure, local government needs to be enabled and better capacitated, with greater resources, expertise and decisional autonomy by national government agencies in order to facilitate local self-organisation (Section 3.3). Resources, in this context, include finance, clear regulatory and legal frameworks, real-time data and assessment tools such as the SUTI (Section 2). Meanwhile, expertise refers to the ability to use and generate knowledge using both quantitative modelling and interpretivist methods, and through participatory and deliberative processes with relevant stakeholders (Section 3.3) in ways that ensure procedural justice and recognise the needs, customs and capabilities of the latter (justice as recognition).

5.3.2 Diminishing flexibility and agility

Across Asian cities the COVID-19 pandemic seems to be accelerating the entrenchment of private car reliance, thereby exacerbating social inequalities between those can and cannot use their own car as well as air pollution and GHG emissions. Slowing down the growth of private car use and ownership and diminishing the adaptability of the private car system will contribute to the flexibility and agility of public transport, shared taxi and car-pool services, and active travel.

Reallocating road space – including parking spaces – away from private car use is a short- and medium-term strategy that has already been mentioned and over which local government often has considerable discretion. This should be complemented with regulatory and pricing measures in the medium-to-long term to make (fossil fuel powered) private car use and ownership less attractive and socially desirable (Rothengatter et al., 2021). Examples include greater taxation of vehicle purchases and petrol/diesel, parking tariffs and levies, and low emission zones. Such measures are often challenging to implement and even trickier to reinforce but can be made more palatable by integrating them into policy packages with measures that make public transport, shared taxi and car-pool services and active travel better accessible and more affordable, efficient and enjoyable (Givoni et al., 2013). Measures that encourage and accelerate electrification, such as financial support for electric vehicle charging infrastructure, can also be integrated into those policy packages, as there will be trips and social groups in the city for whom car use is the only realistic option to satisfy their mobility needs.

6 Conclusion

This Background Study Report has elaborated two approaches to understanding resilience in urban transport and used these alongside UN ESCAP's Sustainable Urban Transport Index (SUTI) framework to derive, from the academic literature about the impacts of the COVID-19 impact on urban transport, a series of recommendations about how to 'build back better' the resilience of urban transport systems in Asian cities that contribute to greater sustainability, equity and resilience.

The main conclusions of the Background Study Report can be divided into three groups related to the SUTI, the impacts of the COVID-19 pandemic on urban transport in Asian cities, and ways in which the resilience of urban transport in those cities can be enhanced.

6.1 The Sustainable Urban Transport Index

The analysis in this Report indicates that the SUTI developed by UNESCAP provides a helpful tool that allows cities across Asia to track not only progress towards greater sustainability in their local (person) transport system but also likely long-term impacts of the pandemic on local transport. This is because, according to the academic literature published to date, the modal share of public transport (part of indicator 2); access, quality, reliability and affordability of public transport (indicators 3, 4 and 6); and operational costs of, and investments in, public transport (Indicators 7 and 8) are among the most likely dimensions of urban transport in Asian cities' transport systems to be affected by the pandemic once this will officially be declared over.

At the same time, the SUTI would be even more effective for monitoring and evaluating the long-term impacts of the COVID-19 crisis on urban transport in Asian cities if it:

- a) included the modal shares of public transport and active travel as separate indicators;
- b) explicitly measured use of micro-mobility (e-scooter and [e-]bike) and ride-hailing;
- c) incorporated local government's investment in infrastructure for all active travel modes as an additional indicator;

- d) recognised the practical importance of 'informal' taxi services by minibus, rickshaw or motorcycle to key dimensions of social sustainability by measuring the extent to which these services are clean (no air pollution or GHG emissions at tailpipe) and characterised by non-exploitative labour relations; and
- e) included several indicators that measure socio-economic and gender inequalities in travel behaviour, access to public transport, traffic safety, and affordability of transport within a city.

6.2 Impact of COVID-19 on urban transport in Asian cities

The Report demonstrates that the academic literature on the effects of the pandemic on urban transport in Asian cities has burgeoned in the 16.5 months since the WHO declared COVID-19 a global pandemic. Nonetheless, peer-reviewed journal articles have so far:

- a) been concerned more with short- than long-term effects of the COVID-19 crisis on transport systems, including those in cities across Asia;
- b) been disproportionately reliant on online surveys with often fairly small, ostensibly non-representative samples; and
- c) failed to capture how the second and subsequent waves of infection have affected travel-activity behaviour and urban transport systems.

The last point is particularly salient as in many cities – e.g., in India – the wave associated with the delta variant of the virus is, or has been, more lethal albeit not always associated with the same lockdown and stay-at-home policies as the first wave.

Its limitations notwithstanding, the academic literature so far infers that, after the pandemic, online activity may substitute for at least some of the trips that individuals take on a given day or per week. Nonetheless, the long-term effects of the COVID-19 crisis on transport mode usage are likely larger than those on trip frequency. There is a consensus that public transport will struggle to recover in terms of both ridership and financial health, quite possibly for some time. Similar yet less pronounced effects may occur for platform-enabled shared taxi and car-pool services, although the evidence for this claim is very limited. At the same time, private car reliance and, to a lesser extent, motorcycle use and active travel – walking, cycling and micro-mobility – may increase. Most unclear is how informal transport services will be affected in the medium-long term, mostly because the impacts of the pandemic on informal transport have hardly been examined so far. It is also likely that impacts on transport systems at the city level will hide increased social and spatial inequalities in realised mobility and accessibility between and within cities, in particular if the fares of public, shared and/informal transport services increase, services are rationalised, and investment in

infrastructure development are reduced and/or tailored to the most profitable services and routes.

6.3 Enhancing the resilience of urban transport in Asian cities after the COVID-19 pandemic

The Report has distinguished between two different approaches to understanding resilience in relation to urban transport, with roots in different disciplines and worldviews:

- a) engineering resilience – the capacity of a transport system to resist and absorb the impacts of a disturbance in order to maintain an acceptable level of service (robustness), to recover and bounce back to pre-disturbance functioning ('bouncebackability'), and/or to transform to a different stage of operation (adaptability); and
- b) socio-ecological engineering – the capacity of a transport system to adapt continuously in light of both expected changes (flexibility) and unanticipated changes (agility) in its environment.

The Report has also argued that both need to be enhanced in the short, medium and long term, if urban transport in Asian cities is to become more sustainable and equitable after the pandemic: the robustness, bouncebackability and adaptability of public transport should be increased as a form of system consolidation while the flexibility and agility of public transport, shared taxi and carpool services, and active travel should be improved in order to achieve system transformation. Greater sustainability and equity and system transformation also require that the flexibility and agility of the private car system be diminished.

Key to greater engineering resilience in public transport is restoring public confidence in this form of transport and in spending time in busy public spaces and high-density settings in the short term. This is because extensive use of public transport will increase fare box ratios, diminish the need to raise fares and create affordability problems for poorer residents, and facilitate and legitimise large investments in expanding and upgrading public transport systems in the medium and long term.

The flexibility and agility of public, shared and active transport systems in Asian cities can be enhanced in at least three ways:

- a) Extending the infrastructures and upgrading technologies for those forms of transport and online activity will be essential. In the short term, pop-up

infrastructures put in place during the pandemic will need to be consolidated. This needs to be complemented by extensive road space reallocation away from private cars in the short and medium term, and extensive new infrastructure development for active mobility and public transport in the medium and long term.

- b) The transformation of urban transport systems in Asian cities can be enhanced by medium- and long-term changes in other urban systems to which transport systems are closely linked, such as land use, public health and social care. Pursuing a compact city and 15-minute city strategy can amplify and multiple the benefits from extension of transport infrastructure and upgrading of technologies for public transport and active travel. If understood as tailored to local conditions and processes and as focused on participatory co-design and co-creation with and for a city's citizens, the smart city approach can help to enhance the sustainability, equity and resilience of urban transport in Asian cities in the long term.
- c) Capacity building among transport system operators and local government actors will also be important. Relevant measures include (short-term) financial support for public and informal transport operators. In medium term, professionalisation and consolidation of informal transport provision should be given priority. Within a multilevel governance structure, local government needs to be enabled and better capacitated, with greater resources (finance, clear regulatory and legal frameworks, data and assessment tools), expertise and decisional autonomy by national government agencies in order to facilitate local self-organisation.

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