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Achieving Cost Effectiveness of passenger and Freight Transport Infrastructure and Services Towards Economic Sustainability – A comprehensive Analysis of Policy Options and Enabling Factors

(Background Paper for EST Plenary Session-3)

Final Paper

This background paper has been prepared by Dr. Karlson Hargroves, Curtin University, Australia, Expert Member of the Regional EST Forum in Asia, for the 14th Regional EST Forum in Asia. The views expressed herein are those of the author only and do not necessarily reflect the views of the United Nations.

Achieving Cost Effectiveness of Passenger and Freight Transport Infrastructure and Services towards Economic Sustainability

Background Paper for the 14th Regional EST Forum in Asia, 18-20 October 2021

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Executive Summary

Resilient and sustainable transport infrastructure and services are key for sustainable economic growth. Today, approximately 57 percent of the world population live in cities with the world's cities generating some 80 percent of global economic output[1]. According to the United Nations it is expected that an extra 2.4 billion people will be added to the world's cities by 2050[2], with some 44 million people added to Asian cities alone[3]. It is estimated that such rapid urbanization will increase demand of transport by 2.6 times around the world until 2050,[4] with annual passenger traffic exceeding 80 trillion passenger-kilometers[5]. To respond to this growth in demand, private car ownership would need to be increased five-fold in nations outside of the Organization for Economic Co-operation and Development (OECD) by 2050 [6].

As a result, some 1.2 billion cars stand to be added to the road network in developing countries, with the majority in Asian cities. This will cause a range of issues especially as many such cities are already over-crowded with private vehicles and are facing significant social, economic, and environmental problems related to transportation. In order to accommodate this immense transport demand countries and cities will need to expand their transportation infrastructure which will require substantial investment. Investment in core transport infrastructure can provide greater access to essential utilities and services. As incomes rise, better transport services are required to support and promote economic growth, business activities and facilitate exports. It is clear that better access to efficient, reliable, affordable, and sustainable transport infrastructure and freight services is critical to poverty eradication, promoting economic growth, supporting social development, and building resilient cities and communities.

The Belt and Road Initiative (BRI), for instance, by the Government of PR China is a one of the most prominent and well-known global infrastructure development strategies that has a strong focus on investment in the transport sector. Similarly, other mega projects have been initiated by emerging economies such as India, Indonesia, Viet Nam, Thailand, the Philippines, and a number of other developing nations to promote greater regional and inter-regional connectivity and trade. The Trans-Caspian International Transport Route (TITR), India–Myanmar–Thailand Trilateral Highway, Jakarta to Bandung high-speed rails in Indonesia, and Thailand's first standard-gauge double-track railway, and dedicated freight corridor (DFC) projects in different regions are among a few examples. Achieving cost

[1] Seto K., Dhakal, S. *et al* (2014) Human Settlements, Infrastructure and Spatial Planning. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[2] UNDESA (2018) World Urbanization Prospects: The 2018 Revision, Methodology. United Nations, Department of Economic and Social Affairs, Population Division Working Paper No. ESA/P/WP.252. New York: United Nations.
[3] ADB (2020) 'ADB's Work in Sustainable Transport', Asian Development Bank.
[4] ITF (2021) 'ITF Transport Outlook 2021', International Transport Forum.
[5] SuM4All (2017) 'The Global Mobility Report 2017: Tracking Sector Performance', Sustainable Mobility for All.
[6] GCEC (2014) 'The New Climate Economy Report: The sustainable infrastructure imperative', Global Commission on the Economy and the Climate Change (GCEC).

effectiveness of passenger and freight transport infrastructure and service development should be the primary goal of all these projects.

Due to 'shelter-at-home' conditions and other restrictions imposed by governments in response to COVID-19, the freight and logistics sector has endured changes in demand and operation due to shifts in consumer behaviours and essential cargo requirements. Implications of the pandemic include an increased shipping demand, increased online shopping, decrease in retail loyalty as up to 70 percent of consumers are estimated to have tried alternative brands[7], and an increase in quantity and importance of essential cargo delivery to aid in crisis relief [8]. In response, some air-cargo operators have coordinated short-term action plans to ensure access to essential services[9]. Further a number of 'Economics Response' platforms have been created to monitor the effect of the pandemic on trade. Such changes in air-cargo operation include the introduction of "green-lanes" for essential cargo and restricted times for passenger flights, from which China has achieved a 45-minute timesaving on cargo delivery[10].

[7] Arora, N., Robinson, K., Charm, T., Grimmelt, A., Ortega, M., Staak, Y. and Whitehead, S. (2020) Consumer sentiment and behavior continue to reflect the uncertainty of the COVID-19 crisis, Online, McKinsey and Company, 08 July 2020.
[8] EC (2020) European Commission Guidelines: Facilitating Air Cargo Operations during COVID-19 outbreak, European Commission, 26 March 2020.
[9] SADC (2020) SADC Regional Response to COVID-19 Pandemic: An Analysis of the Regional Situation and Impact. SADC Secretariat, Bulletin N. 2.
[10] IEC (2020) The Impact of COVID-19: Reflections on the Transport and Logistics Sector, International Economics Consulting.

1. Introduction

To keep the aspirations for achieving the SDGs by 2030, the world needs to invest an average of US$4.7 trillion annually, and 54 percent of this investment needs in Asia (Global Infrastructure Outlook, 2017)[11]. Emerging economy such as P.R. China and India required a major portion of Asian infrastructure investment. The Global Infrastructure Outlook report suggested that emerging economies like P.R. China and India need 34 percent and 8 percent of the total investment, respectively. In case of South Asian countries, they require the highest infrastructure investment -almost 9 percent of their GDP up to 2030 (ADB, 2018)[12]. Similarly, ASEAN need an estimated US$ 2. 8 trillion infrastructure investment and in case of central Asia, about US$38 billion worth of investment is required up to 2030 (AIIB, 2019). According to ADB, the financing gap in Asia cities is about US$ 459 billion a year (ADB, 2018)[13]. Asian Development Bank suggested that to maintain sustainable urban development and improve the economic growth, developing countries will required to invest US$ 26 trillion in the infrastructure development by 2030 with the rate of US$1.7 trillion per year (ADB, 2017)[14].

Many countries in Asia are making strong progress towards achieving improvements in their transport system across economic, environmental, and social outcomes. In 2020, COVID-19 has put enormous pressure on governments across the Asian region and there have been a number of implications for the transport sector. Governments around the world have responded with various forms of restrictions on human movement and interactions, ranging from city wide shutdowns to restrictions on the size of gatherings, in order to slow the spread and contain the virus. Forcing behavioural changes and transforming the way people communicate, work and live, these restrictions have substantially affected transport, providing a unique opportunity to revise and rethink transport strategies and options going forward. In the recovery following the pandemic it will be important for Asian cities to learn from best practices from around the world and develop robust and cost-effective transport systems that learn from the lessons to the pandemic and harness the latest technologies to deliver city wide benefits.

Despite the slowdown caused by COVID-19 a number of studies predict that the global transport and freight demand will recover and quickly grow in coming years. For instance, the Global Mobility Report predicts that global freight volumes will grow by 70 percent until 2030 (The Global Mobility Report, 2017)[15], and ITS predicts that global freight demand will increase with three-fold by 2050 in as usual business scenario (ITF Transport Outlook, 2019)[16]. Quality infrastructure development is crucial to address this passenger and freight demand globally. Robust, well managed and sustainable transport infrastructures such as shared transport systems, highways, railways, airports, seaports, and related services play key role to improve

[11] Oxford Economics (2017) Global Infrastructure Outlook, Global Infrastructure Hub, Oxford Economics.
[12] ADB (2018) Infrastructure Financing in South Asia, ADB South Asia Working paper, No 59, September 2018.
[13] ADB (2018) Infrastructure Financing in South Asia, ADB South Asia Working paper, No 59, September 2018.
[14] ADB (2017) Meeting Asia's Infrastructure Needs, Asia Development Bank.
[15] SuM4All (2017) 'The Global Mobility Report 2017: Tracking Sector Performance', Sustainable Mobility for All.
[16] ITF (2021) 'ITF Transport Outlook 2021', International Transport Forum.

transport options. Nevertheless, the major challenge for the Asian developing countries is how to accommodate the future transport and freight demand as the majority of Asian cities are already over-congested and unable to manage existing urban growth. At the same time, many developing countries are struggling with the lack of high-quality and robust infrastructures and better services, particularly, in transport sector.

The main purpose of publically available shared transportation is to meet the human needs by connecting peoples, goods, and services that promote economic activities and social interactions thereby improve the quality of life. The best shared transport system should be safe, efficient, low-carbon, affordable, people-friendly, socially inclusive, economically beneficial, and environmentally protective. To achieve such shared transport system, demand innovative and better shared transport policy intervention such as transit-oriented development, transit activated corridors, mixed-used development, better traffic demand management using innovative state-of-the are technologies, improved institutional mechanism, increase investment for transparent and good governance-all have significant implication on economic growth with other social, health and environmental benefits. And address the carbon emission thereby mitigate climate change impact. It is equally important to provide capacity and knowledge to the transport stakeholders, policy makers and planners, city leaders and politicians and public and private sectors for making shard transport safe, smart, efficient, inclusive, people and environmentally friendly that help to move towards the sustainable development path.

In the past decade the Transport sector has seen great progress in the design and deployment of next generation transport systems and new technologies that can underpin a transformative change and provide member countries with a range of benefits. Considering next generation transport vehicle types, innovations in electric vehicles, self-driving technologies, precision tracking, and high-speed carriage stabilization have now been combined to create the next generation of urban transport system based around what is called a “Trackless Tram”. Trackless Trams are effectively the same as traditional light rail except they run on rubber tires avoiding disruption and costs associated with construction of in-road rail systems and are powered by on-board batteries that are quickly recharged at stations avoiding overhead cables. Considering new ICT technologies, there has been significant innovation in computer programming that can now offer transport departments a number of significant opportunities. Leading examples of this include Machine Learning, which can be used of predictive congestion management, and distributed computer ledgers, or ‘Blockchains’, which can be applied to facilitate real time road user charging and streamline a range of administrative and financial transactions.

Despite the important role of government, they do not have to do everything alone. Building partnerships is important for delivering integrated win-win outcomes for society while leveraging additional resources and expertise. For example, crucial to the success of Guangzhou’s BRT in the People’s Republic of China, was the collaboration between the Public

Transport Management Office, Traffic Improvement Office, City of Guangzhou and the Institute for Transportation and Development Policy (ITDP). The technical assistance from ITDP in planning and design, rider research and scheduling, coupled with the deployment of specialists to complement the public sector skillsets enabled the entire project to be completed within a year.

2. Impact of Shared Transport Infrastructure and Services

Impacts of Transport

Transport has become one of the major causes of environmental degradation, particularly air and noise pollution, traffic congestion, road accidents and fatalities, and increasing greenhouse gas emissions that contribute to climate change. It is predicted that the average time an urban resident spends in traffic congestion will be 106 hours per year by 2050, which is three-times more than today (Future of Urban Mobility Report, 2011)[17]. A report in 2018 indicated that the residents in India's biggest cities, including Delhi, Mumbai, Bengaluru and Kolkata, spend 1.5 hours more on their daily commutes compare than their counterparts in other Asian cities, which cost the cites about US$22 billion annually (Boston Consulting Group, 2018)[18].

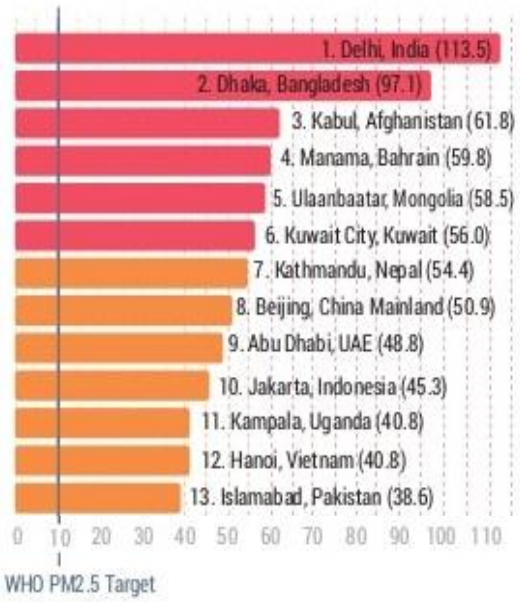

Figure 1: World regional capital city ranking on the PM2.5 concentration. EST member countries in Asia are on the top of the list.

Source: IQAir (2019)[19]

Air pollution contributes to the death of more than 10 million people each year (Vohra *et al*., 2021)[20], and 90 percent of air pollution related death occur in developing countries, costing just over US$5 trillion in welfare losses globally (WHO, 2018)[21]. It is projected that gradually that cost will increase up to US$ 25 trillion until 2060 (OECD, 2016)[22]. Asian mega cities are suffering the most from severe air pollution, as shown in Figure 1[23]. For instance, according to the World Bank, the cost of air pollution-health damages is about US $1 billion a

[17] Lerner, W. (2011) The Future of Urban Mobility: Towards networked, multimodal cities of 2050, Arthur D Little.
[18] BCG (2018) Unlocking Cities: The impact of ridesharing across India, Boston Consulting Group.
[19] IQAir (2019) Air quality in the world: Air quality index (AQI) and PM2.5 air pollution in the world, IQAir.
[20] Vohra, K., Vodonos, A., Schwartz, J., Marais, E., Sulprizio, M., and Mickley, L. (2018) Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem, *Environmental Research*, Volume 195, April 2021.
[21] WHO (2018) 'Health benefits far outweigh the costs of meeting climate change goals', World Health Organisation, 05 December 2018.
[22] OECD (2016) The Economic Consequences of Outdoor Air Pollution. OECD Publishing, Paris Science for Environment Policy, 2018.
[23] IQAir (2019) Air quality in the world: Air quality index (AQI) and PM2.5 air pollution in the world, IQAir.

year in cities such as Bangkok and Jakarta. Air pollution related cost many Asian developing countries ranges from 2 to 4 percent of their GDP annually (UNCRD, 2016)[24].

Approximately 1.3 million people die each year because of road traffic accident worldwide (WHO, 2018)[25]. Despite having just 16 percent of vehicle fleet, more than 60 percent of global road fatalities occur in the Asia-Pacific region (UNESCAP, 2019)[26]. It could cost Asian economy 3 to 5 percent of their gross domestic product (GDP). In the case that Asian developing countries can improve the road safety they can save significant economic loss. For instance, the World Bank predicted that if P.R. China, India, Thailand, and the Philippines reduce road traffic deaths and injuries by 50 percent they could generate the income (in percentage of their national GDP) equivalent to 7.2 percent in Philippines, 14 percent in India, 15 percent in P.R. China and 22.2 percent in Thailand (World Bank, 2017)[27].

A recent report published by Swiss Re projected that the climate change could cost the world economy approximately $23 trillion by 2050, which is equivalent to one-fourth of world entire GDP (Swiss Re, 2021)[28]. South Asian developing countries will be most affected by climate change, and these countries could loss up to 11 percent of their GDP by end of the century (ADB, 2018)[29]. In case of India, it is projected that the country will lose up to US$13.8 billion annually due to climate change impact (Eckstein *et al*, 2019)[30].

The magnitude and intensity of natural disasters has been increasing in recent decades, with the global economic losses from coastal flooding set to exceed US$1 trillion annually by 2050 if major coastal cities do not adequately prepare (Hallegatte *et al*, 2013)[31]. The rise in sea level another major problem, with a 2019 report warning that over 800 million people living in some 570 coastal cities around the world will be at risk of coastal flooding by 2050, and that unchecked this could cost the world economy about US$1 trillion (C40, 2019)[32].

[24] UNCRD (2016) Low-Carbon Transport – Health and Climate Benefits. Report presented at the 9th Regional EST Forum in Asia 17-20 November 2015 Kathmandu, Nepal.
[25] WHO (2018) Global Status Report on Road Safety 2018. World Health Organisation.
[26] UNESCAP (2019) Road Safety Status in the Asia-Pacific Region, United Nations Economic and Social Commission for Asia and the Pacific.
[27] World Bank (2017) The Macro-Economic And Welfare Benefits of Reducing Road Traffic Injuries in Low-& Middle-Income Countries, World Bank.
[28] Swiss Re (2021) The Economics of Climate Change, Swiss Re, 22 April 2021.
[29] ADB (2018) Infrastructure Financing in South Asia, ADB South Asia Working paper, No 59, September 2018.
[30] Eckstein, D., Hutfils, M-L, and Winges, M. (2019) Global Climate Risk Index 2019: Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2017 and 1998 to 2017, GermanWatch.
[31] Hallegatte, S. Green, C., Nicholls, R. and Corfee-Morlot, J. (2013) Future flood losses in major coastal cities, Nature Climate Change Volume 3, pages802–806.
[32] C40 (2019) C40 Cities Annual Report 2019, C40 Cities.

Addressing Transport Impact through the Potential of Corridor Transit

Such impacts from transport need to be addressed and one clear way is to create effective and efficient shared transit corridors that unlock development opportunities and provide greater accessibility. It is clear that when 'Environmentally Sustainable Transport' is effectively integrated with land use to create dense, mixed-use developments this not only delivers development outcomes it encourages physically active lifestyles by integrating active modes (walking and cycling) that have risen to prominence during the COVID-19 pandemic (Newman *et al,* 2017)[33]. When new shared transit corridors are introduced with strong public private partnerships the increased accessibility in areas around stations is a significant attractor for development (and higher land values) with some of the most extensive railway networks in the world have leveraged this opportunity to expand, such as the Hong Kong Special Administrative Region of China.

The activation of development opportunities along corridors using integrated shared transit was pioneered in Asian Cities but has largely been overlooked as an economic development strategy. The need to reduce congestion and provide greater mobility services calls for a revival of this very successful approach, combined with the latest in technologies to provide a cost-effective shared transit solution suitable for integration into existing road corridors. Given the level of growth in Asian cities the shift to focusing on corridor mobility options that are effectively integrated into land development is inevitably going to be the next big agenda in transport policy.

This will involve building on the success of 'Transit Oriented Development' or TOD that was focused on individual stations and intended to help transform rail policy, to create 'Transit Activated Corridors', or TAC, that is focused on a corridor of stations with the intention to transform road policy (Newman *et al*, 2021).[34] There are now a number of options for shared transit suitable for application in main road corridors (such as buses, light rail and trackless trams) that can underpin quality urban development on, in and around stations, which can include access to 'last mile' options such as walking paths, shuttles and micro-mobility modes. Rather than being a government responsibility as in the case of the majority of TODs the delivery of a TAC will rely on effective partnerships between government and the private sector, calling for new approaches and strategic governance.

As with all transport options, corridor transit systems require financial investment. Attracting such investment is more likely for a light rail system than a bus system as a rail system is designed to follow a fixed route with substantive stations. This means that a long-term regular flow of passengers can be generated at a set of fixed locations which is of value to venues, vendors, developments, hospitality, and business located near stations. Traditionally this value has been captured last, meaning that transport agencies decide on the

[33] Newman, P., Davies-Slate, S., and Jones, E. (2017) The Entrepreneur Rail Model: Funding urban rail through majority private investment in urban regeneration. Research in Transportation Economics.
[34] Newman, P., Davies-Slate, S., Conley, D., Hargroves, K., and Mouritz, M. (2021) From TOD to TAC: Why and How Transport and Urban Policy Needs to Shift to Regenerating Main Road Corridors with New Transit Systems. Urban Science. 2021; 5(3):52.

location of the route and stations and then municipal governments increase land taxes and rates for those located near new stations. In principle the notion of 'value capture' presents as a sound approach, however results have been mixed. This is due in part to the dynamic that imposing greater costs to those located near stations is not always politically acceptable and the higher costs can stifle future land development ambitions. Hence new approaches are needed to catalyse greater corridor transit investment.

Newman *et al* (2017)[35] propose a new model to leverage the increase in land value in a manner that encourages greater levels of land development, called the 'Entrepreneur Transit Model' (ETM). The ETM suggests a 21st century method of financing corridor transit based on establishing partnerships between local government, developers, and financial institutions like superannuation companies, as well as with state and national governments. The mechanism of the ETM then leverages real partnerships to select routing and station locations that both deliver transport services to the community and increase the value of specifically chosen land parcels. The key is to adopt an entrepreneurial approach that brings together transport and land agencies to partner with the private sector to deliver both transit services and enhanced land development opportunities. This involves finding new ways to partner across government agencies and with the private sector to identify routing and station locations that deliver transit services while increasing the value of specifically chosen land parcels to attracting new investment.

Assuming land is acquired at 'pre-rail' prices, and that the transit service delivers the anticipated level of patronage to generate value for businesses and developments around the stations, this approach can leverage funding. Hence rather than the businesses and developments around a newly constructed station being forced to pay higher local government rates even if they don't benefit financially from the new station, this model ensures the co-location of stations and development interests to leverage the benefits of both. Not only can this result in private investment being accessed to pay for the stations and contributing to the carriages and road preparations it also creates the potential for private interests to operate the transit system along that corridor. There is evidence that this value creation is not just shifting land value increases from one area to another but is creating value for the whole urban economy that would not have been created without such investment (Sharma and Newman, 2017)[36].

[35] Newman, P., Davies-Slate, S., and Jones, E. (2017) The Entrepreneur Rail Model: Funding urban rail through majority private investment in urban regeneration. Research in Transportation Economics.
[36] Sharma, R., and Newman, P. (2017) Urban Rail and Sustainable Development Key Lessons from Hong Kong, New York, London and India for Emerging Cities. Transportation Research Procedia, 26, 92-105.

3. Efficient Freight Transport Infrastructures and Networks

Freight Trends, Prospects and Impacts

According to study in 2014 by Ernst and Young rising congestion levels and urban encroachment are reducing the efficiency of the freight sector and considering that the level of congestion on metropolitan roads is likely to continue to grow in the coming decades, this presents an issue. The study points out that "*much of the infrastructure used by the freight sector is shared [with other road or rail users], and conflicts around access and use are not efficiently managed or addressed*". The study considered the potential for investment in dedicated freight infrastructure, such as the privately funded railway lines currently used to transport coal and iron ore but found that either dedicated railways or roadways are unlikely to be economically viable without allowing for mixed use given upfront costs (Ernst and Young, 2014)[37]. This then raises the question of how the movement of freight can be made more efficient, particularly within metro areas, whilst being embedded in the wider transport system. According to the Australian National Freight and Supply Chain Strategy a key element will be to "*develop an evidence-based view of key freight flows and supply chains and their comparative performance to drive improved government and industry decision-making, investment and operations*."(Transport and Infrastructure Council, 2019)[38]

Given the high value of freight there has been much work done to investigate ways to increase the efficiency of freight movement. However, on the whole, limited technical capacity of both the freight sector and the transport system itself has meant that such efforts are yet to demonstrate meaningful improvements. Early approaches have involved freight vehicles being equipped with GPS guidance systems that can provide information to the driver on the level of congestion along potential routes (Hargroves *et al*, 2020)[39]. More recently private companies are offering tracking and analytics services to monitor vehicle location to ensure the use of approved routes and monitor driver behaviour, such as hash breaking or exceeding speed limits. Although such passive approaches stand to deliver some benefits they are ultimately restricted by the fact that there is no direct interaction with the transport system (Hargroves, 2021)[40].

More recent efforts have been focused on investigating the potential for freight vehicles to interact directly with traffic lights in order to gain priority signalling at intersections, using similar technology to that used by emergency vehicles. The intention is to avoid freight vehicles within the vicinity of a particular intersection having to stop by recognising its presence and allowing an extended green signal, hence avoiding the slow

[37] EY (2014) A study of the potential for dedicated freight infrastructure in Australia, Report to the Australian Government, Ernst & Young.
[38] TIC (2019) National Freight and Supply Chain Strategy, National Action Plan, Transport and Infrastructure Council, Commonwealth of Australia.
[39] Hargroves, K., Shirley, D., Seppelt, T., Callary, N., Tze Wei Yeo, J. and Loxton, R. (2020) 'Overview of Options to Collect Vehicle Generated Data to inform Traffic Management Systems', Project 3.73 – Road Freight and Network Efficiency, Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[40] Hargroves, K. (2021) Introducing the 'FreightSync Roadmap' - A Pathway to Linking Freight Vehicles and Transport Systems, Project 3.73 – Road Freight and Network Efficiency, Sustainable Built Environment National Research Centre (SBEnrc), Australia.

acceleration on the next green signal that slows overall traffic (Ioannou, 2015)[41]. Early trials based on simulations have shown that there is potential for improvement at the intersection level (Zhao and Petros, 2016).[42] However it is not clear if this translates into reduced overall trip times, as it may be the case that *ad hoc* responses by individual traffic lights due to last minute notifications from trucks will have a detrimental impact on the effectiveness of system wide signalling. Hence unlike the movement of a small number of emergency vehicles across an entire city this approach may not deliver benefits when applied to many freight vehicles moving all across a transport network, calling for a more dynamic approach, one that will involve new forms of data exchange and the use of advanced analytics.

A number of government agencies, industry bodies and research institutions are producing public freight related datasets, however these often focus on highly aggregated historic data rather than real time tracking data held by freight and logistics companies. Such data, including vehicle classification, current location, and intended destination for both general and restricted access vehicles would be of great benefit to traffic management if exchanged in an appropriate way for mutual benefit. According to CISCO (2018) [43], "*While it is perfectly reasonable for individual transport mode operators to be exclusively focused on the benefits that digitisation will bring to their domain, there is significant value that will be missed if the opportunities that transportation Data Exchanges bring are not realised*." The inability to synchronise the location and destination of freight vehicles in real time with the transport system means that still today freight vehicles are effectively invisible to the system and are left to use third party apps in order to navigate traffic. However, before such exchange can be possible a number of concerns need to be addressed such as what real value will this create for companies, who will have access to the data, and how will it be used. For instance, can the data be limited to use only by the transport system, or will it be open to use by enforcement agencies to issue speeding fines or other infringements?

Benefit of improved freight transport networks

It is important when considering a change to the way industry operates to clearly understand the associated benefits and beneficiaries. For instance, when considering the exchange of data between freight operators and the transport system there are a range of potential benefits for freight operators, transport management, and transport planning, namely: (Hargroves, 2021)[44]

- ***Likely benefits for Freight Operators*:** Currently freight operators navigate the transport system much like any other road user, namely through the use of third-party traffic applications that provide an indication of the level of congestion and expected trip times. This approach provides benefits to freight operators as it allows areas of high congestion

[41] Ioannou, P. (2015) Design and Evaluation of Impact of Traffic Light Priority for Trucks on Traffic Flow, University of Southern California.
[42] Zhao, Y. and Petros, I. (2016) A traffic light signal control system with truck priority, IFAC-PapersOnLine, vol. 49, no. 3, pp. 377-382, May 2016.
[43] CISCO (2018) Towards a Multimodal Transportation Data Framework, Public White Paper, CISCO.
[44] Hargroves, K. (2021) Introducing the 'FreightSync Roadmap' - A Pathway to Linking Freight Vehicles and Transport Systems, Project 3.73 – Road Freight and Network Efficiency, Sustainable Built Environment National Research Centre (SBEnrc), Australia.

to be avoided and trip times to be compared to job requirements. However, such a passive approach misses the opportunity to interact with the traffic management system directly, along with missing out on a range of future benefits from aggregating data to establish authenticity, providence and to reduce transaction time and costs (as others are now doing). Given freight vehicles influence vehicle flow rates, the more the transport system knows about their movements the better it can manage traffic. In short, the benefit of appropriately exchanging data with transport agencies is that both daily traffic conditions and longer term transport planning outcomes will be improved, such as:

a) Improved Traffic and Transport Planning Outcomes: Providing access to information of freight vehicles, such as classification, location, and destination, can improve traffic flow conditions across the network, such as via responsive signalling to manage cycle times and offsets, and other adaptive traffic management methods. Such data will allow traffic management systems to understand both current and near future behaviour of freight vehicles allowing for tailored traffic responses and even direct communication with freight vehicles on preferred routes and timings. Along with short term traffic management benefits, in the longer-term data exchange can improve transport planning decisions and associated investments by providing much better data than is currently available.

b) *Direct Benefits to Operators*: Apart from benefits to traffic management such a system of data exchange may underpin a range of other benefits, such as: automated clearance for road access for various vehicle classification types; improved vehicle flow at loading points; informing freight forwarders of anticipated level of *driver* promptness; consistency across state borders; and linking freight tracking with container parks, rail services, and port stevedores to improve synchronisation.

c) *Positioning for Future Benefits*: Such a system of data exchange would position the sector well to take advantage of a range of future digital productivity options. For instance (Hargroves, 2020)[45], using emerging digital distributed ledgers, such as Blockchains, to deliver new value to the logistics sector, such as:

- *Verifying Authenticity*: The ability to provide access to secured proof of origin and sourcing evidence for a range of high-value goods, *such* as wine and other exports.
- *Establishing Provenance*: The ability to track the movement of freight from initial pick up to final delivery and provide customers with origin *information*, and if it has been sold already.
- *Streamlining Transactions*: The ability to have multiple transactions on one permissioned database to share customs releases, *commercial* invoices, cargo lists, broker loads, etc.

[45] Hargroves, K., Stantic, B. and Allen, D. (2020) Exploring the Potential for Artificial Intelligence and Blockchain to Enhance Transport – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.

Furthermore, once established such systems would provide a rich pool of information for new applications of Artificial Intelligence to optimise freight routes, staging and storage of freight, and inform the potential for sharing of facilities and avoiding running empty.

- ***Likely benefits for Traffic Management:*** Live data on freight vehicles can be beneficial to traffic management systems in a number of ways, including:
  a) *Improved Signalling*: Improving signalling to account for the presence of freight vehicles across the network (rather than at an intersection-by-intersection basis) allowing improved network capacity by pre-empting increases in freight vehicle frequency.
  b) *Vehicle Communication*: Informing freight vehicles of preferred routes to encourage use of parts of the transport network with lower congestion levels, this may also include providing freight vehicles with target speeds to reduce likelihood of meeting a red light.
  c) *Enhanced Safety*: Alerting inappropriate road use by restricted access vehicles to increase safety, providing the location and progress of dangerous goods movement, and informing the designation of gazetted routes and timings based on actual freight movements.
  d) *Real-time Monitoring:* Identifying trouble spots with intersections or bottlenecks in traffic flow that may warrant investigation and intervention and allowing monitoring of actual bridge crossings to compare to strength assumptions of bridges.
  e) *Predictive Analysis*: Inferring driving patterns of vehicles to include typical acceleration speeds, breaking distances, etc. to predict future behaviours, and informing predictive analytics by comparing real-time conditions to historic data to predict the likelihood of congestion events.
  f) *Streamline Data*: The benefit of such as system would be to streamline access to data and reduce duplication with the data observatory aggregating and curating the data.
- ***Likely benefits for Transport Planning:*** Building a database of tracking data on freight vehicles will be a valuable source of information to create a record that shows where the freight load is being transported across the transport system. Such high levels of detail on freight vehicle movement will provide a much clearer view of vehicle behaviours and can generate a range of benefits. This type of data is typically gathered using periodic surveys that may not be repeated for a number of years, or by making assumptions, such as the percentage of freight and other heavy vehicles in traffic flows, with both options proving little indication of time of use patterns. Having a real time stream of such data can allow a comparison between the quality of the road system and the quantity of freight carried at particular times (especially high value freight) which can influence decisions as to where to invest in infrastructure betterment and upgrades.

4. National connectivity and green growth economic development

Connectivity is a major issue in developing countries worldwide. Although urban population is increasing globally almost 45 percent of the World's population lives in rural areas, with the majority living in Asian developing countries. World Bank statistics show that the EST developing Member Countries have more than 50 percent of rural populations, as shown in Figure 2.

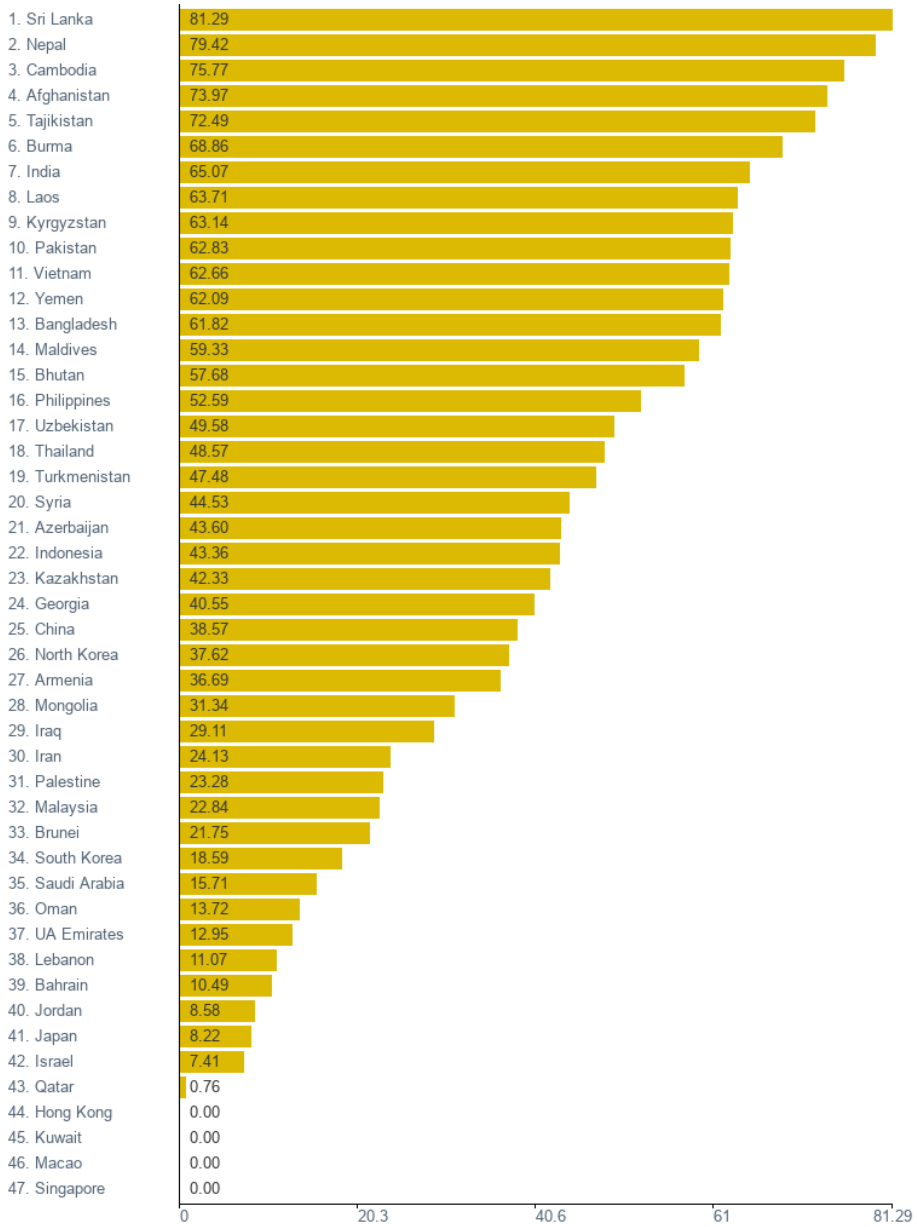

Figure 2: Rural population percentage in Asian countries -2020

Source: The World Bank[46]

[46] The World Bank (2021) Rural Population, Percent in Asia, GlobalEconomy.com.

Almost 40 percent of the rural population in the Asia and the Pacific Region lacks access to all-session roads, according to UNESCAP [47] . Inadequate shared transport infrastructure and services in rural areas makes the situation more serious. Therefore, improvement of rural access and national connectivity through increased investment in transport infrastructure and services should be the priority area for developing countries in Asia.

Green Grow Development

In the last 5 years there has been a significant increase in availability of electric vehicles with substantial improvements to battery technology revolutionizing the design of most forms of transport. Not only can battery powered vehicles significantly improve fuel economy in hybrid vehicles they can shift a nations energy economy form physical fuels to electricity with many local economic benefits. This has major implications for Asian cities for both the types of vehicles that will be used in the coming decade and the requirement for supporting infrastructure. Electrification of vehicles will not only significantly reduce air pollution form vehicles in cities, which is being realized due to COVID-19 restrictions on travel, but it will also provide the opportunity for domestic energy industries to grow and implement decentralized renewable energy options. This transition will allow a significant reduction in greenhouse gas emissions from vehicles and power generation.

Not only will electrification of vehicles improve fuel economy and reduce greenhouse gas emission it will also create new urban business opportunities with strong local and domestic demand. For instance, the Shenzhen Bus Group has recently become the first fully electric bus fleet in the world and found that not only did this shift reduce the running cost of buses but the need to also secure real estate for charging facilities across the city has provided the opportunity to provide charging and maintenance services to other electric vehicles within the city (such as garbage trucks, taxis, and private vehicles). Cities around the world are now considering how to best support the transition to electrification of mobility and grappling with the best way to provide supporting infrastructure.

The transition to electro-mobility will call for the modification and creation of a range of new systems and approaches, for instance to ensure that vehicles can interact with the electricity grid in a manner that is mutually beneficial.[48] Benefits for vehicle owners include reduced travel costs when switching from the purchase of fossil fuels to the use of electricity, along with the potential to provide services to the electricity grid while connected (Hargroves and James, 2021) [49]. For government agencies there are also a range of benefits, including: new taxes and tariffs, road user charges, revenue from grid services from fleets, data utilisation options, park and ride charging, and second life revenue from decommissioned

[47] UN ESCAP (2016) Rural connectivity to wider networks. United Nations Economic and Social Council.
[48] Economou, D., James, B., Hargroves, K., and Newman, P. (2021) Urban Design and Distributed Grid Management - A RACE CRC Literature Review, Curtin University Sustainability Policy Institute.
[49] Hargroves, K. and James, B. (2021) Perception and Capacity Factors affecting the Uptake of Electric Vehicles in Australia, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.

batteries, along with improving job creation, industry growth, green investment credentials, and energy security (Hargroves and James, 2021).[50]

Nations around the world have begun putting in place regulatory frameworks to underpin the transition to electro-mobility in order to both avoid the negative impacts of fossil fuel combustion and to capture the new opportunities associated with EVs. For instance, the EU has set a requirement that new cars registered in the EU from 2020 must emit less than 95 grams of carbon dioxide per kilometre, otherwise the manufacturer will be fined €95 per gram per kilometre over this minimum level. If this requirement was in place in 2019 this restriction would have generated some €34 billion in fines (JATO, 2019)[51]. The fines however can be offset through the sale of EVs and other approved 'Zero Emission Vehicles' (ZEV) that earn the manufacturer credits, providing a meaningful incentive (European Parliament and Council, 2020)[52]. Such incentives have demonstrated strong potential for future EV sales in the EU that has attracted the attention of EV manufacturer from around the world. Nations are also using taxation mechanisms to discourage internal combustion vehicles. For instance, since 2001 the UK has imposed specific taxation levels based on a vehicle's CO_2 emissions (UK Government, 2021)[53].

The freight and logistics sector—for dry goods as well as for food—are similarly facing huge challenges but also opportunities to become more sustainable. The moment internal and external borders closed, governments needed to take fast measures to ensure that key daily goods such as food and other necessities could be made available to residents in locked-down areas. Domestically, it was truck drivers who became some of the first people to be frequently tested for coronavirus in China, and with their health tracking mobile phone apps, and application of Personal Protective Equipment (PPE) were able to continue to bring freight to lock down areas. The impact of COVID-19 on international freight has not been so easy. Air freight has been significantly reduced due to heavy impacts on the business models of airlines that make use of both passenger freight and cargo freight to balance their business models. For some time, flights full of PPE delivered to various countries and locales were flown at a premium cost. Now, the air freight sector is awaiting the arrival and production of a viable COVID-19 vaccine in order to secure revenue.

Sea freight has also been heavily affected. At the beginning of the pandemic, ships were not welcome to arrive at port for fear of crew infecting on-shore staff and residents. Even today, many ships' crews are not allowed to disembark from their ships without a 14-day quarantine. Given that many crews are staffed by citizens of Bangladesh, Myanmar, Philippines and other Asian countries, many people were stranded at sea, unable to return home to their families. Recently, countries have started to recognize that different origin

[50] Hargroves, K. and James, B. (2021) Investigation into Revenue Implications of EVs for Transport Agencies, A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[51] JATO (2019) '2021 CO2 targets would generate €34 billion euros in penalty payments within Europe' JATO Dynamics
[52] European Parliament and Council (2020) Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011, European Parliament and Council, EUR-Lex.
[53] UK Government (2021) Vehicle Tax Rates, United Kingdom Government.

countries have different risk levels in terms of crews infecting on-shore staff and residents when they arrive at port. The Commerce Ministry of India for example, has requested that the Shipping Ministry reduce the quarantine period for vessels arriving from China to be reduced from 14 days to 7 days, both in order to better facilitate trade, but also based on lower risk potential of ships from China. Furthermore, India faces a shortage of containers because ships are not able to come to port as quickly as needed.

Slower border crossings provide a risk to sustainable development of cross-border trade. However, the development of track-and-trace technologies across borders offers an opportunity to open up borders in the long term and avoid waits at borders that result in resource waste, fuel consumption from idling trucks, and other severe inefficiencies that come about from drivers needing to wait for border crossing approvals. Track-and-trace systems that integrate between the private sector and governments could result in more seamless supply chains through cross-border freight for all sorts of goods, and in particular food.

5. Safe, Low-Carbon and Sustainable Passenger and Freight Transport

Investment in shared transportation affects to the economy directly and indirectly and can deliver economic and health benefits, employment generation, increased wages, new business opportunities, and improved efficiency and productivity. The economic multipliers of investment in shared transport reach much further than those that use it with a 2020 study suggesting that for every US$1 invested as much as US$4 is crated in economic returns, not to mention that one billion of investment in shared transit can create more than 50,000 new jobs (American Public Transportation Association, 2020) [54]. Investment in high-quality transport infrastructure and services can bring transformational changes in several dimensions from economic, health and education, and market development, such as:

Economic benefits

One of the most important benefits of the well-functioning shared transport system is for providing better accessibility, mobility, and connectivity to the people and goods improve the economic growth by:

- Reducing costs of travel, vehicle ownership, fuel, and maintenance given shared transport is cheaper and cost effective compared to using private cars.
- Increasing land-value along the corridor and around the transit stations.
- Reducing air pollution and noise pollution related economic impacts.
- Reducing urban sprawl and promoting mixed use developments.
- Reducing traffic congestion and associated time cost, fuel efficiency cost, air pollution and carbon emission cost, and business operation cost.
- Increasing the number of local and international tourists due to better shared transport, market, and business opportunities.
- Improving productivity, labor markets, commercial prospects by expending new transit.
- Increasing competitiveness by providing broader labor market and more diverse skilled labor force.
- Creating new market, trade, and business opportunities due to expansion of the shared transit service area.

Social benefits

- Improving social inclusion, integration, connection, and networking opportunities which make people happier and more productive.

[54] APTA (2020) Economic Impact of Public Transportation Investment 2020 Update, American Public Transport Association.

- Increasing mobility, accessibility, connectivity and freedom.
- Shared transport is safer and easy to use and people-friendly.
- Providing a good alternative for disadvantage groups-children, women, physically disabled, and elderly.

Health benefits

- Reduction of public health problems associated with driving private cars in congested conditions.
- Decreasing air pollution and improve health of the city dwellers.
- Increasing road safety, security, and comfort.
- Providing opportunity to cycling and waking to transit stations produce healthy society.
- Shared transportation helps to aging population, children and women, physically restricted people, and their well beings.
- Mobility freedom, easy and save to use and less stressful transport system.

Environmental benefits

- Protect city ecology and biodiversity.
- Environmentally friendly.
- Reduce negative environmental externalities from private vehicles.
- Reduce carbon footprint.
- Mitigate climate change due to emission reduction that help to prevent global warming and sea-level rise.

State-of-the-Art Passenger and Freight Transport Technologies

This section highlights how new state-of the-art digital technologies, such as Big Data, Blockchain, AI can complement ITS to reduce the cost and improve safety, efficiency, reliability, accessibility, and effectiveness of the passenger and freight transport, including during the time of unexpected health emergencies like COVID-19 pandemic that cause logistics disruptions.

In the past decade the Transport sector has seen great progress in the design and deployment of next generation transport systems and new technologies that can provide member countries with a range of benefits. There are a number of key innovations that can provide mobility that is cheaper, smarter, and cleaner, with improved ride quality. The way that these types of technologies are navigated will have a direct impact on the very functioning of cities, affecting quality of life, accessibility, commuting times, and the level of urban regeneration that can be unlocked by effective and efficient transport networks. However, it is often difficult to identify the operational considerations associated with such

new technologies which can hinder progress and slow implementation of options that could deliver substantial benefits.

Considering new technologies, there has been significant innovation in computer programming that can now offer transport departments a number of significant opportunities. For instance, the International Data Corporation anticipates that spending on artificial intelligence technologies will increase by more than 50 percent each year, reaching $57.6 billion in investments by 2021 (International Data Corporation, 2017)[55]. Although a focus on Artificial Intelligence is not new there are a number of new or underutilised applications and that are very relevant to the transport sector, such as the following as identified by research by the Sustainable Built Environment National Research Institute (Hargroves, *et al* 2020)[56]:

- *Better Traffic Management:* The 'Malaysia City Brain' created by Alibaba uses Artificial Intelligence to process data from traffic lights, CCTV cameras, shared transport, and other data streams, to reduce traffic congestion and direct emergency services. Deployed in Hangzhou China the system resulted in an average increase of 15 percent in vehicle speed.
- *Traffic Signal Optimisation*: The application of AI to optimise traffic signalling is in its early stages and delivering a system that can allow for variations in real time comes with challenges as such programs need to learn favourable traffic light cycles and timings.
- *Vehicle Prioritisation:* The 'Public Transport Information and Priority System' in Sydney can detect if a bus is more than 2 minutes behind schedule and provide priority signalling. A 2001 trial on the Sydney Airport Express Bus showed a reduction in travel time of 21 percent and reduce variability of travel time by 49 percent (BITRE, 2017)[57].
- *Route Optimisation:* Logistics company UPS has created an AI system called ORION (On-road Integrated Optimisation and Navigation) that identifies the most efficient routes for its fleet based on customer, driver and vehicle data, with routes updated in real time depending on road conditions and other factors.
- *Traffic Risk Management:* A system designed by UK company Predina uses AI and geospatial analytics to predict road transport risks. The system generates risk mitigation intervention suggestions based on historical incidents and near-misses, weather data, real-time traffic information and driver risk profiles.
- *Self-Driving Vehicles*: Developed by Cornell University, 'DeepTraffic' is a computer program using neural network technology to simulate self-driving vehicles at varying speeds in dense traffic conditions to identify efficient vehicle movement patterns to avoid collisions.

[55] Shirer, M (2017) International Data Corporation, Press Release 25 September 2017.
[56] Hargroves, K., Stantic, B. and Allen, D. (2020) Exploring the Potential for Artificial Intelligence and Blockchain to Enhance Transport – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[57] BITRE (2017) Costs and benefits of emerging road transport technologies, Report 146, Bureau of Infrastructure, Transport and Regional Economics, BITRE, Canberra ACT.

- *AI Based Ride-Sharing:* German company Door2door has created an on-demand ride-sharing service that uses AI to optimise pooling configurations and routes to simulate demand and respond in real time, while managing dispatches, bookings, route planning and drivers.
- *Fare Evasion:* Spanish company AWAAIT has created a system for detecting when someone sneaks through entry gates behind paying customers on the Barcelona Metro that uses AI to analyse camera images of travellers entering the metro entry barriers for suspicious behaviour resulting in a 70 percent decrease in fare evasion.

Another example of new technologies is the development of distributed computer ledgers, referred to as 'Blockchains', that have been initially applied to allow for digital currencies to operate without intermediaries such as banks and credit card companies. This technology stands to reduce associated transaction costs and make financial transactions more accessible to people, especially people in developing nations that do not have access to bank accounts (estimated to be half of the world's population). In April 2017 Japan eliminated consumption taxes on such 'crypto-currency' transactions and deemed them a legal tender. The World Economic Forum predicts that by 2027 some 10 percent of global GDP will be stored on Blockchains, in the order of $8 trillion. Blockchain technology has a number of tangible applications to transport such as increasing the uptake of automated vehicles, ride sharing, and pay-as-you-drive options along with improved management of congestion, freight and logistics, and administrative processes such as licensing and vehicle ownership. Currently $140 billion per day is spent in disputes of payments in the transportation industry, with average invoices taking 42 days to be paid (Commendatore, 2017)[58]. A Blockchain-based system is likely to reduce the potential for these disputes.

Despite Blockchain technology being relatively new, and early applications such as cryptocurrencies experiencing challenges, there are a growing number of applications of this form of distributed ledger technology that will be of significant benefit to the transport sector. The following list includes some of these applications that harness Blockchain-based platforms as identified by research by the Sustainable Built Environment National Research Institute (Hargroves, Stantic, and Allen, 2020)[59]:

- *Global Freight Tracking:* IBM and Danish shipping container company Maersk released a Blockchain for global freight tracking, with 94 groups initially involved, to instantly share customs releases, commercial invoices and cargo lists. The system quickly reached over 160 million shipping events, with roughly one million events per day.
- *Logistics Documentation:* Europe's largest port, the Port of Rotterdam, has set up a 'BlockLab' to use Blockchain to replace the paper-based 'Bill of Lading' system. This allows tamper-proof records to be available in real time to all necessary parties in the supply

[58] Commendatore, C. (2017) Blockchain in trucking: What about the middlemen? FleetOwner, October 20 2017.
[59] Hargroves, K., Stantic, B. and Allen, D. (2020) Exploring the Potential for Artificial Intelligence and Blockchain to Enhance Transport – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.

chain, significantly reducing transaction costs and associated time spent along the supply chain.

- *Traffic Management*: Blockchain technology can provide the ability for vehicles to make and receive payments using a cryptocurrency wallet based on real-time vehicle location. This can allow for encouraging or discouraging the use of particular routes using a financial mechanism, along with processing fines and parking fees in real time.
- *Supply Chain Transactions:* The company ShipChain has a Blockchain system that tracks products from the manufacturer to its arrival with the customer, allowing for automated delivery confirmation, which means that all the parties involved across the supply chain can automatically be paid when it has been verified that they have completed their part.
- *Digital Identification (Drivers Licences):* Secure Logic Group has developed a 'TrustGrid' platform as the digital platform for digital driver's licenses and was trialled in NSW. The second trial will see more than 140,000 drivers entitled to opt-in for a digital driver's license that can be used for police checks and to gain entry to pubs and clubs.
- *Establishing Provenance:* Walmart is testing Blockchain Technology to track the movement of food to identify which producer is responsible in the event of poor quality or spoiled food, including accessing temperature sensor data from shipping spaces. In 2018, the Commonwealth Bank of Australia supported a trial of Blockchain technology to track an international shipment of almonds.
- *Establishing Authenticity:* In the UK, the company Everledger is developing a Blockchain system that provides access to secured proof of origin and sourcing evidence for a range of high-value goods including diamonds, wine and fine art. De Beers mines, trades and markets more than 30 percent of the world's diamonds and plans to use Blockchain technology to allow permitted agents – such as those involved in mining, cutting, wholesale and retail – to enter or edit data to ensure validation of non-conflict and child labour diamonds.

It is estimated that the global market for freight forwarding will be worth 166.7€ billion in 2024, an increase of nearly 20 percent from 2020 levels. Furthermore, despite the significantly reduced passenger air travel the air freight sector is anticipated to grow by a compound growth rate of 5.4 percent annually, with shipping anticipated to grow at 5 percent per year (Pakulniewics, 2020)[60]. The freight sector now has more opportunities than ever before to harness technology to increase productivity and streamline transactions (such as Blockchain Technology) along with improve routing, and collaborating with traffic agencies to enhance traffic management for mutual benefit, using Artificial Intelligence and associated data collection technologies (Hargroves *et al*, 2019)[61]. Hence it will be important for freight

[60] Pakulniewics, P. (2020) 'Global freight forwarding market to grow by over a fifth by 2024', Trans.info, 15 December 2020.
[61] Hargroves, K., Conley, D., Emmoth, E, Warmerdam, S, Kahindi, N., Cui, F., and Spajic, L. (2019) 'Investigating the Potential for Artificial Intelligence and Blockchain Technology to Enhance the Transport', Sustainable Built Environment National Research Centre (SBEnrc), Australia.

vehicles to be effectively managed in order to deliver benefits for transport agencies, private sector logistics companies, and the road using public. Better freight management reduces congestions, leading to less pollution and a range of direct and indirect economic benefits (Hargroves *et al*, 2020)[62].

Other Cost-effective Policy Measures for Shared Transport

There are a number of other cost-effective policy measures which can assist efforts to improve the shared transport management functions.

- *Fare reductions for shared transport:* Fare reductions for shared transport can help not only to increase the number of passengers but also encourage the shift from private vehicle for the use of shared modes. In addition, if further allow people for walking and cycling from and to the transit stations which have a lot of health several studies have shown the effects of fare reduction.
- *Transport pricing reform:* Applying transport pricing reform policies such as road pricing, parking pricing, fuel pricing, congestion pricing, and removing fuel subsidies can significantly discourage of the use of private cars and encourage the sustainable mode of shared transport.
- *Mobility management:* The main objective of mobility management is to change travel behaviours of private car users and encourage them to use shared transport and active mode of transport-cycling and walking by providing specific information, travel information, better facility and services.
- *Integrating Transport System:* Integrated transport system allows combining of different modes of transport to increase efficiency, reliability, and comfort of transit by providing safe, convenient, and affordable transportation means for all sector of society. A successful integrated transport system brings a lot of benefit to shared transport especially increase in demand for shared transport and substantially decrease traffic congestion and air pollution.
- *Use of high-occupancy vehicle:* High occupancy vehicles play key role to overcome the traffic congestion, which reduces the amount of available road space for single-occupancy vehicles that helps to improve traffic congestion and pollution significantly.
- *Transit-priority traffic control system:* The transit-priority traffic control system provide priority to shared transit over the private car. A successful transit priority traffic system will enhance shared transit performance by offering additional time to shared transportation at signalized intersections. It helps to improve efficiency, cost effectiveness, and lowering transit fuel consumption, reduce private vehicle travel and traffic congestion.

[62] Hargroves, K., Shirley, D., Seppelt, T., Callary, N., Tze Wei Yeo, J. and Loxton, R. (2020) 'Overview of Options to Collect Vehicle Generated Data to inform Traffic Management Systems', Sustainable Built Environment National Research Centre (SBEnrc), Australia.

- *Ridesharing programs:* Ride sharing is the practice of sharing transportation, especially by commuters, typically in the form of carpooling and vanpooling, motorbike-sharing and bicycle-sharing. Shared ride programs greatly help people and solve the traffic congestion level, mainly in pick hours.
- *Vehicle Behaviour:* How vehicles interact with other vehicles, the frequency and location of stops, time spent at traffic signals etc. can be used to build a baseline of expected behaviour that can be used to identify abnormalities on the network and create vehicle risk profiles.

6. Case Studies

Examples of Cost-Effective Passenger and Freight Transport

The following section provides a snapshot of specific applications of new technologies to improve transport outcomes with a focus on implementation relevant to EST Member Countries. The following list demonstrates the potential for Artificial Intelligence systems to be applied to deliver significant improvements in traffic management:[63]

- *Kuala Lumpur, Malaysia*: The 'Malaysia City Brain' created by Alibaba uses Artificial Intelligence to process data from 300 traffic lights, 500 CCTV cameras, shared transport data systems and other data streams to reduce traffic congestion (Bhunia, 2018)[64]. The system uses the data to predict traffic conditions and can make recommendations for emergency services routing (MDEC, 2018)[65]. The 'City Brain' AI technology was deployed in Hangzhou China in September 2018 and has resulted in '*an average traffic speed increase of 15 percent and reporting traffic violations with 92 percent accuracy*' (E&T, 2018)[66].
- *Delhi, India:* The Delhi Traffic Police have developed a system based on radar-based monitoring to analyse traffic patterns, overall vehicle volumes, and the number of vehicles in order to improve traffic management on motorways. The system also contains features like high-resolution CCTV cameras to capture commuters and motorists breaking laws and automated number plate recognition to directly send the fine. Approximately, 7,500 cameras with multidirectional infrared and colourless laser sensors will count the volume on arterial roads based on image pattern analysis. The aim is to all but eliminate the manual interface.
- *Bengaluru, India*: The city of Bengaluru regularly faces long traffic jams with an average speed during peak hours in some areas of just 4 km/h. Siemens Mobility has built a prototype monitoring system for the city that uses AI and traffic cameras to automatically detect vehicles and estimate the density of traffic on the road to alter traffic light patterns based on real-time road congestions.
- Developed by Cornell University, 'DeepTraffic' is a computer program developed using neural network technology to simulate driving '*a vehicle (or multiple vehicles) as fast as possible through dense highway traffic*'. The focus of the software is to learn efficient movement patterns in traffic which prevents a vehicle from colliding by either preventing an action which would lead to a collision or altering the speed of the vehicle (Friedman *et al*, 2018)[67].

[63] Hargroves, K., (2021) Introducing the 'FreightSync Roadmap': A Pathway to Linking Freight Vehicles and Transport Systems – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[64] Bhunia, P 2018, Malaysia City Brain initiative to use real-time, anonymised traffic data from Grab, *Open Gov Asia*, 20 April 2018.
[65] MDEC 2018, 'City Brain FAQ', Malaysia Digital Economy Corporation, 2017.
[66] E&T 2018, 'Alibaba's AI traffic management system to be rolled out in Malaysia', *Engineering and Technology*, 30 January 2018.
[67] Fridman, L., Jenik, B., Terwilliger, J. 2018, 'DeepTraffic: Driving Fast through Dense Traffic with Deep Reinforcement Learning', Cornell University, 2018.

Although Blockchain Technology is in the early stages of deployment it has already been shown to deliver a range of benefits to the transport sector, such as taking advantage of automated data collection from a range of devices connected to the internet (referred to as 'Internet of Things' or IoT devices). An IoT device, for instance, may be used to reduce food spoilage by monitoring temperature and humidity levels in containers and transmitting the data to the ledger to form an accurate and tamper-proof log to be used to trigger alerts if conditions are exceeded. One key strategic consideration for the logistics and the supply chain sector will be how to leverage existing IoT technology and who in the network pays for the necessary hardware upgrades or sensors.

There are several current examples of IoT and Blockchain projects (Hargroves, 2021)[68]:

- AT&T is developing a system for improving fleet and cargo management, goods tracking and regulating driver compliance.
- The World Wildlife Fund and ConsenSys have piloted a project to trace tuna throughout the supply chain using Radio-Frequency Identification (RFID) and QR codes.
- Bosch has developed an open-source system to connect over 10 million IoT devices by various manufacturers, and working with German energy supplier EnBW, have announced a prototype system to manage devices that charge electric vehicles allowing for reserving and paying for e-charging services.
- Bosch and Siemens have a system for smart parking where vehicles communicate with parking facilities and negotiate parking terms.

One of the most prominent applications of Blockchain Technology in supply chains is by IBM and Maersk called 'TradeLens' that has created efficiencies of up to 40 per cent in transit time for US shipments (Global Trade Review, 2019)[69]. TradeLens tracks shipments in real-time on a secure, permissioned ledger and comprises logistics companies, inland and intermodal providers, ports and terminals, ocean carriers and some customs and other governmental authorities. Over 1.5 million shipping events are recorded per day, including information on contractual shipping data, cargo movements, IoT sensor information, and identification details about shippers, carriers and other participants. TradeLens enables permissioned sharing of data between authorised parties, and is working on developing new standardised structured document types for better document functionality and analysis (including integration into existing systems). The Blockchain Technology underlying TradeLens also ensures the immutability and integrity of documentation by checking the consistency of documentation against their previous record.

[68] Hargroves, K., (2021) Introducing the 'FreightSync Roadmap': A Pathway to Linking Freight Vehicles and Transport Systems – Final Industry Report', Sustainable Built Environment National Research Centre (SBEnrc), Australia.
[69] Wass, S. (2019) TradeLens Blockchain platform for global trade expands to Russia, Global Trade Review, Fintech, 11 June 2019.

As such there are a range of potential benefits related to the delivery of effective shared transport options, such as (Newman and Hargroves *et al*, 2019)[70]:

- *Overcoming Congestion Issues*: Traffic congestion is an ongoing issue facing transport planners and network managers with levels of congestion growing to unworkable levels in many of the world's cities, calling for alternatives to simply allowing for more automobiles (Litman, 2011)[71]. In the US, the cost of congestion in 2012 was estimated to be in the order of $121 billion, the equivalent of $818 per commuter per year, and some additional 25 million tonnes of CO_2 per year (Bloomberg, 2013)[72]. Given the issues related to congestion such as wasted time, air pollution, and greenhouse gas emissions, it makes sense to take advantage of higher capacity options wherever feasible. For instance, the new Hong Kong rail line provides a capacity 86,000 people per hour with services of 12 rail cars running every 2.5 minutes (MTR, 2018)[73]. Combined with emerging technologies these options become even more feasible with reduced operating costs by adopting driverless technologies, predictive maintenance, trackless carriages etc (Hargroves, et al, 2016).[74]

- *City Shaping to Unlock Development Opportunities*: The retrofitting of cities with effective corridor transit is a keyway to cope with growth in the future and to unlock economic and social development opportunities (Newman and Kenworthy, 2015)[75]. A key element of this is the aggregation of trips to create greater land development opportunities. Glazebrook and Newman (2018)[76] also suggest that the corridor transit model can be augmented by a number of advances in transport vehicle technology.

- *Slowing the Urban Sprawl:* Effective shared transport can slow urban sprawl. For instance, in the Thimphu, the capital city of Bhutan, has a population of 100,000 with aspirations to grow to 400,000 in a valley with limited development space available. Thimphu has seen the rapid rise in automobile use and the subsequent consumption of petroleum-based fuels which is a national concern as both are being 100 percent imported. Given the steep topography of the valley the city is located in it will be crucial for Thimphu to increase urban density in order to accommodate the anticipated population increase. When comparing an urban fringe approach with a shared transport focused approach a study commissioned by the UNCRD found that the shared transport could half the amount of land needed (Hargroves and Gaudremeau, 2017)[77].

[70] Newman, P., Hargroves, K., Davies-Slate, S., Conley, D., Verschuer, M., Mouritz, M. and Yangka, D. (2019) The Trackless Tram: Is It the Transit and City Shaping Catalyst We Have Been Waiting for?. Journal of Transportation Technologies, 9, 31-55.
[71] Litman, T. (2011) Smart Congestion Relief: Comprehensive Analysis of Traffic Congestion Costs and Congestion Reduction Benefits, Victoria Transport Policy Institute.
[72] Mullich, J. (2013) 'Drivers avoid traffic jams with Big Data and Analytics', *Bloomberg L.P.*, New York.
[73] MTR (2018) Rail Operations: A Service of World Class Quality. MTR.
[74] Hargroves, K., Stantic, B. and Conley, D. (2016) Big Data, Technology and Transport - The State of Play: A Sustainable Built Environment National Research Centre (SBEnrc) Industry Report, Curtin University and Griffith University, Australia.
[75] Newman, P. and Kenworthy, J. (2015) The End of Automobile Dependence: How Cities are Moving Beyond Car-based Planning, Island Press, Washington DC.
[76] Glazebrook, G. and Newman, P. (2018) The Future City, Urban Planning, Volume 3, Issue 2, Pages 1–20.
[77] Hargroves, K. and Gaudremeau, J. (2017) Pre-Feasibility Study to Investigate Potential Mass Transit Options for Bhutan, A Report to the United Nations Centre for Regional Development (UNCRD), Tokyo, Japan.

- *Reducing the Need for Car Parking*: The International Energy Agency (IEA, 2013)[78] reported in 2013 that by 2050, India was on track to require between 10,000-20,000 square kilometres of surface parking area, equating to 35 times the size of Mumbai. According to Newman and Kenworthy (1999)[79] automobile dependant cities around the world can typically have between 5 and 8 car parking spaces for every car in the city. In Thimphu rather than a 4 inner-city and 10 outer suburb parking allocations as is the case of Perth, it is assumed that there will be allocation for 2 inner city and 4 outer suburb car parks per person, with a development-oriented transit approach saving as much as 7.7km^2 of parking space. (Hargroves and Gaudremeau, 2017)[80].

- *Job creation from greater urban density*: Transit stations integrated into land development create the conditions of walkability in densely occupied areas surrounding stations that enable the face-to-face creative discussions for the jobs of the new economy to flourish (Newman and Kenworthy, 2015)[81]. As densities continue to increase, automobile dependence cannot facilitate the movement of large amounts of people, and therefore shared transit is required. Workers need to be able to move efficiently between homes and workplaces, and reduced travel times and costs enable greater agglomeration benefits to be realised (Graham, 2007)[82].

- *Health Related Benefits*: Urban transport from automobiles particularly diesel and two-stroke engines is one of the most significant contributors to air pollution in urban areas in Asian countries (Stockholm Environment Institute, 2008)[83]. The World Health Organisation (WHO) released data in 2016 stating that 4 in 5 people living in monitored urban areas are exposed to air quality pollution that exceeds recommended levels, and further that in low-and-middle income cities above 100,000 inhabitants, 98 percent do not meet the air quality guidelines (World Health Organisation, 2016)[84]. In Thimphu for instance, the level of particulate matter (PM10) was just over double the WHO Guideline Level for the annual average (IISD, 2013).[85]

- *Safety Benefits*: In addition to air pollution benefits a shift to corridor transit will reduce vehicle collisions and road fatalities. According to the WHO more than 1.3 million people die annually on the road in the world and another 20-50 million are injured. Furthermore, a study by the WHO and the Asian Development Bank found that Bhutan is second only to Nepal in the number of road deaths per 10,000 vehicles in South Asia (ADB, 2011)[86].

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7. Conclusions and the Way Forward

To tackle and prevent negative impacts associated with the rapid urbanization and motorization, and to mitigate the climate change impacts, Asian countries need not only build the resilient and robust transport infrastructures, but it is also important to introduce innovative policies, planning and institutional frameworks. Advanced transport policies, inclusive and integrated planning, better maintained, managed, and operated transport infrastructure and services are essential enabler for economic sustainability. It is equally important to build safe and low-carbon shared transport system, green and efficient supply chains and logistics, improve vehicles design and fuel efficiency, ensure vehicle inspection and maintenance, and implement a range of eco-driving options to address the transport related externalities. Improved, well-managed and low-carbon shared transport help to reduce the transport externalities through reducing, air and noise pollution, improving road safety and reduce the traffic congestion. It further helps to improve resilience of cities and communities. Therefore, it is essential to invest in shared transport infrastructures and services to capture these socio-economic and environmental co-benefits.

High-quality shared transport not only support to economic prosperity but also help to make cities and communities more resilient, liveable, and sustainable. However, the shared transport is not well-developed and managed in most of the Asian developing countries. Many cities in developing countries lack necessary shared transport infrastructures and services. Therefore, these cities are unable to meet the travel needs of their residence, particularly for disadvantage group such as poor, women, children physically disabled, elderly and socially disadvantaged group. Invest in shared transport plays a crucial role in improving the lives and livelihood of the people and provides better mobility and connectivity options for all sectors of society so that *no one left behind*.

Better shared transport connectivity shapes land use and urban development pattern along and around the transit corridor that support to increase land value, offers the new business and trading opportunities, generate new jobs and marketplace. Shared transport further support to establish factories and industries that help for manufacturing local goods and products, generate wealth and spurs economic growth. Consequently, local economy flourishes, and the government get sufficient tax revenue, which can be utilized for improving the quality-of life of the people. Safe, efficient, and sustainable shared transport and freight and logistic are vital for economic activity in modern era. Better transport infrastructures and services not only support fast and efficient movement of people and goods but also help to improve the economic sustainability of countries.

As Asian EST member countries expected to adopt a New Declaration-Aichi 2030 Declaration on Environmentally Sustainable Transport - Making Transport in Asia Sustainable (2021-2030) Sustainable Transport Goals for achieving universally accessible, safe, affordable, efficient, resilient, clean and low-carbon passenger and freight transport in Asia, and EST member countries are ready to embark to new sustainable path for decades following the new declaration. In this context, investment on improve and sustainable shared

transportation and green freight can significantly help to achieve all 6 goals- *Environment sustainability, Road safety*, *Economic sustainability*, *Rural-urban-and national access and connectivity* of declaration. Proper introduction of innovative policies, integrated transport and urban planning, investment in better quality, resilient and sustainable transport infrastructures, strong enforcement of public-private-partnership with improving institutional and human capacity by using innovative state-of-the-art technologies and good governance, countries can well achieve all goals of the proposed declaration.

Of course, it is equally important to build strong collaboration among the EST member countries to share the knowledge, experiences, technical know-how, and best practices and examples. Similarly, bilateral, and multilateral development banks, UN agencies, international organizations, NGOs and research institution should align their policies, programmes, finance and capacity building in support of the goals of the Aichi 2030 Declaration.