Training Materials

For Implementing Smart Cities in Asia and the Pacific for Inclusive, Resilient, and Sustainable Societies

Smart Mobility and Transport

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Training Modules on
Smart Mobility for Creating Inclusive, Resilient, and Sustainable cities and communities in Asia and the Pacific

Abbreviations

ADB - Asian Development Bank

AI - Artificial Intelligence

ASEAN - Association of Southeast Asian Nations

BRT - Bus Rapid Transit

BRT - Bus Rapid Transit

CCTV - Closed Circuit Television

EU - European Union

EV - Electric Vehicle

GDP -Gross Domestic Product

GHG - Greenhouse Gas Emissions

HOV - High Occupancy Vehicle

ICT - Information and Communication Technologies

IoT - Internet of Things

ITS - Intelligent Transportation System

LRT - Light Rail Transit

LVT - Land Value Tax

MNT - Non-Motorized Transport

MoD - Mobility on Demand

MRT - Mass Rapid Transit

OECD - Organisation for Economic Co-operation and Development

SBEnrc - Sustainable Built Environment National Research Centre

SDG - Sustainable Development Goals.

SLOCAT - Sustainable Low Carbon Transport

TAC - Transit Activated Corridor

TDM - Transportation Demand Management)

TIF - Tax Increment Financing

TOD - Transit Oriented Development

TOD - transit Oriented Development

UN - United Nations

UNCRD - United Nations Centre for Regional Development

UNESCAP - United Nations Economic and Social Commission for Asia and the Pacific

UNESCO - United Nations Educational, Scientific and Cultural Organization

USC - United Smart Cities

V2X - Vehicle to Everything

WEF - World Economic Forum

WHO - World Health Organisation

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Executive Summary

Since the mid-1900s, most cities around the world have grown with the private automobile as the central mode of transport and transportation planning. This has led to a number of urban challenges, particularly in regard to global climate change as a result of greenhouse gas emissions, of which transport is the fourth largest contributor. Automobile dependence also has implications for the health of populations, with 80 percent of air pollution in Asia caused by the transport sector. Transport pollution also results in severe health impacts with the WHO estimating that 92 percent of the world's population living above the World Health Organisation's air pollution guideline limit. Cities and nations are also suffering detrimental economic inefficiencies due to congestion and long travel times. These factors call for a reconsideration of transport systems and a shift towards integrating land development and electrified transit services to create 'Station Precincts' along corridors. The benefits of this approach include improved transport mode integration; enhanced walking and cycling; allowing greater urban density; potential for mixed-use developments; and improved public space. The design benefits of Station Precincts on urban form and function include congestion reduction, reduced cost of local infrastructure, space savings from reduced urban sprawl, and space savings from reduced car parking requirements.

Such an approach would see a focus shift from 'Transit Oriented Development' to 'Transit Activated Development' and is best undertaken in close collaboration with the private sector from the start of the process to design transit services. The co-benefits of sustainable urban development including environmentally sustainable transport include Healthier city (such as reduced negative health outcomes of air pollution, increased physical activity (Walking and cycling), and reduced road-based accidents); Greater climate resilience (including reducing the urban heat island effect); Increased economic productivity and innovation (including densification and agglomeration economies); and reduced social inequality (including greater accessibility).

It is now clear that in order for cities to achieve strong economic, social and environmental outcomes in the coming decades there needs to be a focus on harnessing data and an array of new technologies to integrate and enhance urban systems - to create what is known as a '*Smart Sustainable City*' (SSC). According to the United Nations Economic Commission for Europe, a 'Smart Sustainable City' is "*an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects*".[1] This is particularly relevant to cities in the Asian region as they often have challenging development needs and high levels of technological literacy and ability.

There are various components of a 'Smart Sustainable City', including, housing and development, civil infrastructure like sewerage, telecom and water systems, energy networks, and transport systems. Typically, each of these components have been managed as separate systems although they have a relationship rarely integrated effectively for greater benefit. There is now one component that all others will rely on, that of transport. Transport provides access to housing and development, provides space for sewerage, telecom, and water infrastructure, and now is becoming integrated into the energy system with the rise of electric vehicles. Hence 'Smart Sustainable Mobility' will be at the core of a SSC, and not only offers such benefits as reduced travel time, costs, and emissions, but also creates new opportunities for a range of industry and economic development opportunities.

[1] UNECE (n.d.) Sustainable Smart Cities, United Nations Economic Commission for Europe, UNECE.

Smart Sustainable Mobility, or "Smart Mobility", initiatives can provide numerous benefits both directly and indirectly. Direct benefits from smart mobility include reduced congestion, increased accessibility, reduced pollution, reduced noise, and a reduction in the traffic associated injuries and deaths. Such benefits can be considered small compared to the in-direct benefits possible when smart transport systems are integrated into urban systems. For instance, when smart mobility is integrated with housing and development to create 'transit activated corridors' this has been shown to improve development potential and spur on urban revitalisation efforts. Such integration has been proved over many decades in Asia and the next new frontier will be the integration with energy systems.

The integration of Smart Mobility with urban systems will require innovation in two key areas, namely Technology and Governance. Firstly, innovative technologies (such as innovative transport modes such as Trackless Trams and micro-mobility), and advances in data management and analytics (such as machine learning, predictive management, and distributed ledgers) will be needed, with Asian cities uniquely placed to leapfrog to higher levels of innovation. Secondly new governance models and business cases will need to be developed to enable policy and industry to build structures and strategies to harness the value that can be created by a focus on smart and sustainable mobility in a city. In particular the shift to electric vehicles and increase in use of micro-mobility options such as e-scooters and bicycles, will bring numerous new business models, beginning with various sharing models such as ridesharing and car-sharing, and now including new vehicle-as-energy-storage options across the electricity grid. Improved communication and availability of information for users and service providers will also enable improved services such as seamless multi-modal transit options that can significantly reduce the dependence on automobiles.

In short, a Smart Mobility system is a human-focused communication system that harnesses innovative technologies to rapidly adapt to meet user demands and create synergies and opportunities across the entire urban system. Hence it is clear that smart mobility has multiple benefits, although there are a number of challenges to implementation that need to be addressed, such as: a lack of integration of various systems across a city, the need for new infrastructure to be constructed, the need to maintain data security, the selection of appropriate innovative technologies, and the need to ensure that stakeholders are engaged and in active support. Hence it is important that Transport Agencies around the Asian Region are provide with the most up to date knowledge and advice in order to inform initiatives.

Existing resources include the EU '*Mobility Strategy*' that includes a goal to create a multi-modal Trans-European Smart Transport Network by 2050. The EU strategy includes several action points that are in line with the UN 'United Smart Cities' (USC) program. The EU is also collaborating with ASEAN to explore challenges and opportunities related to ITS, and the UN has commissioned a program on '*Mobilizing Sustainable Transport for Development*' to consider how sustainable development goals can be addressed by sustainable transport. Asian Development Bank has shown strong interest in supporting SSC's through the ADB Smart Cities Fund as part of the Strategy 2030 and ASEAN's Sustainable Urbanization Strategy. Building on from these valuable capacity building resources this dedicated training package has been developed, with a focus on Asian cities, using an integrated approach to delivering strong transport outcomes that also enhance energy, development, and economic growth outcomes.

Introduction

Educational Aim

The aim of this module is to provide an overview of key considerations that stand to effect transport planning and operation in Asian cities in the coming decade. The module is based on the assumption that many of the world's cities are now automobile dependent and that this is causing significant economic, social and environmental issues. In order to respond these issues, approaches are needed to integrate land-use and transport planning to deliver effective shared transit corridors that harness smart technologies.

Key Learning Points

1. Since the mid-1900s many cities around the world have grown assuming the private automobile that use fossil fuels will be the main mode of transportation, creating automobile dependence. This has led to a number of urban challenges such as congestion, air pollution, noise, and road injuries and fatalities, along with transport being the fourth largest contributor to global greenhouse gas emissions.
2. In Asian countries, approximately 80 percent of air pollution is attributable to pollution caused by the transport sector. Air pollution such as nitrous oxide and Sulphur dioxide along with particulate matter causes numerous health issues including pulmonary disease, ischemic heart disease and strokes. The World Health Organization estimates that in 2012, 3 million deaths were attributable to ambient outdoor air pollution, and that 87 percent of these deaths occurred in low and middle-income countries.
3. Asia’s transport sector will be facing several critical challenges in future due to the existing and emerging challenges like climate change, increasing frequency and magnitude of natural disasters and health emergencies like COVID-19 pandemic. This calls for consideration of resiliency to be an integral part of approaches to transport in Asian countries and cities.
4. Rapidly increasing urban populations and consequent pressures on infrastructure and the environment are driving many nations, particularly those in the Asia region, to reconsider the modes of implementation of transport infrastructure. Decreasing dependency on fossil fuels particularly in the transport sector will result in a number of positive outcomes such as the reduction in levels of ambient air pollution and associated co-benefits.
5. Improving access to transport, particularly low-carbon transport, to those who are most vulnerable such as women, the elderly, and the poor, will improve access to basic infrastructure including health care, education, and employment opportunities – all pivotal to reducing poverty, improving well-being, and growing prosperity.
6. Although transport does not have a dedicated SDG, improved shared transit and overall mobility have a key role in enabling a number of SDGs and related targets, contributing directly to targets around road safety, energy efficiency, sustainable infrastructure, urban access, and fossil fuel subsidies. Transport will also contribute strongly to achieving the Paris Agreement goal of limiting the global temperature increase to below 2 degrees Celsius.
7. Fostering sustainable urban development requires integrating the land-use and transport planning processes that enable residents to decrease their dependence on automobiles through access to efficient and effective shared transport options. Creating smart, resilient, and liveable cities and

communities will help to address a range of economic, social, and environmental issues. This calls for cities around the world to focus on ways to create smart cities that leapfrog old, outdated methods and take advantage of appropriate Technologies.

8. With the rapid growth in digitization of cities around the world there is a growing call for creating 'Smart Cities', however it is important to understand that this term is often misinterpreted. When considering the transport system, in the case that a city persists with an assumption of automobile dependence, no matter how much technology it employs it will ultimately fail to achieve the broader goals of liveability, sustainability and resilience, despite using 'smart technologies', as the innovative technologies will just build on the fundamental structure of a city.
9. The combination of both smart and sustainable can create a set of systems and infrastructure that can not only accommodate rapid growth and high densities but continue to offer accessibility, safety and quality of life making cities 'more liveable, safe, resilient and sustainable'.
10. Alternatively, cities that shift from a focus on providing infrastructure predominantly for private vehicles, to providing infrastructure for effective city-wide mobility are far more likely to cope with rapid urban densification by harnessing road and land space to provide an interconnected system of mobility and development – creating 'Smart Transit Cities'.
11. The question becomes how to enable cities to find a meaningful scale of shared transit system that can compete with individualized solutions of cars and motorbikes, especially for commuters during peak times. This calls for a return to a focus on dedicated corridors with a fast, high capacity, quality transit service as has been used in the past in many of the world's cities.
12. The main focus of the Transit Activated Corridor approach is to prioritize high quality, efficient corridor transit with last mile connectivity running between a series of dense station precincts. This then allows for fast, high-quality mobility along the corridor that can harness emerging technologies to improve efficiency and reduce costs that are built in as part of the urban regeneration process.
13. Although the automobile has provided access and mobility for decades, like the horse and cart before it, it is no longer suitable as the primary form of transport in rapidly growing cities around the world – the negatives simply outweigh the benefits.

Background Information

Asia's trend of urbanization and motorization

Since the mid-1900s, the majority of cities around the world have grown assuming the private automobile will be the main mode of transportation, creating automobile dependence. This has led to a number of urban challenges such as congestion, air pollution, noise, and road injuries and fatalities, along with transport being the fourth largest contributor to global greenhouse gas emissions. Automobile dependence has serious implications for the health of populations, with 80 percent of air pollution in Asia caused by the transport sector (ADB, 2018),[2] and 92 percent of the world's population living above the World Health Organisation's air pollution guideline limit (WHO, 2016).[3] Cities and nations are also suffering detrimental economic inefficiencies due to congestion and long travel times. Asian cities are amongst the fasted growing cities in the world with large populations migrating to cities. The United Nations estimates that over two-thirds of the world's population will live in cities by 2050, with some recent studies emerging estimating from the European Commission suggesting that this could be a sizable under-estimation (WEF, 2018).[4] As population increases, and more people move to urban areas, another 2.5 billion additional people will be living in cities by 2050, with 90 percent of these in Asia and Africa (UN, 2018).[5] Asia is adding 120,000 people to its urban population every day (ADB, 2018).[6]

Figure A: Bangkok City, Thailand (*Source*: Christophe Archambault)

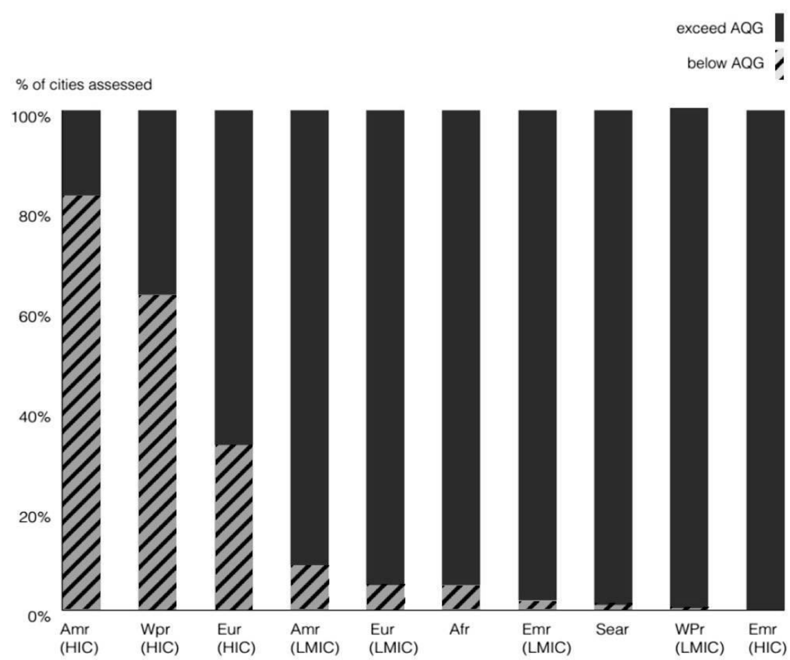
- The trend towards fossil fuel-based motorization in Asia has increased substantially over the last two decades, with vehicle numbers doubling every 5-7 years. It is estimated that in 2006, Asia produced approximately 19 percent of global transport emissions and based on current trends, by 2030 Asia will contribute 31 percent. This is driven by increasing wealth, urbanisation and population growth, however excessive automobile-induced congestion and emissions come at a cost (Roy and Braathen, 2017).[7] It is estimated that 2-5 percent of GDP in Asian economies is lost due to time spent in

[2] ADB (2018) Urban Transport, Asian Development Bank.
[3] WHO (2016) Ambient air pollution: A global assessment of exposure and burden of disease, World Health Organisation.
[4] WEF (2018) Everything you've heard about urbanization might be wrong. Here's why. Media article. World Economic Forum.
[5] UN (2018) World Urbanization Prospects: The 2018 Revision. Key Facts. United Nations.
[6] ADB (2018) Urban Transport, Asian Development Bank.
[7] Roy, R. and Braathen, N. (2017) The Rising Cost of Ambient Air Pollution thus far in the 21st Century, OECD Working Paper, No, 124.

congested traffic conditions. In big cities these impacts can be more severe. In Beijing, it is estimated that the total social cost of automobile dependence is between 7.5-10 percent of GDP, when congestion and air pollution is considered. Since 2013, Beijing has had to restrict the number of vehicles in the city to 5 million when air pollution levels reach a certain level - highlighting the level of health concern. (ADB, 2018)

In Asian countries, approximately 80 percent of air pollution is attributable to pollution caused by the transport sector (ADB, 2018). Air pollution such as nitrous oxide and sulphur dioxide along with particulate matter cause numerous health issues including pulmonary disease, ischemic heart disease and strokes (WHO, 2016).[8] The World Health Organisation estimates that in 2012, 3 million deaths were attributable to ambient outdoor air pollution, and that 87 percent of these deaths occurred in low and middle-income countries. It is further estimated that air pollution is the cause of around one quarter of deaths resulting from heart disease, stroke, lung cancer and almost half the deaths of chronic obstructive pulmonary disease (WHO, 2016). Additionally, increases in motorisation have often not been met with the ability to provide appropriate infrastructure, leading to greater incidences of road fatalities and injuries particularly in developing nations. According to the World Health Organisation 90 percent of global road fatalities annually occur in low and middle-income countries.

A study by the World Health Organisation in 2016 found that many cities assessed exceeded the recommended levels, as shown in Figure B, with the majority of these low-to middle income countries in South-East Asia, Western Pacific, Africa, Europe, and the Americas. The study suggests that an estimated 92 percent of the world's population are currently exposed to air pollution greater than the WHO air quality guidelines. (WHO, 2016)



Amr: Americas; Wpr: Western Pacific; Eur: Europe; Amr: Americas; Sear: South-East Asia; Afr: Africa; Emr: Eastern Mediterranean. LMIC: Low-and middle-income countries; HIC: High-income countries. AQG: WHO Air Quality Guidelines.

Note: AQG = Annual Mean PM_{10}: 20µg/m^3 and Annual Mean $PM_{2.5}$: 10µg/m^3

Figure B: Annual mean particulate matter concentration of selected measured towns and cities, compared to WHO Air Quality Guidelines. (*Source*: WHO, 2016)

[8] WHO (2016) Ambient air pollution: A global assessment of exposure and burden of disease, World Health Organisation.

Global Sustainability Goals and Agreements

Sustainable Development Goals

In 2015, member countries of the United Nations adopted the global agenda of the Sustainable Development Goals (SDGs). The SDG is the collection of 17 goals and 169 targets covering the spectrum of human development including — economic, social, and environmental aspects. The SDGs were designed to cover a wide range of sustainable development aspects from poverty eradication, food availability, education, health, and gender equality, and decent work environment to better institutional, business, and development of livable and sustainable cities and communities, as shown in Figure C. Mobility and shared transit are directly and indirectly linked to many of the SDGs and related targets.

Figure C: Sustainable Development Goals (SDGs) (*Source*: United Nations)

Although transport does not have a dedicated SDG, shared transit and improved mobility have a significant role in enabling a number of SDGs and related targets (Vandycke and Fabian, 2020).[9] Without a reliable transport system, it is almost impossible to realize most of the SDGs. For instance, SDG-1 based on poverty eradication is very much related to economic growth, industrialization, and business. All these sectors directly or indirectly depend on better transport infrastructures and services.

Of the 169 SDG targets, 15 are indirectly related to the transport sector, as can be seen in Figure D. For instance, mobility and better transport can contribute directly to targets on road safety (Target 3.6); energy efficiency (Target 7.3); sustainable infrastructure (Target 9.1), urban access (Target 11.2), and fossil fuel subsidies (Target 12.c) Hence, sustainable transport is not needed solely for its own sake, but it is essential to facilitate the achievement of a wide variety of SDGs. The Target 3.6 calls to halve the number of global deaths and injuries from road traffic accidents, and Target 11.2 aims to, by 2030, provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable groups - women, children, elderly, and the person with disabilities.

The diagram below shows the contribution transport can make to the SDGs. Countries with the highest scores on the SDGs have robust and sustainable transport systems in place, whereas countries with inadequate transport infrastructure and poor quality of transport services show less achievement on SDGs.

[9] Vandycke, N. and Fabian, M. (2020) 'Sustainable Development Goals: What if transport was the missing piece?' World Bank, March 17, 2020.

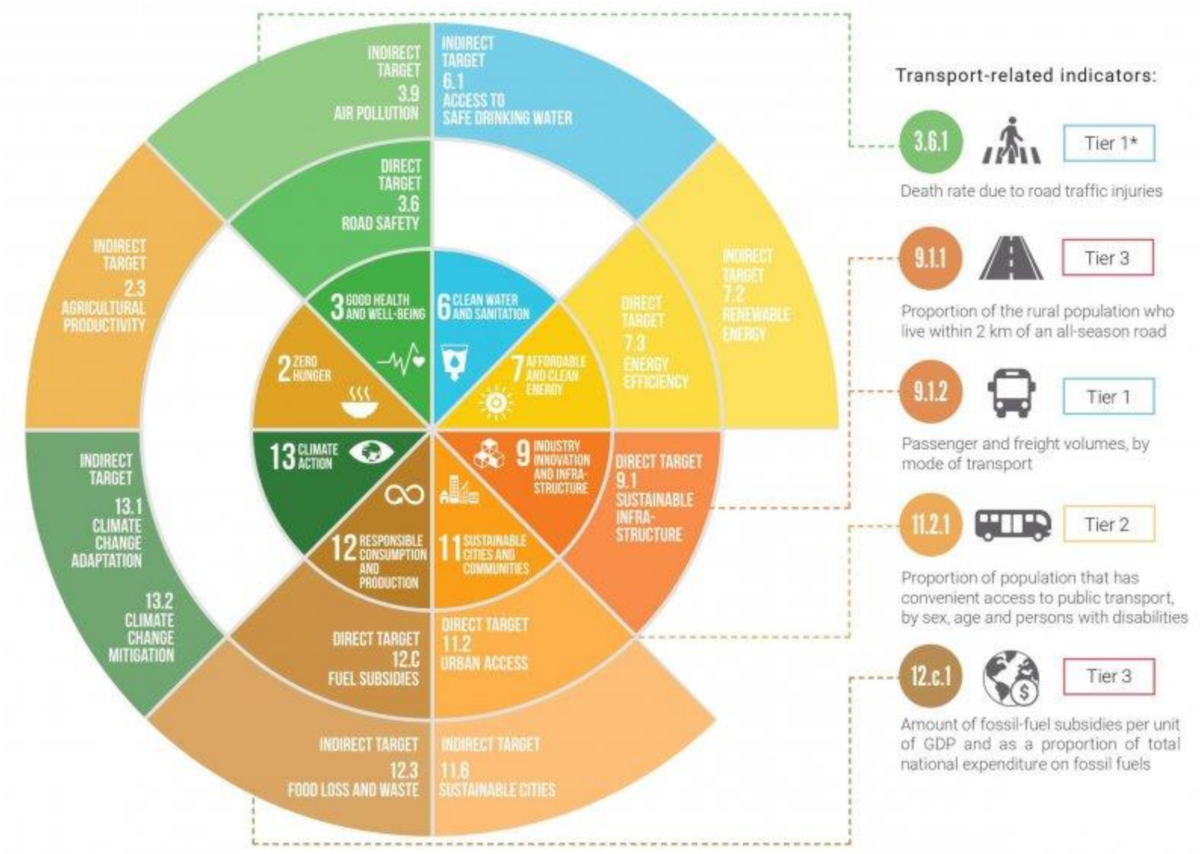


Figure D: Sustainable Transport contribution to achieving the Sustainable Development Goals (SDGs) (*Source:* SLOCAT)

The Paris Agreement

The importance of mobility and transport for climate action is well recognized under the United Nations Framework Convention on Climate Change (UNFCCC). On 12 December 2015, the 196 member countries of the United Nations adopted a legally binding international treaty on climate change widely known as the 'Paris Agreement' which entered into force on 4 November 2016. The main aim of the Paris Agreement is to limit the level of average global warming to below 2 degrees Celsius, compared to pre-industrial levels. Given the global transport system accounts for about 23 percent of energy-related greenhouse gas emissions and the air pollution and GHG emissions are main cause of global climate change and sea level rise, it is essential to focus on smart mobility to underpin efforts to achieve the goals of the Paris Agreement.

The UNFCCC Conference of the Parties held in Paris, agree on climate commitments as Intended Nationally Determined Contributions (INDCs) for CO_2 reductions. As transport is one of the major sectors for CO_2 and GHG emissions, it is important for the transport community to develop transport systems, which are secure, green, and energy-efficient that reduce health impacts from air pollution and environmental degradation from GHG emissions. In this regard, a wide range of policies, planning, and investments is required to reduce transport emissions. This calls for continued decarbonizing of the transport sector through vehicle design upgrades, fuel quality improvement, better and more effective climate mitigation measures, and improving the quality of transport infrastructures and services. Moreover, a keyway to significantly reducing global GHG emissions is the use of renewable and green sources of energy, electrified transport systems and promoting non-motorized transport options, and improving fuel quality.

Aichi 2030 Declaration

The Aichi 2030 Declaration (2021-2030) is a milestone in progressing transport related aspects of the SDGs and the Paris Agreement within the EST member countries. As a result of several years of preparation and intensive consultation with member countries and international partners the Aichi 2030 Declaration provides a valuable milestone that will be an important blueprint to support countries across Asia, and the world, to achieve environmentally sustainable transport in Asia. The Aichi 2030 Declaration paves the way for ongoing collaborative processes towards implementation in order to support the transformative changes needed. The Declaration provides a valuable resource to inform the development of policy frameworks to underpin the transition to Net Zero cities, supported by communities of interest on particular topics.

The Aichi 2030 Declaration provides a comprehensive framework to ensure that important elements of an environmentally sustainable transport system can be considered, informed and implemented so that all members of society can benefit. The Declaration seeks to enhance collaboration between key stakeholders with the annual Regional EST Forum providing a platform for sharing and learning the best practices.

Smart Mobility Planning and Approaches

Asia's transport sector will be facing several critical challenges in future due to the existing and emerging challenges like climate change, increasing frequency and magnitude of natural disasters and health emergencies like COVID-19 pandemic. This calls for consideration of resiliency to be an integral part of approaches to transport in Asian countries and cities. Transformative policies, institutions, programmes, and investment decisions in transport sector are necessary to put the countries and cities on the path of resilience. Public-private partnerships can play a very vital role in this direction. However, the transport sector cannot work on its own. Transport agencies should diligently work with the city planning agencies (Ewing and Bartholomew, 2013).[10] A collective effort is needed to decarbonise the sector and adopt beneficial modern technologies. Transit activated corridors brings together transport, development, and energy by acting as an aggregator of activity (Newman, *et al* 2021).[11]

Figure E: CicloRuta Cycling System in Bogotá (*Source*: CicloRuta)

[10] Ewing, R. and Bartholomew, K. (2013) Pedestrian and Transit Oriented Design. Urban Land Institute and American Planning Association, Washington DC.

[11] Newman, P., Davies-Slate, S., Conley, D., Hargroves, K. and Mourtiz, M. (2021) From TOD to TAC: The Transport Policy Shift to Transit Activated Corridors along Main Roads with New Technology Transit Systems. Urban Science, 5, 52.

Rapidly increasing urban populations and consequent pressures on infrastructure and the environment are driving many nations particularly those in the Asia region to reconsider the modes of implementation of transport infrastructure. Decreasing dependency on fossil fuels particularly in the transport sector will result in several positive outcomes such as the reduction in levels of ambient air pollution, and associated co-benefits (Hargroves, *et al* 2018).[12] For example, co-benefits include a reduction in noise resulting from motorised transport, a reduction in the urban heat island effect, an increase in exposure to green spaces, and an increase in physical activity i.e., walking and bicycle riding. Environmentally sustainable transport plays a key role in the reduction of air pollution and climate change mitigation in cities around the world.

Improving access to transport, particularly low-carbon transport, to those who are most vulnerable such as women, the elderly, and the poor, will improve access to basic infrastructure including health care, education, and employment opportunities – all pivotal to reducing poverty, improving well-being, and growing prosperity. A key part of sustainable urban design is to reduce automobile dependence by integrating transport networks with medium to high density mixed-use developments, centred on efficient and low-carbon shared transit. These developments will provide sufficient infrastructure for local residents, reducing the need to travel extended distances and rely on motorised, private vehicles. Fostering sustainable urban development requires integrating the land-use and transport planning processes that enable residents to decrease their dependence on automobiles through access to efficient and effective shared transport options. Creating smart, resilient, and liveable cities and communities will help to address a range of economic, social, and environmental issues. This calls for cities around the world to focus on ways to create smart cities that leapfrog old, outdated methods and take advantage of appropriate technologies.

Improving transport efficiency through operational innovations and smart solutions will be a key part of the growth of the world's cities. Smart mobility options and technologies can provide real-time travel information to traffic management and travellers, improve travel efficiency and reduce congestion, streamline pricing and payments, and help to manage multi-modal trips. Many cities are currently exploring the possibilities to enhance their capacity, infrastructures, data, technology, networking, and partnership to enhance efficiency and performance.

With the rapid growth in digitisation of cities around the world there is growing call for creating 'Smart Cities', however it is important to understand that this term is often misinterpreted. When considering the transport system, in the case that a city persists with an assumption of automobile dependence, no matter how much technology it employs it will ultimately fail to achieve the broader goals of liveability, sustainability and resilience, despite using 'smart technologies', as the modern technologies will just build on the fundamental structure of a city. For example, if 'smart' systems are installed on freeways in order to improve vehicle flow it may initially alleviate some of the congestion, but it will ultimately lead to rebounding congestion with more cars now able to fit on the freeway. This phenomenon is referred to as 'induced demand' where improvements to the traffic management system just induces more private vehicle use, leading to 'lock in' of automobile dependence (Newman and Kenworthy 1985).[13] Smart city technologies based around this structure and priorities in investment is simply creating a 'Smart Automobile Dependent City'.

> *Typically, a 'Smart City' is considered to be one that uses information and communication technology to improve the quality of life of its citizens. However, these technologies are often*

[12] Hargroves, K., Conley, D., Spajic, L., and Gallina, L. (2018) 'Sustainable Urban Design Co-Benefits: Role of EST in Reducing Air Pollution and Climate Change Mitigation', Background Paper for UNCRD Eleventh Regional EST Forum in Asia, Mongolia, Ulaanbaatar, 2-5 October, 2018.

[13] Newman, P., Kenworthy, J., and Lyons, T. (1985) Transport energy use in the Perth Metropolitan Region: some urban policy implications, *Urban policy and research, vol. 2, pp. 4-15.*

supplemental to a city's core infrastructure, such as its transport and energy systems, and as such can only do so much if the infrastructure is not well aligned to achieving multiple sustainability objectives. The combination of both smart and sustainable can create a set of systems and infrastructure that can not only accommodate rapid growth and high densities but continue to offer accessibility, safety and quality of life making cities 'more liveable, safe, resilient and sustainable' (SDG 11).

Alternatively, cities that shift from a focus on providing infrastructure predominantly for private vehicles, to providing infrastructure for effective city-wide mobility are far more likely to cope with rapid urban densification by harnessing road and land space to provide an interconnected system of mobility and development – creating 'Smart Transit Cities'. Well designed and operated, shared transit corridors with dedicated space, such as railways, subways, or trams, have been shown to provide mobility and accessibility effectively and comfortably despite the high density of travellers. It is well understood that this type of development also leads to a number of urban design and walkability benefits compared to increasing coverage of roads and freeways.

In order to facilitate economically productive and socially inclusive cities, the transport system needs to accommodate large numbers of people moving quickly in and out of areas of the city with high activity density. Hence at its core, transport decisions are about selecting the right combination of shared and individualised transport infrastructure to suit the availability of space. However, as it is inevitable that most large Asian cities will quickly grow in density, meaning that space will continue to be a premium, a combination that offers effective shared transit services as the primary form of transit complimented by private vehicles or low occupancy services stands to deliver the best outcomes in the longer term (Ewing and Bartholomew, 2013;[14] Sharma and Newman, 2017;[15] Newman *et al* 2018[16])

Shared transit, particularly bus, train and metro services, are critically important to the functioning of developing Asian cities and provide a cost and time effective service for a large proportion of the cities people, however services are often limited or undersized. In response there has been a growth in automobiles and motorbikes that has caused numerous problems. The question becomes how to enable cities to find a meaningful scale of shared transit system that can compete with individualised solutions of cars and motorbikes, especially for commuters during peak times. Despite bus services offering shared transit, given that they operate in-traffic, and often meander through areas stopping at multiple locations, and rarely provide a service comparable to the use of private vehicles. This calls for a return to a focus on dedicated corridors with a fast, high capacity, quality transit services as has been used in the past in many of the world's cities.

[14] Ewing, R. and Bartholomew, K. (2013) Pedestrian and Transit Oriented Design. Urban Land Institute and American Planning Association, Washington DC.

[15] 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.

[16] 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, Scientific Research Publications.

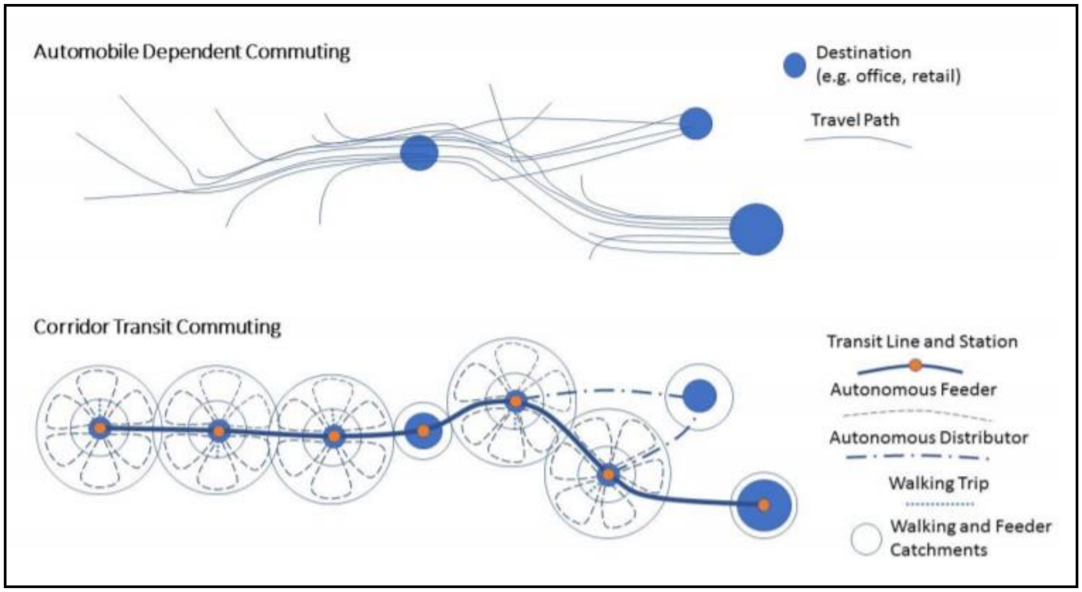


Figure F: Comparison of traditional 'automobile dependent commuting' to 'Transit Activated Corridor commuting' (*Source:* Adapted from Glazebrook & Newman, 2018 by Hargroves, K.)[17]

Cities that have emphasised shared transit infrastructure have found that effective partnerships between government and the private sector are needed to combine the new transit infrastructure with new development opportunities along the route, an approach referred to as creating a 'Transit Activated Corridor' (TAC) (Newman *et al*, 2021).[18] Figure F shows both an automobile dependent city and a transit dependent city corridor. In the first case trip times are acceptable and accessibility is convenient until population and vehicle levels grow too high leading to lengthy commute times and difficulty parking vehicles when arrived. In the second case accessibility is provided by offering a local shared transit service to bring travellers to high density precincts built around shared transit stations that can continue to offer accessibility and convenience despite growing population levels.

If done well this model can attract new investment in station precincts that is not possible in the automobile dependent model. With cars and buses as the focus, development is scattered with high spatial requirements to provide extensive car parking and wider roads, creating less dense nodes. To accommodate growth and provide quality of life, cities need to shift to the corridor transit approach that creates Transit Activated Corridors with their ability to enable denser land use. This approach can also be enhanced with smart technologies, both in cities already experiencing space constraints and congestion issues and in cities that are likely to face such constraints in the near future are currently automobile dependent. The main focus of the Transit Activated Corridor approach is to prioritise high quality, efficient corridor transit with last mile connectivity running between a series of dense station precincts. This then allows for fast, high-quality mobility along the corridor that can harness emerging technologies to improve efficiency and reduce costs that are built in as part of the urban regeneration process.

> *Although the automobile has provided access and mobility for decades, like the horse and cart before it, it is no longer suitable as the primary form of transport in rapidly growing cities around the world – the negatives simply out-way the benefits. Such cities, if they have not already, need to upgrade their transport systems to now fully harness existing land and road space to*

[17] Glazebrook, G. and Newman, P. (2018) The City of the Future. Urban Planning, 2018, Volume 3, Issue 2, Pages 1–20.

[18] Newman, P.; Davies-Slate, S., Conley, D., Hargroves, K. and Mourtiz, M. (2021) From TOD to TAC: The Transport Policy Shift to Transit Activated Corridors along Main Roads with New Technology Transit Systems. Urban Science, 5, 52.

accommodate shared transit options that deliver both mobility and development outcomes. This approach will call for new partnership arrangements not to mention it will need to draw on a range of smart technologies.

Key Resources

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Module 1: Smart Mobility Principles

Education Aim

This Module aims to provide clarity on the difference between a 'Smart Car City' and a 'Smart Mobility City' and provide a set of Smart Mobility Principles to be used as a framework for exploring options for transitioning from car dependence to smart mobility.

Learning Points

1. The term 'Mobility' refers to the ability for a person to move from one part of the city to another and can be achieved through a range of modes such as walking, scootering, running, cycling, driving, or catching a bus, tram or train. Mobility is a key factor in the livability of a city with highly mobile cities providing mobility infrastructure and systems that are safe, clean, affordable, efficient, and effective to allow people to move around the city with ease.
2. The term 'Smart Mobility' refers to the use of technology to enhance the mobility of a city through a focus on interconnected systems of mobility - rather than dominance of a particular mode that inevitably leads to inefficiencies and externalities. In the context of urban development not only can technology enhance the safety, cleanliness, affordability, efficiency and effectiveness of mobility, such technologies can deliver a range of additional benefits such as reducing travel costs, air pollution and GHG emissions, while creating a range of new development opportunities.
3. Cities across Asia are growing at unprecedented rates with over one billion people born in Asian cities between 1980 and 2010 and a further one billion expected by 2040. Many of these cities are quickly becoming megacities, with populations over 10 million people, with increasing urbanization leading to lifting millions out of poverty, increasing average incomes, and improving quality of life. However, taking the lead from Western cities, much of this urbanization has assumed that automobiles, mainly, cars and motorbikes, are the best primary mode of transport for cities leading to what is known as ‘Automobile Dependence’.
4. Private vehicles are mostly dependent on fossil fuels, and therefore, when car ownership increases in a city so does the level of air pollution and GHG emissions. As a result, traffic congestion, air pollution, GHG emissions, and increasing numbers of traffic accidents are common features of developing cities. This approach may be effective for low density cities in initial stages of development, but it is unable to cope with rapid increases in private vehicle ownership, population, and urban density. This often results in implementation of stop-gap measures such as roadway lane expansions, bypass freeways, tunnels, and even vertical multi-layering of roadways the provide short lived congestion relief.
5. A 'Smart Car City' uses technology to improve the flow of private vehicles, avoid network congestion, and to ensure that private cars remain the dominant mode of transport. This may improve conditions in the short term but overall, it will have diminishing returns until eventually the additional negative impacts will outweigh the benefits. Despite initial aspirations to improve conditions it may in fact lead to an overall worsening of conditions leading to growing economic, social, and environmental impacts.
6. A 'Smart Mobility City' uses technology to improve the operation of shared transit services, facilitate seamless mode changes and ticketing, and provide last mile accessibility. Suh an approach is not only better in terms of short-term transport goals but long-term goals that include all the SDG 11 characteristics of an ‘inclusive, safe, resilient and sustainable city’.

7. Hence given the rise of smart technologies it is important to clearly understand how a range of urban issues can be exacerbated using such technology, or else there will be significant lost opportunity and misdirection of investment if cities seek to use this new technology to further entrench car dependent systems, while branding themselves a “Smart City”.
8. Given a 'Smart Mobility' approach is superior to a 'Smart Car' approach the focus shifts to how to make the transition, especially given that many cities in Asia already have extensive automobile dependent infrastructure and services. An important aspect is to integrate transport and land use planning to create transit activation of existing road corridors, where effective shared transit services based around fixed station precincts activate greater development potential that in turn attracts people to the shared transit.
9. Achieving smart mobility outcomes will require a multi-stakeholder approach that integrates a range of factors which can be expressed as a set of 'Smart Mobility Principles' as described in the Background Information.

Background Information

What is Mobility?

In the context of urban development, the term 'Mobility' refers to the ability for a person to move from one part of the city to another. Mobility can be achieved through a range of modes such as walking, scootering, running, cycling, driving, or catching a bus, tram, or train. The quality of mobility is affected by the provision of infrastructure (such as footpaths and cycle lanes), level of safety (such as cycle lanes interacting with traffic lanes), level of cleanliness (such as clean shared transit vehicles), level of affordability (such as providing a cheaper option than a private car) level of efficiency (such as the frequency and duration of shared transit services minimizing trip time), and the effectiveness of transport management (such as the level of congestion experienced and the interconnection of shared modes). Mobility is a key factor in the livability of a city with highly mobile cities providing mobility infrastructure and systems that are safe, clean, affordable, efficient, and effective to allow people to move around the city with ease.

What is 'Smart Mobility?

The term 'Smart Mobility' refers to the use of smart technology and systems to enhance overall mobility of a city through a focus on interconnected systems of mobility - rather than dominance of a particular mode that inevitably leads to inefficiencies and externalities. In the context of urban development not only can technology enhance the safety, cleanliness, affordability, efficiency and effectiveness of mobility, such technologies can deliver a range of additional benefits such as reducing travel costs, air pollution and GHG emissions, while creating new opportunities for a range of industrial and economic development options. If done well a system of smart mobility can be one of the major components of a smart city that underpins safe, clean, efficient, reliable, convenient, and sustainable mobility through advance and intelligent transport solutions. Smart mobility involves harnessing technology through digitization and automation and blending this with physical infrastructure and human interaction. Smart mobility is mostly supported by technological innovations and balanced transport infrastructures that can offer multimodal transport options for the people and freight to fulfil all mobility needs by optimizing the overall and integrated transport system. Smart mobility can bring transformational changes in transport sector to support economic growth and sustainable urban development. Smart mobility technologies such as driverless vehicles present a valuable option for mid-tier shared transit, such as shuttle buses that operate more frequent services to collect passengers and take them to station precincts to access effective corridor transit options, such as driverless Trackless Trams (See Module 4).

Why is Smart Mobility important?

Cities across Asia are growing at unprecedented rates with over one billion people born in Asian cities between 1980 and 2010 and a further one billion expected by 2040. Many of these cities are quickly becoming megacities, with populations over 10 million people. Increasing urbanization has led to many benefits and is consistent with the 'Rise of Asia' that has occurred in recent times, lifting millions out of poverty, increasing average incomes, and improving quality of life. However, taking the lead from Western cities, much of this urbanization has assumed that automobiles, mainly, cars and motorbikes, are the best primary mode of transport for cities leading to what is known as 'Automobile Dependence' (Newman and Kenworthy, 1989[19]; Newman and Kenworthy, 1999[20]; Newman and Kenworthy, 2015[21]).

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[19] Newman, P. and Kenworthy, J. (1989) 'Cities and Automobile Dependence: An International Sourcebook', Gower Publishing, United States
[20] Newman, P. and Kenworthy, J. (1999) Sustainability and Cities: Overcoming Automobile Dependence. Island Press.
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Private vehicles are mostly dependent on fossil fuels, and therefore, when car ownership increases in a city so does the level of air pollution and GHG emissions. As a result, traffic congestion, air pollution, GHG emissions, and increasing numbers of traffic accidents are common features of developing cities. This approach may be effective for low density cities in the initial stages of development, but it is unable to cope with rapid increases in private vehicle ownership, population, and urban density. This often results in implementation of stop-gap measures such as roadway lane expansions, bypass freeways, tunnels, and even vertical multi-layering of roadways (Duranton and Turner, 2011).[22] Such investments typically deliver short term relief from congestion with only minor longer-term improvements in mobility while exacerbating a range of negative impacts that are particularly relevant to Asian cities given the high densities.

In short, an approach to providing a city with mobility that is based around private vehicles has a number of insurmountable shortcomings as it leads to a number of adverse outcomes that affect the economy, environment and communities, such as: increasing levels of congestion and delays; reduced accessibility due to increased trip times as cities begin moving outwards; increased risk of injury and fatality from road accidents; reduced physical activity leading to health related issues; significant increases in local air pollution and global greenhouse emissions; and continued dependence on oil which is often imported. In short, there are impacts on livability, safety, resilience, and sustainability – the core goals of SDG 11 and the heart and soul of environmentally sustainable transport as set out in the UNCRD Bangkok Declaration.

In particular, a model based on automobile dependence struggles to accommodate density given the need for extensive road and parking-based infrastructure as well as the loss of economic opportunities from the associated and growing traffic congestion. The many advantages of urban density in enabling economic development are well established (Newman, *et al*, 2017[23]; Glaeser, 2011[24]) hence a transport method better suited to supporting density or even facilitating density needs to be considered. Growing cities in Asia and around the world are seeking ways to offer effective transport systems that can accommodate rapid increases in urban density as part of their continuing need to increase economic development opportunities and to provide improvements to the key parameters in SDG 11. It is clear that a strategy to simply provide ore road space will attract more traffic, meaning that relief from congestion is short lived, while negative impacts are multiplied. Hence given the construction of additional road space cannot solve a city's congestion, pollution, and road safety issues and it is essential to promote low-carbon smart mobility solutions to deliver safe, clean, affordable, efficient and effective mobility options.

What is the difference between a 'Smart Car City' and a 'Smart Mobility City'?

Many cities are now turning to what is referred to as 'Smart City' technologies in an attempt to make their cities achieve these goals, however the application of such technologies may not lead to improved outcomes. Smart city technologies, like any technology, need to be directed and city governance systems will need to make choices about how best to implement the various sensors, information systems, and control services that are now available. There are two distinct scenarios for how smart city technologies can be applied to cities: the 'Smart Car City' and the 'Smart Mobility City', in order to compare how the application of smart city technology can be directed and how the resulting outcomes can include environmentally sustainable transport.

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[22] Duranton, G. and Turner, M. (2011) The Fundamental Law of Road Congestion. American Economic Review Vol 101:6, pp2616-2651.
[23] Newman, P., Beatley, T., Boyer, H. (2017) *'Resilient Cities',* Island Press Washington, DC.
[24] Glaeser, E. (2011) Triumph of the City: How our Greatest Invention Makes us Richer, Smarter, Greener, Healthier, Happier, The Penguin Press, New York

Smart Car City

This city uses smart technologies in several ways, namely: to inform efforts to increase the flow of private vehicles; to enable greater awareness of how to avoid network congestion; to offer greater opportunities for cars to remain the dominant mode of transport; and to facilitate development of the city at its fringes (rather than around the high-capacity roads that cannot be serviced by private vehicles). Such a city may indeed see some short-term improvements in mobility by using smart technologies, however these benefits will inevitably be lost as population and traffic density increases, leading to the exacerbation of the issues that called for a new approach in the first place. Such outcomes are often overlooked when proponents of smart city technologies present associated products and services as a solution to almost any urban problem if their smart technological system is adopted.

Smart Mobility City

On the other hand, a *Smart Mobility City* uses smart technologies in a number of ways that enhance multiple outcomes, namely: to inform the effective and efficient expansion and operation of shared transit services (such as train lines, metro lines, light rail and tram lines, bus services etc); to enable seamless mode changes as part of a journey; to streamline ticketing between modes; to allow for predictive maintenance to reduce associated costs; and to enable the transport system to deliver enhanced mobility across a city. Such a system, better connected for last mile accessibility, is more affordable, promotes walkability and density around stations, provides information services for simplicity, and enables the funding/financing through effective private-public partnerships. This city is not only better in terms of short-term transport goals but long-term goals that include all the SDG 11 characteristics of an 'inclusive, safe, resilient and sustainable city'.

If designed well a 'Smart Mobility City' approach can be both well aligned to long term planning goals of cities and nations along with having a clear rationale and evidence to counteract a focus on automobile-oriented solutions that are heavily promoted but are not part of what makes a good city. Such an approach can leverage similar technologies that are promoted for 'Smart Car Cities' such as smartphone applications, sensors, and control systems – however the core planning ethos driving this vision must prioritize transit and sustainability rather than persist with the notion that private vehicles can be accommodated on mass in growing cities.

> *If a city is primarily automobile dependent the application of Smart City technologies and approaches may improve conditions for a short while but overall, it will have diminishing returns until eventually the additional negative impacts will outweigh any benefit achieved, which will further strengthen the 'lock in' to automobile dependence. Hence despite initial aspirations to improve conditions it may in fact lead to an overall worsening of conditions leading to growing economic, social, and environmental impacts and damages. If such cities are to see lasting improvements such technologies need to be used to accelerate a transition to greater shared mobility options that are seamlessly connected and effectively integrated with new and existing urban development that create vibrant liveable city centers.*

Given a smart mobility city approach is far superior to a smart car city approach, the question becomes how to make the transition, especially given that many cities in Asia already have extensive automobile dependent infrastructure and services, meaning that roads are seen as places for private vehicles rather than the logical place for a number of effective shared transit options. The core of this question comes down to how transport and land use related investments in cities can be directed to not only avoid miss-using the opportunities provided by smart city technologies, but to begin to reduce the growing negative impacts of automobile dependence. This challenge is not new as cities have long been struggling with how to integrate new technologies to achieve better outcomes whilst also needing to demonstrate clear benefits for their economies, societies, and ecosystems. Given the rise of smart technologies it is important to clearly understand how a range of urban issues can be exacerbated using such technology, or else there will be significant lost opportunity and misdirection of investment if cities seek to use this new technology to further entrench car dependent systems, while branding themselves a "Smart City".

The key to achieving such a transport system is to integrate transport and land use planning to create strategies that focus on transit activation of existing road corridors, where effective shared transit services based around fixed station precincts will activate greater development potential that in turn attracts people to the shared transit. This will call for an innovative approach that sees new partnerships formed between government agencies and between government and the private sector to deliver such corridors. (See Module 5)

These partnerships would use dedicated lane corridor transit services (with the potential for other shared transit vehicles to streamline behind trams) to activate greater land value along the corridor, working with developers to attract investment around stations and help pay for the transit service – rather than simply using this space for car parks. In effect, the transport service provides the patronage for the station precincts and the precincts provide destinations for travelers as well as homes and businesses that can be serviced by local transit services. This is a synergistic relationship that can make such transit activated corridors a primary method of urban transport and urban development that harnesses existing road space to increase capacity rather than expect it to be continually expanded to accommodate more and more private vehicles. Such an approach is used in a few cities in Asia but is not common as it requires new governance and partnership approaches that are not well understood or supported.

Hence it is important that smart city technologies are prioritized that can improve efficiency, quality, and modal interconnectivity of shared transit options to create a quality transit system supported by new electric micro-mobility for last mile connectivity. This is at the heart of a 'Smart City' and it needs to be the focus of planning, investment, and capacity building in Asia. A number of Asian cities foresaw this eventuality and along with a focus on providing infrastructure for cars have also long embedded public transport options into their urban form, with differing degrees of success, some like Tokyo, Hong Kong Administrative Regions of PR China and Singapore have become world best practice in reduced car dependence, something increasingly being seen as important in most Asian cities, along with recent financing priorities of the Asian Development Bank.

Smart Mobility Principles

The overarching goal of smart mobility is to provide safe, clean, affordable, efficient, and effective mobility that takes advantage of integrated land use and transport opportunities with the help of smart technologies and solutions. Achieving smart mobility outcomes will require a multi-stakeholder approach that integrates a range of factors which can be expressed as a set of 'Smart Mobility Principles'. For the purpose of this Module the following 15 Smart Mobility Principles have been developed:

1. *Safety and Security*: Improve safety and security of transport systems through improved design, operation and management in order to reduce traffic accidents, serious injuries, and fatalities. Smart cities ensure that public spaces are designed and maintained in such a manner as to discourage criminal activities.

2. *Improved accessibility and connectivity:* A key principle of smart mobility is to improve accessibility and connectivity for people and goods through creating a system of transit corridors that connect city nodes with shared transit options.

3. *Encourage Non-motorized Transport:* Smart cities encourage the use of basic, active, and cost-effective non-motorized transport options such as walking and cycling, and integrate them in to a multi-model mobility system.
4. *Promoting clean, green, and low-carbon transport:* Smart mobility promotes clean, green, and low-carbon transport options, such as through the use of renewable energy sources for mobility and energy generation such as eMobility and use of zero emission vehicles.
5. *Social Equity and Inclusion:* Smart mobility options are suitable for all regardless of income, age, gender, or race. The transit should be prioritized to vulnerable groups, such as women, girls, children, elderly, physically disabled, and people who are economically, socially, or physically disadvantaged to ensure *no one left behind*.
6. *Planning dense and human scale cities:* Smart mobility encourages human scale cities in which cities are highly dense and compact to allow human interaction and a vibrant city environment. In these cities, human settlements and buildings are well connected with variety of city streets where human settlement and nature go side by side in suitable arrangements.
7. *Optimizing existing transport infrastructure:* Smart mobility seeks to optimize existing road and transit networks for improved outcomes. This can be through enhanced traffic management using big data and AI to undertake predictive congestion management.
8. *Discouraging private vehicles:* Smart Mobility approaches in cities promote alternatives to private vehicles and ensure effective and affordable shared transit services are provided that are easy to use and to link together to form complete trips with different modes.
9. *Harnessing Technology:* Smart mobility harnesses a range of technologies and smart solutions such as information and communication technology (ICT), Intelligent Transport System (ITS), Internet of Things (IoT), Wireless and cellular networks, and a range of mobile devices. Such systems are supported by sensors, big data analytics, Blockchain, and smart mobility apps.
10. *Promote Innovation and R&D:* Advanced research and development can help to improve smart technologies and solutions. Innovation and unique local perspective should be encouraged and considered for smart mobility development options.
11. *Encourage public-private partnership:* Public-Private-Partnerships are a key part of Smart Mobility projects in order to overcome the shortage of public finance and incentivise the private sector to develop new and expanded services at station precinct.
12. *Data collection, sharing and analytics:* Date collation, sharing and analytics is a key element of smart mobility, with the potential to improve the transit options and prediction of the transport demand and management are the essential part of the smart city.
13. *Promote community engagement and participation:* Community engagement and participation is the essential element of smart mobility, with consideration needed from the planning phase to the implementation phase.
14. *Providing a healthy environment:* Smart mobility options such as electric vehicles and non-motorised modes can contribute to reducing a city's health impacts such as physical inactivity due to automobile dependence, vehicle exhaust pollution levels and noise levels.
15. *Protect urban biodiversity and ecology:* Urban biodiversity and ecological assets are important to the functioning of urban spaces having direct impacts on the micro-climate experienced in cities.

Key Resources

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Module 2: Smart Mobility Planning and Development

Educational Aim

Smart mobility of people and freight in cities and communities optimises a fundamental function of society. This module aims to highlight principles and benefits of best practice transport systems to facilitate mobility primarily in cities.

Key Learning Points

1. Integrated planning creates optimized and effective systems by coordinating land use, transport, energy, housing and other urban development sectors. Mutual benefits emerge for transport and land users and owners (of nodes and land amongst transport) from a synergistic system which improves vehicle operation, special management, and flow with nodes and built infrastructure while facilitating smart city transport – including human-centred transport (walking and micro-mobility) and 'last mile' movement. Successful and comprehensive multimodal transport integrates all modes of public transport (such as rail, bus and ferries) amongst mass transport systems (such as micro-mobility, ridesharing and air services), via smart system design and system management.
2. Design and development which combines residential, commercial, cultural, institutional and entertainment parties into single areas can foster community-centred design and high-quality of space, fed by a core of pedestrian transport with access transport services for increased scale of movement and intercommunity movement. The connectivity of communities, facilities and spaces can be improved in dense urban development via intensive consideration of transport systems the use and coordination of people and spaces, centred around walkable communities and pedestrian facilitation amongst reduction in private vehicles dependence.
3. Existing transport infrastructure can be optimized for flow of people and freight by prioritizing more efficient modes – such as public transport, ridesharing, micro-mobility and pedestrian movement – via different strategies: avoiding transport system loading by improving connectivity of infrastructure and providing alternatives when considering proximity and accessibility via improved system cohesion, communication and trip design (utilising data systems to relieve physical system loads); shifting the system to higher density flow of people and freight with higher occupancy vehicles and shifting from private to public transport (coupling to lower carbon and costs); and improving design for purpose and better delivery of a built-for-purpose yet flexible transport which uses appropriate technologies and hosts capability for future change as user behaviour evolves.
4. Transport activated corridors encourage regenerative urban development by integrating communities, businesses, and urban centres with the people amongst them and in their fringes, while reducing dependence on private vehicles and increasing human-intensive mobility (micro-mobility and walking) for human-centred spaces. The five design principles for transport activated development are: define transit activated corridors; create walkable and sustainable station precinct design; create collaboration and partnerships from the start of projects; value creation rather than prediction; and begin with available resources rather than pre-determined targets.
5. Smart cities provide equitable and accessible services, and address barriers to people in functionality of system design across all infrastructure – resulting in a system which all people can use, and more people want to use. Key concepts include accessible design for the entire public (including those with disabilities); usability design addressing effectiveness, efficiency and satisfaction with which users

access facilities (as per the International Organization for Standardizations); and universally designed transport systems for use by all people (made possible by collaboratively developed accessibility standards). These embrace principles of equitable use; perceptible information flexibility in use; simple and intuitive use; perceptible information; tolerance for error; low physical effort; and size and space for approach and use.

6. Cities are centers of economic growth and energy consumption, with operations coupled to greenhouse gas (GHG) emissions. Smart cities can transition to sustainable transport systems by reducing the energy intensity of systems (with increased density of people and good flow) and powering systems with clean energy. Best-practice planning, and operation of transport systems should fully utilize data technologies to inform and action optimal solutions via the internet of things, digitalized movements, and digital saturation operations, including retrofitting.

7. Smart mobility policies and solutions deliver robust and resilient transport systems, enabling sustainable communities, cities, and countries. It is achievable in collaborative design initiatives by designers, engineers, politicians, developers, financiers, communities and leaders across all facets and Stake holding parties. UNESCAP identifies that smart mobility is an efficient transport service which fully utilizes data from all areas for informing all activities and parties.

8. Other cost-effective benefits of smart mobility policies and solutions are mobility management (encouraging low road-space intensive modes like public transport, ride sharing, micro-mobility and walking); transport pricing reform (financially dissuading users from private vehicles via road and fuel pricing); fare reductions for shared transport (incentivizing ridership and shifting people from private vehicles to shared modes); high-occupancy vehicle use (increased intensity per vehicle improves energy efficiency of the vehicle and the infrastructure); integrating transport system (cooperative modes relevant to the cityscape, optimized together); ridesharing programs (increasing intensity of vehicles and trips, relieving traffic and capital from services); transit-priority traffic control system (intersections and corridors increasing passenger throughput); and vehicle behaviour (understanding and profiling network loads or abnormalities).

Background Information

Principles of Mobility Planning

As the city grows, it faces a lot of transport related challenges such as crowding and traffic congestion, air pollution and road accidents. By connecting people, commodities, and data, both physically and digitally, the smart mobility policies provide efficient and better connection of people and goods keeping the city inclusive, liveable, and attractive. The following are the important basic mobility policies which have significant positive implications and benefits to developing smart mobility solutions.

1) Integrated Planning

Integrated land use, urban and transport planning is an essential tool in the smart mobility development. Integrated planning and management can play a key role to deliver truly effective mobility service in the city. Integrated transport planning and management strategies should design to satisfy the mobility needs of people and businesses across the cities and their surroundings for improving quality of urban mobility options. It is necessary to have integrated planning that creates synergistic among land use, transport, energy, housing, and other urban development sectors. Land use planning serves better urban space management balancing competing for demands for people, urban space, and the natural environment. While urban planning and design regulate the uses of urban space focusing on physical form, economic functions, and social impacts of the built environment. Similarly, transport planning focuses on improving vehicle flow, parking operation, provision, and management of new transit services and freight facilities among the different modes of transport. It is equally important to include cost-effective opportunities to improve basic transport options, Smart city uses basic smart mobility options such as non-motorized transport-walking and cycling as an obvious choice for achieving safe, efficient, convenient, inclusive, and sustainable movement for people.

2) Multimodal Integration

Multimodal integration can be defined as seamless connectivity between different modes of transport that maximize the impact of mass transport and support sustainable urban mobility. Multimodal transport usually carriage of people and goods by more than one mode of transport. Smart mobility promotes multimodal integration through smart technologies and solutions. The full-scale multimodal integration is characterized by two key features:

i. Integration of public mass transport modes such as Bus Rapid Transit (BRT), Light Rail Transit (LRT), Mass Rapid Transit (MRT) and High-speed railways can well connect with other modes of public transport and

ii. Integration of mass transport modes including walking and cycling, taxis, shared-mobility services like car-sharing and bike-sharing, ferry and ships with other feeder modes that help to deliver first- and last-mile connectivity.

Figure 2.1: Building blocks of multimodal integration (*Source*: EMBARQ).

3) Mixed-use Development

Mixed-use is an urban planning, design and development strategy that promote mix-use development and combines different facilities such as residential, commercial, cultural, institutional, entertainment, into one space, which are well integrated and connected with the pedestrian-friendly development. Mixed-use development planning seeks to foster community design and development that aim to offer various benefits to the economy, community, public health, and the environment. Mixed-use provides better connections, convenience, and stronger felling of neighbourhoods that support better access through public transit as well as walking and biking.

4) Transit-Oriented Development (TOD)

Transit oriented development (TOD) is urban planning for creating vibrant, liveable, sustainable cities and communities that maximizes the amount of residential, business entertainment and public leisure areas within walking distance along and around the public transport corridors. TOD promotes the dense, compact, and connected urban development through high-quality public transport system. TOD revitalize city by reducing the use of private vehicles and promoting sustainable urban growth. TOD is also a major solution to address climate change and global warming, and energy security by creating walkable communities and pedestrian facility that greatly-reduce the need for private vehicles and thereby energy consumption.

5) Transportation Demand Management (TDM)

Transportation demand management refers for strategies that result in more efficient use of transportation infrastructures and services using transport resources in optimum level. TDM emphasizes the movement of people and goods giving priority to public transit, ridesharing, non-motorized mode of transport for efficient and smooth urban movement. There are many potential smart mobility management strategies. Some strategies reduce the need for physical travel and improvement of the transport options whereas the other provide incentives for change the mode, frequency, destination, route, and timing for their travels.

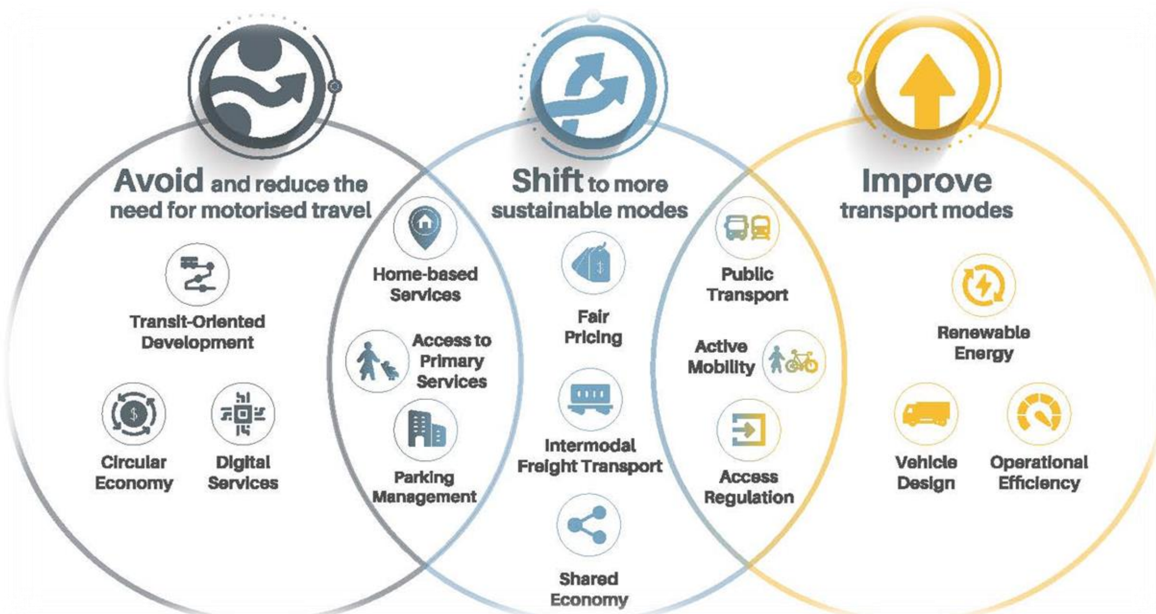

Figure 2.2: Transportation demand management strategies-avoid, shift, and improve. (*Source*: Slocat)

According to the 'Partnership on Sustainable Low Carbon Transport' (SLOCAT) TDM strategies can be dived into three categories-avoid, shift, and improve as shown in Figure 2.2.

1. *Avoid:* In this strategy focuses on avoiding all unnecessary movement of people and goods. Avoiding unnecessary motorized trips based on proximity and accessibility. Provide communicative solutions such as telecommunicating, online shopping and reduced vehicle trips significant help to reduce the transport needs.
2. *Shift:* Shifting to higher occupancy and low-carbon transport modes mainly from private vehicles to public transport, shared mobility, water-based transport, walking and bicycles for last-mile connectivity which can help to shift better transport options.
3. *Improve:* Provide better transport solutions through an improved transport system. This includes improving vehicle design, inspection and maintenance, fuel efficiency and clean energy sources for different types of passengers and freight transits. Improve traditional railways and bus systems to electrified rail transports, electric buses, and low-emission mode of cargo and freight transport system.

6) Transit Activated Development (TAC)

Transit Activated Corridors (TAC) is urban design and development strategy which refurbished the main road corridors to provide higher capacity modern technology transit integrated with higher density urban regeneration and affordable housing projects (Newman, *et al* 2021).[25] TAC emphasizes the role of new road-based transit technology in enabling denser development along whole main road corridors with a series of station areas by creating new transit technology based urban regeneration in the major transport corridor. The need for TAC as a new element of transport policy has been recognized the need to do more than simply increase road capacity for more vehicles. The delivery of TAC strategies mainly depends on better coordination and more integration with private sector partnerships with all levels of government,

[25] Newman, P., Davies-Slate, S., Conley, D., Hargroves, K. and Mourtiz, M. (2021) From TOD to TAC: The Transport Policy Shift to Transit Activated Corridors along Main Roads with New Technology Transit Systems. Urban Science, 5, 52.

an openness to a range of new transit technology and electric micro-mobility and a new way of bringing all this together in terms of multi-purpose governance.

There are five design principles for Transit Activated Development:

Principle 1: Define Transit Activated Corridors

Principle 2: Create walkable and sustainable station precinct design

Principle 3: Create collaboration and partnerships from the start

Principle 4: Value creation rather than prediction

Principle 5: Begin with available means rather than pre-determined ends

7) Barrier-Free and People-Friendly Urban Design

According to WHO, about 15 per cent of the global population lives with some form of disability, and 4 per cent of them experience significant difficulties in functioning (WHO, 2011).[26] Smart city should consider these people and made the design such as way that more and more people with limited physical capacities can also live with equitable and dynamic lives and enjoy accessible mobility services. In this regard, transport infrastructures - road, bridge footpaths, vehicle design, public transport stations, public buildings and public restrooms should be designed barrier free so that these infrastructures and services are accessible for all. Barrier-free smart mobility options include slopes, elevators, and escalator to eliminate the need to use steps within stations, barrier-free toilets, platform screen doors, and tactile paving for the visually impaired. The smart city must promote the barrier-free and people-friendly design of transport infrastructures and services.

8) Accessible, Usable, and Universal Design

The terms accessible design, usable design, seamless and universal design are all urban design approaches that build physical and digital infrastructures in such a way that they are usable by a wide range of people regardless of age, size, and disabilities. Although universal and seamless design promotes access for all individuals with disabilities, but it also benefits for others. These concepts apply to the design of the built environment and transport services. Accessible, usable, universal, and seamless design in public transport is essential for providing equal opportunity for all sectors of the society to no one is left behind.

1. *Accessible design:* Accessible design is a design process which focuses on the needs of people with disabilities are specifically considered. The main aim of the accessible design is to provide accessibility, public facilities, and services to people with physical handicaps and physical disadvantages.

2. *Usability design:* According to International Organization for Standardization usability design is defined as the effectiveness, efficiency, and satisfaction with which a specified set of users can achieve a specified set of tasks in a particular environment. Usable design serves to create products that are easy and efficient to use. The constraint of the usability design is that it can or cannot be accessible for all.

3. *Universal design:* Universal design is a broader concept that is defined as "*the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design*" (DO-IT, 2022).[27] An example of universal design in urban mobility

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[26] WHO (2011) *World Report on Disability 2011*, World Health Organisation.

[27] DO-IT (2022) 'What is the difference between accessible, usable, and universal design?', DO-IT. Disabilities, Opportunities, Internetworking, and Technology.

includes automatic doors of bus and train systems. They benefit people with disabilities, parents with baby strollers, delivery workers, and others. It is important to consider human characteristics in universal designs such as age, gender, stature, race/ethnicity, culture, native language and learning preference. To maximize benefits of "universally designed" transport systems, legal and regulatory processes of establishing accessibility standards should be embraced by larger group of transport stakeholders, including governments, road operators, and mobility service providers (FIA, 2022).[28]

There are seven principles of universal designs which include:

Principle 1: Equitable use

Principle 2: Flexibility in use

Principle 3: Simple and intuitive use

Principle 4: Clear information

Principle 5: Tolerance for error

Principle 6: Low physical effort

Principle 7: Sufficient size and space for approach and use

9) Low-Carbon and Green Growth Development

Cities are powerhouse of economic growth and energy consumption. Greenhouse gas emission (GHGs)-a major cause of global warming are emitted in large-quantities in cities. Smart cities should support green transport by investing in low-carbon energy efficiency transport infrastructures that provide attractive benefits for green growth development and climate change mitigations. It is equally important to use renewable energy sources for low-carbon transit development. E-mobility options such as electric buses, light rail transits, electric high-speed railways can significantly help to green growth development.

10) Smart Technology and Innovation

Smart mobility uses the invention, advance technologies, and smart solution such as Internet of Things, Intelligent Transport Systems, and autonomous vehicles. It further uses wealth of urban data from smart phones and sensors that offer new possibilities to address urban mobility challenges that developing cities are facing. Smart technologies help choosing and designing the appropriate technology and design and devices to improve the passenger and freight transport in particular context of the city.

Benefits to Cities from Smart Mobility

Smart mobility offers intelligent facilities for improved connection of people in a more robust transport system, enabling sustainable cities and communities. The sustainable development and design for smart mobility depend on collaborative approaches among different stakeholders including designers, engineers, politicians, developers, financiers, communities and leaders across all facets and stakeholders (Caldera, *et al* 2020).[29] UNESCAP identifies the concept of smart mobility as transport services which effectively utilise data, communication and coordinating technologies to provide informed logistical solutions, resulting in improved convenience, time and resource efficiency for consumers and operators (UNESCAP, 2022).[30] There are a lot of issues related to urban mobility in cities from developing countries-infrastructure shortages, lack of digitalisation, un-balanced freight model split, inefficient and fragile

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[28] FIA (2022) 'Accessibility: a changing paradigm towards mobility for all transport', FIA, Federation Internationale de l'Automobile.

[29] Caldera, S., Desha, C., Reid, S., Newman, P. and Mouritz, M. (2020) 'Principles of Design for ensuring Sustainable Urban Centers', 1st Asia Pacific Sustainable Development of Energy Water and Environment Systems (SDEWES), 6-9 April 2020, Gold Coast, Australia.

[30] UNESCAP (2022) 'Increasing the use of smart mobility approaches to improve traffic conditions in urban areas in the Southeast Asian Subregion', United Nations Economic and Social Commission for Asia and the Pacific, UNESCAP, 18 January 2022.

transit arrangements, manual checks at the border crossings, divergent standards on vehicles, drivers and international transit, and connectivity across the region (UNCRD, 2021).[31]

Major benefits of smart mobility policies and solutions include:

- Reduce traffic congestion, air, and noise pollution
- Decrease traffic accidents, injuries, and fatalities
- Enhance greater mobility, connectivity, and access
- Reduce household spending on transportation
- Reduce GHG emissions
- Improve natural environment and green growth
- Active and healthier lifestyle with more walking and cycling
- Reduce urban sprawl
- Promote compact mixed-use development
- Businesses growth in local community
- Improve resilience of cities by access of high-quality public transport
- Increase property values
- Enhance energy security by reducing oil dependency
- Improve the quality of life with a better living and working environment

There are several other cost-effective benefits of smart mobility policies and solutions:

- *Mobility management:* The main objective of mobility management is to change travel behaviors of private car users and encourage them to use public transport, shared transport and active mode of transport-cycling and walking by providing subsides in improving the quality of public transport, providing specific subsidies in fare, better travel information, and improved facility, and services.
- *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 use of private vehicles and encourage for the use of other sustainable mode of transport.
- *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 vehicles to shared modes. It further allows people to walk and cycle from and to the transit stations which have a lot of health benefits.
- *Use of high-occupancy vehicle (HOV):* High occupancy vehicles play crucial role to overcome the traffic congestion by allowing significant number of travellers to move from place A to place B. HOV reduces the amount of available road space for single-occupancy vehicles that reduce traffic congestion and air pollution. In addition, this reduces the use of private cars and encourages ride sharing and public transit use.

[31] UNCRD (2021) 'Next Generation Transport Systems for Achieving SDGs and Carbon Neutrality – for a Safer, Affordable, Accessible and Resilient Asia - Forum Summary', 14th Regional Environmentally Sustainable Transport Forum in Asia, 18-20 October 2021, Aichi, Japan (Hybrid Online Forum)

- *Integrating Transport System:* Smart city should promote the integrated transport system combining of different modes of transport such as public transport-buses, railways, waterways, airways; shared mode - shared cars and taxies, with active mode of transport-walking and cycling. Integration of all modes of transport considerably increases efficiency, reliability, and comfort to travellers. This further helps to improve safety, convenience, and affordability. A successful integrated transport system brings a lot of benefits to shared transport, especially an increase in demand for shared transport and decrease traffic congestion and air pollution.

- *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, air pollution and GHG emissions, mainly in pick hours.

- *Transit-priority traffic control system:* The transit-priority traffic control system provides priority to shared transit over private vehicles. A successful transit priority traffic system can enhance shared transit performance by offering additional time to shared transportation at signalized intersections. It helps to improve efficiency, cost effectiveness, and lower transit fuel consumption, reduce private vehicle travel and thereby reduce the traffic congestion.

- *Vehicle Behaviour:* Vehicle behaviours means 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.

Key Resources

- Caldera, S,. Desha, C., Reid, S., Newman, P. and Mouritz, M. (2020) 'Principles of Design for ensuring Sustainable Urban Centres', 1st Asia Pacific Sustainable Development of Energy Water and Environment Systems (SDEWES), 6-9 April 2020, Gold Coast, Australia.

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- Pettit, C., Bakelmuna, A., Lieskeb, S., Glackinc, S., Hargroves, K., Thomson, G., Shearer, H., Dia, H., and Newman, P. (2018) Planning support systems for smart cities, City, Culture and Society Journal, March 2018.
- UNESCAP (2022) 'Increasing the use of smart mobility approaches to improve traffic conditions in urban areas in the Southeast Asian Subregion', United Nations Economic and Social Commission for Asia and the Pacific, UNESCAP, 18 January 2022.

Module 3: Smart Mobility Technologies

Educational Aim

This module highlights how innovative and advance smart technologies and mobility solutions can reduce costs and improve safety, efficiency, reliability, accessibility, and effectiveness of the passenger and freight transport system.

Key Learning Points

1. The transport sector has seen great progress in the advancement of smart technologies and solutions that can provide a range of benefits with a number of key innovative solutions that can provide enhanced mobility, accessibility, and connectivity. The way that these types of technologies are navigated will have a direct impact on a city's transport performance and the quality of life.
2. Smart technologies are increasingly being applied to cities that have been designed around private vehicles and despite the best of intentions progress to improve conditions efforts are likely to be stifled by the sheer size of growth in car use, population, and urban densities, calling for shared transport options to be integrated into the urban form.
3. In the last 10 years several new and powerful digital systems and software options have been developed that stand to significantly improve the functioning of transport systems, with a set of new options now finding early adoption. The use of communication enabled sensors in the transport network provides a unique opportunity to improve the management of transport systems especially in traffic management, safety, and system efficiency.
4. Internet of Things technologies (IoT) allows communication between people, processes, and things by connecting physical and digital assets through connected embedded devices that interact and function as part of a network. IoT is widely used for smart mobility solutions. Transport and logistics systems can benefit from a variety of IoT applications.
5. Intelligent Transportation Systems (ITS) enable the application of information and communication technologies in the transport system. ITS typically includes the application of visual sensing, data analytics, along with automated control and management of transport devices to improve safety, mobility, and efficiency. ITS can provide reliable information before the journey to help plan travel outcomes, select route, and connect transport modes.
6. Even though there is a range of current beneficial technologies to support smart mobility efforts are limited due to the dependence on private vehicle use. Hence the real 'smart' choice is to increase shared transit services, especially along designated corridors, offering a range of vehicle types including private automobiles and shared transit modes.
7. Using data to improve the management of transport networks is nothing new, however the coming decades will see a massive shift in how data is generated and harnesses which will completely change the game. Those that can quickly identify and access the important data and use it to enhance decision making will find it an enormously powerful tool; however, it has some complexity that is yet to be unravelled.
8. Artificial Intelligence can be a powerful tool for learning how to manage and predict flows of objects, making it particularly useful for the transport sector. Of particular interest is the ability for artificial intelligence to harness big data analytics to enable predictive congestion management by comparing historic data to real time conditions and then alerting operators when congestion conditions are likely

to be experienced in the near future. Other benefits include Traffic Management, vehicle behaviour, traffic signal optimisation, vehicle prioritisation, route optimisation, traffic risk management, self-driving vehicles, ridesharing and fare evasion.

9. Despite Blockchain technology being relatively new, and early applications such as cryptocurrencies experiencing challenges, there is a growing number of applications of this form of distributed ledger technology that will be of significant benefit to the transport sector. Benefits include freight tracking, logistics documentation, traffic management, supply chain transactions, digital identification, establishing provenance and establishing authenticity.

Background Information

Making ‘smart’ choices about transport technologies

In the past decade, the transport sector has seen great progress in the advancement of smart technologies and solutions that can provide a range of benefits to urban residents and the local governments. There are several key innovative solutions that can provide enhanced mobility, accessibility, and connectivity. The way that these types of technologies are navigated will have a direct impact on city’s transport performance and the quality of life. Smart technologies can play vital role to connect a cities physical, digital, and natural resources. The main purpose of smart technology is to connect the city’s resources and assets – people, infrastructures, information, and services.

Smart technologies are increasingly being applied to cities that have been designed around private vehicles and despite the best of intentions progress to improve conditions is likely to be stifled by the sheer size of growth in car use, population, and urban densities, calling for shared transport options to be integrated into the urban form. Several technologies can then be employed to enhance the operation of the system and ensure that accessibility, safety, and quality of life are maintained as part of rapid urban growth. Cities around the world have deployed smart city type technologies in a range of functions to improve information about transport networks. However, in the last 10 years several new and powerful digital systems and software options have been developed that stand to significantly improve the functioning of transport systems, with a set of new options now finding early adoption.

Current Technologies for Smart Mobility

Real Time Information

Access to real time information allows the provision of information on mobile phones or public signs that can improve understanding of traffic conditions for road users and shared transit passengers. Real time information can also inform changeable speed limits, ramp metering timings on motorways, lane allocations to different modes, and anticipated trip times. The use of sensors in transport systems has a long history, however in more recent times the ability for these sensors to communicate via the internet in real time provides a unique opportunity to improve the management of transport systems. For instance, sensors can be used to change the cycle duration of traffic lights in response to real time traffic conditions, manage entry ramps on freeways to achieve improved vehicle flow rates, and monitor safety concerns to provide alerts and warnings. Access to real time information both from on-board sources and road-side sources will be a key enabler for driverless vehicles.

Information and Communication Technologies (ICT)

The term 'Information and Communications Technologies' (ICT) is widely known to refer to an integrated system of infrastructure, telecommunications and computer systems that enables users to access, store, transmit and manipulate data and information with the help of software devices. ICT can be used to connect three major elements of the transport system, namely: (i) Transport Facilities, (ii) Transport Modes and (iii) Transport users, in real-time. Basic components of an ICT system are landline telephones, radio signals, television broadcasts, and mobile phone coverage. More advanced ITS components include the internet, computers, smartphones, and digital televisions. The cutting-edge advance in ITS technologies includes Internet of thing protocols, artificial intelligence, advanced sensors, and big data analytics.

In recent years, a range of ICT options have been implemented by cities in their transport systems leading to improvements in traffic management, safety, and system efficiency. ICT technologies can be used to improve route selection and inform congestion management, reducing the air and noise pollution, and related greenhouse gas emissions. For instance, using GPS navigation software route selection can be reviewed in real time for transit and freight deployment, automatic license plate recognition is used by law enforcement agencies, and electronic tolling systems offer fast payments while providing real time road usage information. Roadside sensors are increasingly being used to monitor intersections and blind spots and notify of incidents, while on-board sensors are being used to detect and locate obstacles and alert drivers.

Electronic signboards are increasingly being used to display real time broadcast messages and information on congestion levels, road network conditions, changing weather condition, and roadworks locations to drivers. Advanced driver's assistance systems provide information to drivers in-vehicle related to best route options, public transit options, travel time and location, available facilities, and other travel solutions. Smart parking apps now allow drivers to identify, reserve, and pay for parking spaces to save time and fuel (with it being common for some 30% of CBD traffic consisting of people looking for a parking space). In addition, ICT can be used by Transport Agencies to inform the use of congestion pricing, resource optimization methods, digital video surveillance, and video analytics from multiple sources for risks identification.

Internet of Things (IoT)

The term 'Internet of Things' (IoT) refers to a network of physical objects which is known as "things" that are embedded with computers, robotics, sensors, automation, software, and other advanced technologies for connecting, functioning, and exchanging data with other computers, devices, and systems, connected by the internet. IoT allows communication between people, processes, and things by connecting physical and digital assets through connected embedded devices that interact and function as part of a network. With the help of computers, the cloud, big data, mobile and sensor technologies, hardware assets, data can be shared and collect with or without human involvement that can be used to improve the function of the system. The physical and digital systems can be recorded, monitored, analysed, and adjusted as necessary with feedback and commands able to be shared amongst connected devices. Because off its widespread application, IoT has become one of the most valuable functionalities of the 21st century.

IoT is widely used for the smart mobility solutions. Transport and logistics systems can benefit from a variety of IoT applications. Urban fleets such as private cars, public transit vehicles, and commercial vehicles that carry inventory can relate to IoT so that it is easier to track location and function. IoT allows drivers to understand traffic conditions, weather conditions, and consider the viability of alternative routes. In case of public transport, passengers can receive real time information around the location of the bus or train relative to the station, seat availability, price and payment methods, and last mile connectivity options. Cargo trucks, freight trains and/or the inventory itself could also be equipped with devices that can be tracked using various methods. This is of particular interest to the food and beverage industry that transports perishable vegetables, flowers, fruits, and meat that are temperature sensitive along with the pharmaceutical and drug industries that need constant temperature conditions. For example, using IoT the inventory could be connected to temperature-control monitoring sensors that send alert information when temperatures rise or fall to a level that threatens the product. Likewise, IoT sensors can inform systems that operate drones and self-driving vehicles and help fleet management services with preventative maintenance by detecting impending equipment failure.

Intelligent Transport Systems (ITS)

The term 'Intelligent Transportation System' (ITS) refers to application of information and communication technologies, as described above, in the transport system. ITS typically includes the application of visual sensing, data analytics, along with automated control and management of transport devices to improve safety, mobility, and efficiency. ITS can provide reliable information before the journey to help plan travel outcomes, select route and connect transport modes. ITS includes a wide range of applications that process and share information that can be used to reduce air pollution and congestion, improve road safety and traffic management, minimize environmental impacts, and increase the benefits of transportation system (Chowdhury and Sadek, 2022).[32] ITS plays a significant role in improving the mobility of people and goods by improving data used in operational decision making. ITS include a variety of tools such as sensing, communications, and computing technologies which improve the resilience and sustainability of transport system. By coordinating various data sources and analytics options ITS can assist driverless vehicle operation such as self-driving taxies, auto-vans, shuttle buses, trams, and trains, that will be key to making shared transit more affordable and reliable.

Benefits of ITS:

- Improved safety and security by providing early warning of potential congestion or collisions.
- Automated road safety inspections and maintenance management.
- Enables driverless shared vehicles that reduce operating costs and allow for smaller vehicles due to avoidance of driver costs.
- Improving traffic flow by informing congestion management, including predictive congestion management, leading to improved air quality and reduced GHG emissions.
- Detection of incidents across transport system to inform responses.
- Reduced occurrence of human error in traffic management leading to traffic incidents.
- Improve scheduling and reliability of shared transit modes through real/near-time information.
- Inform processes to increase network capacity by linking modes of transit, such as passenger journeys and freight connections.

Emerging Technologies for Smart Mobility

Even though there is a range of current beneficial technologies to support smart mobility efforts are limited due to the dependence on private vehicle use. Hence the real 'smart' choice is to ramp up the provision of shared transit services, especially along designated corridors, offering a range of vehicle types including private automobiles and shared transit modes. It is likely that growing congestion levels in several cities in the Asian region will call for a shift away from automobile dependence (Newman and Kenworthy, 2015)[33], driving urban transport planners to focus on shared-transit and multi modal solutions. This process starts with planning that conceives of appropriate ways to ramp up shared transit services in a manner that attracts development and reduces disruption to the current system. Such a transition will require a range of smart mobility technologies to achieve more effective mobility outcomes that are beneficial to multiple parties associated with the transport system. Such smart mobility technologies that can enhance chard modes include:

[32] Chowdhury, M., and Sadek, A. (2022) '*What is ITS'*, World Road Association, PIARC.
[33] Newman P. and Kenworthy, J. (2015) The end of automobile dependence: How cities are moving beyond car based planning. Island Press.

Bike-sharing and Car-sharing

Bike-sharing or car-sharing is widely used mode of transport where people rent bike or car for short periods of time. This method enables an occasional use of a vehicle in particular route or the area. Bike-sharing or car-sharing can be offered by government, public agencies, or the private sector. Users can unlock the vehicle in real time with the app, agree to insurance and liability conditions and the rate and pay for the trip. Many cities in the world are offering this facility that offer local and tourists to visit the city which helps to reduce the congestion and air pollution by reducing use of private vehicles. Bike and car-sharing offering more local place to visit that promote local business and companies. Currently, electric cargo bikes are also widely used to rental in number of cities that help to carry small amount of cargo in the short distance in city centres. Such sharing reduces many inner-city car journeys and improves urban environmental and public health conditions related to current vehicle fuel choices.

Mobility on Demand (MoD)

The mobility on demand is widely used modern-day smart transport option which doesn't need ownership of private vehicle. It is fast, efficient convenient mode of transport that gives access to all for a range of travel modes. This is cost effective, inclusive, and social mode of transport. Nowadays, as a part of low-carbon and green growth development electric vehicles are widely used for MoD. Integrated mobility on demand services can significantly contribute towards modal shift to public transport and addresses spatial inefficiencies of private mode of transport. However, in this system, small automobiles such as vans and car equipped with intelligent transportation systems are widely used.

Mobility-as-a-Service (MaaS)

Mobility as a service allows multimodal mobility options by providing user-centric travel information and services including navigation, location, booking and payment methods that allow traveller more freedom, better mobility options and seamless service across various modes of transport. App-based mobility platforms have the potential to allow for the integration of different transport modes such as shared transit options, taxi/Uber services, and last mile options including shuttles, scooters, and bicycles into a single user interface. By doing so users will be able to see different options for their travel, choose a combination of particular modes based on time and cost, and then make a single payment. Hence in cities where effective shared transit options are provided (such as a metro system or a light rail corridor) such a platform could steer people towards alternatives to car use. This could be done by removing barriers such as needing multiple tickets or being caught in the overlap between services and having to wait for long-periods for the next service.

Advanced Technologies for Smart Mobility

Big Data Analytics[34]

Using data to improve the management of transport networks is nothing new, however the coming decades will see a massive shift in how data is generated and harnesses which will completely change the game (Hargroves *et al*, 2017). Those that can quickly identify and access the important data and use it to enhance decision making will find it an immensely powerful tool; however, it has some complexity that is yet to be unravelled. For transport managers, efficient data access and use has the potential to enhance the ability to digitally simulate transport planning options, inform the greater utilisation of existing infrastructure and modal interconnections, and significantly improve disaster and emergency responses. However, after these early wins comes the real value, being able to predict issues or bottlenecks before

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[34] This section provides an edited extract by of the following report by its lead author: Hargroves, K., Stantic, B., Conley, D., Ho, D. and Grant, G. (2017) Big Data, Technology and Transport - The State of Play, Sustainable Built Environment National Research Centre (SBEnrc), Australia.

they occur. Given the right data and software this can be done by comparing historical records to real time data streams to see if current conditions are shaping up in a similar way to conditions associated with past issues, such as congestion hot spots.

When the term ‘Big Data’ is used, it typically means data sets that are so large they cannot be analysed using current methods. To get an idea of the scale we are talking about, consider that a study by transport researchers in Tokyo, that had access to GPS data from over 18,000 taxis across the city, generated some 360 million items of data per second. Given the scale of Big Data, this then calls for new computer-based data analysis software, referred to as ‘Big Data Analytics’. For example, software such as ‘Hadoop’ can analyse data on many servers at once to run traffic scenarios and has been shown to be able to carry out collision analysis on 2.4 billion vehicles in just ten seconds.

It is not news that there is more and more data available about the transport network and its users. Data has long been collected on traffic counts, average vehicle speed, weather conditions, and traffic signalling. This data forms a valuable database of historical conditions; however, what is more interesting is the promise of new types of data that will become available very soon, such as data streamed directly between vehicles and infrastructure. What is even more interesting, is how the plethora of data generated by our ever-digitising society can be harnessed for transport management, such as from social media, destination information and whatever is trending locally. So, the big question becomes, how can Big Data be harnessed to enhance transport management in our ever-growing cities?

Figure 3.1: Rio de Janerio Traffic Control Centre

As an example, Rio de Janeiro is an early leader in terms of integrating disaster sensing and management technologies. The city’s Traffic Control Centre receives footage from over 900 video cameras that is combined with 120 layers of associated data including data related to weather, emergency services, traffic conditions and utilities. The system has decreased the response time to natural disaster related emergencies in the city by 30 per cent (Berst, 2013).[35] Based on the premise that increased social media activity in particular areas during a disaster can correlate to areas of greatest need for assistance, researchers in Korea have designed a process to identify such areas to inform response efforts (Choi and Bae, 2015).[36]

[35] Berst, J. (2013) ‘Why Rio’s citywide control centre has become world famous’, *Smart Cities Council.*

[36] Choi, S. and Bae, B. (2015) ‘The Real-Time Monitoring System of Social Big Data for Disaster Management’, *Computer Science and its Applications*, Springer Berlin Heidelberg, pp 809-815.

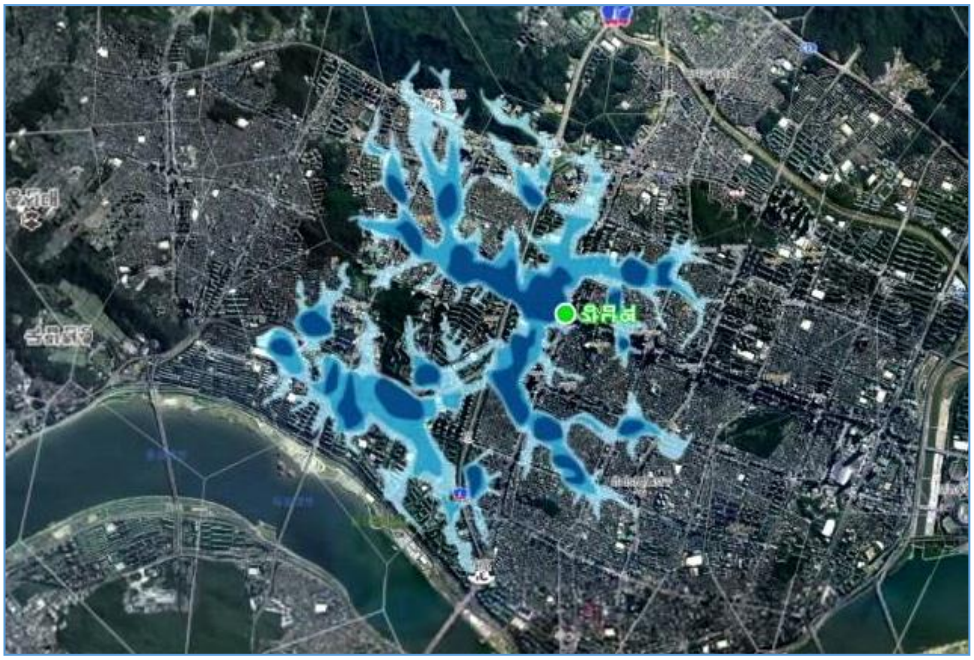

Figure 3.2: The 'Smart Big Board' mapping social media data flows during a disaster in Korea

Research by Australia's Sustainable Built Environment National Research Centre (SBEnrc) on the practical use of Big Data in transport has informed a set of recommendation for transport agencies namely:

- Be clear on the exact outcomes required from data analysis, ensure systems are tailored to these outcomes, and only store what is absolutely needed.
- Ensure existing data is harnessed fully and systematically consider accessing new forms of data that have strong utility.
- See if there is potential for sharing data between transport agencies with multi-jurisdictional data standards to ensure compatibility.
- Consider the development of specific policies to ensure privacy concerns associated with Big Data are appropriately handled, such as storing as de-identified or derived trends.
- Ensure that in the case that sensors are added to the network that they are located at high priority locations and can communicate with the selected data platforms.
- Decide on the format, language and syntax of data and ensure historic datasets are formatted accordingly.
- Ensure software platforms can integrate private, mass transport and social data to both undertake predictive analysis and run simulations on the network to inform optimal use of existing infrastructure to defer capital expenditure and maintenance.

Artificial Intelligence

Artificial Intelligence can be a powerful tool for learning how to manage and predict flows of objects, making it particularly useful for the transport sector (Hargroves *et al*, 2019).[37] Of particular interest is the ability for artificial intelligence to harness big data analytics to enable predictive congestion management by comparing historic data to real time conditions and then alerting operators when congestion conditions are likely to be experienced in the near future. Although a focus on Artificial Intelligence is not new,

[37] Hargroves, K., Conley, D., Ho, D., Grant, G. and Stantic, B. (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.

research by the Sustainable Built Environment National Research Centre (SBEnrc) has identified several new or underutilised applications that are truly relevant to the transport sector, such as (Hargroves, Stantic and Allen, 2020)[38]:

- *Traffic Management:* The 'Malaysia City Brain' created by Alibaba uses Artificial Intelligence to process data from traffic lights, CCTV cameras, public transport, and other data streams, to reduce traffic congestion and direct emergency services. Deployed in Hangzhou People's Republic of China (hereafter PR China) the system resulted in an average increase of 15 percent in vehicle speed.
- *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.
- *Traffic Signal Optimization*: The application of AI to optimize 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 Prioritization:* 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).[39]
- *Route Optimization:* Logistics company UPS has created an AI system called ORION (On-road Integrated Optimization 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 the 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.
- *Ridesharing:* German company Door2door has created an on-demand ride-sharing service that uses AI to optimizes 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 analyze camera images of travellers entering the metro entry barriers for suspicious behaviour resulting in a 70 percent decrease in fare evasion.

[38] 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.

[39] BITRE (2017) Costs and benefits of emerging road transport technologies, Report 146, Bureau of Infrastructure, Transport and Regional Economics, BITRE, Canberra ACT.

Blockchain Technology

Blockchain Technology provides a suite of new functionality that is very beneficial for the transport sector and can underpin smart city agendas. Blockchains work by providing an intermediary free trust protocol to allow decentralised and distributed computing services to be accessed anywhere in the world. According to the World Economic Forum, "*Blockchain enables network participants to exchange data with a high degree of reliability and transparency without the need for a centralized administrator. Cities have a variety of stakeholders and the exchange of data among stakeholders is essential for highly convenient urban services*".[40] This sentiment was reinforced by Forbes magazine, saying "*Blockchain is essential to create more secure, transparent, efficient and resilient cities. The use of Blockchain for smart cities can play a crucial role in city development and management, solving these societal issues and improving day-to-day operations".*[41]

Despite Blockchain technology being relatively new, and early applications such as cryptocurrencies experiencing challenges, there is 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 the applications identified by the Sustainable Built Environment National Research Centre (SBEnrc) that harness Blockchain-based platforms (Hargroves, Stantic & Allen, 2020):[42]

- *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 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 New South Wales, Australia. 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.

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[40] Hori, S. (2021) 'How Blockchain can empower smart cities - and why interoperability will be crucial', Word Economic Forum, 06 April 2021.
[41] Joshi, N. (2022) '6 Ways in Which Blockchain Makes Your Smart City Even Smarter', Forbes Magazine, April 7 2022.
[42] 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.

- *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.

Key Resources

- Hargroves, K., Conley, D. and Dia, H. (2018) Considering the Implications of Technology-enabled Transport on Investment in Transport Infrastructure – Final Industry Report, Sustainable Built Environment National Research Centre (SBEnrc), Australia.
- 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.
- 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.
- Hargroves, K., Stantic, B., Conley, D., Ho, D. and Grant, G. (2017) Big Data, Technology and Transport - The State of Play, Sustainable Built Environment National Research Centre (SBEnrc), Australia.
- Hargroves, K., Stantic, B., Newman, P., and Ho, D. (2017) Mining the Datasphere: Big Data, Technologies, and Transportation: Congestion Management, Sustainable Built Environment National Research Centre (SBEnrc), Australia.
- Newman P. and Kenworthy, J. (2015) The end of automobile dependence: How cities are moving beyond car-based planning. Island Press.
- Stantic, B., Allan, D. and Hargroves, K. (2019) Investigating the Viability of Artificial Intelligence and Blockchain Technology to Enhance the Transport Sector, Sustainable Built Environment National Research Centre (SBEnrc), Curtin University, Griffith University and RMIT Australia.

Module 4: Smart Low Carbon Mobility Solutions

Educational Aim

This module aims to provide an overview of key low carbon mobility solutions and focuses on the transition to electro-mobility and the associated opportunities. The Module provides details two leading forms of mid-tier transit to demonstrate how such technologies can be adopted cost-effectively in Asian cities.

Learning Points

1. Given the issues associated with fossil fuels, such as pollution, greenhouse gas emissions, high running costs, volatile fuel prices etc, many nations of the world are now focusing on low carbon transport options. Much of this focus has been on electrification of mobility with early efforts often focused on buses, trams and trains, while private purchases of electric cars has substantially increased.
2. Over the coming decade the supply of electricity to vehicles will be an important infrastructure consideration in cities, resulting in a merger of the interests of the energy and transport sectors in new ways. This is likely to involve a shift from a focus on charging stations to a focus on managed changing of EVs to compliment the electricity grid.
3. It is difficult, if not impossible, to predict the uptake of EVs over time to a level of assurance suitable to inform public policy and decision making, mostly because it will be driven by consumers, hence the question is not whether the transition will happen, but rather how quickly cities will respond and position themselves to capture the associated advantages and deal with the associated risks.
4. The widespread adoption of EVs will present both risks and with the level of 'government ambition' influencing how much of each is experienced, with higher ambition leading to lower risk and greater opportunity. Government ambition can be communicated through a range of mechanisms, including policy, standards, financial incentives, infrastructure investments and awareness campaigns.
5. It is likely that most electric vehicles will be charged overnight at home using equipment provided with the vehicle to take advantage of off-peak tariffs. However, this is the least advantageous outcome for the energy sector with the batteries in vehicles not available to the grid during the day, meaning EV owners and operators will largely miss out on the opportunity to be compensated.
6. It is clear however that the world is now moving beyond early adopters of EVs and will see an increasing rate of uptake due to much lower running cost for EVs compared to internal combustion engine vehicles with comparative driving ranges.
7. In the longer term there will be a number of implications for Transport Agencies including: the opportunity to provide daytime charging facilities at different charging rates for both private and commercial customers; the opportunity to provide grid services using out-of-service vehicles such as buses, trains, and government agency fleets; and the need to develop effective road user pricing mechanisms.
8. Bus Rapid Transit systems provide a number of low carbon benefits, such as the Guangzhou BRT in PR China, the first of its kind in PR China to collaborate with private sector operators. The system has 26 stations, each designed as multi-modal transport hubs, and has saved People's Government of Guangzhou Municipality an estimated US$14 million due to increased patronage.

9. In the first year of operation alone, the system prevented the emission of an estimated 45,000 tonnes of CO_2, and has reduced the emissions of particulate matter by four metric tonnes annually. From a transport efficiency perspective, the speed of buses travelling in the corridor has increased by 29 percent.
10. The trackless tram has the potential to provide a mass transit solution for cities that are struggling with congestion and air pollution, but without the need to construct rails and disrupt cities' transport networks. Trackless trams are characterized by using rubber tires rather than rails (avoiding the majority of construction costs for light rail alternatives), being fully electric with fast charging on-route (using batteries with 25-year lifespans), and being driverless, although a driver is often providing assistance when needed.
11. Non-motorized transport friendly policies, planning, and infrastructural development are essential for developing smart cities and achieving safe and clean mobility for all.

Background Information

Given the issues associated with fossil fuels, such as pollution, greenhouse gas emissions, high running costs, volatile fuel prices etc, many nations of the world are now focusing on low carbon transport technologies that use cleaner fuels and have enhanced vehicle performance, efficiency and safety.

Much of this focus has been on electrification of mobility with early efforts often focused on buses, trams and trains, while private purchases of electric cars has substantially increased. Such vehicle upgrades need to be complimented by improved traffic management and transportation planning, appropriate vehicle inspection and maintenance approaches and a raft of low-carbon mobility policies, standards and codes.

The Transition to Electro-Mobility

Over the coming decade the supply of electricity to vehicles will be an important infrastructure consideration in cities, resulting in a merger of the interests of the energy and transport sectors in new ways. As part of the preliminary stages of the transition to electro-mobility the focus has been on the provision of charging stations or charging docks to provide power to electric vehicles (EVs). However due to a significant increase in vehicle range in recent years the focus has shifted to managing charging of EVs at the home or workplace so that they can both be charged and also contribute to local scale energy storage. Research by the Sustainable Built Environment National Research Centre (SBEnrc) suggests that:[43]

1) It is difficult, if not impossible, to totally predict the uptake of EVs over time to a level of assurance suitable to inform public policy and decision making, mostly because it will be driven by consumers, hence the question is not whether the transition will happen, but rather how quickly cities will respond and position themselves to capture the associated advantages.
2) The transition to EV saturation is now well underway globally, is unstoppable, and is likely to follow a standard innovation diffusion curve, with a slow rise followed by a period of rapid uptake reaching saturation sometime before 2050.
3) The widespread adoption of EVs will present both risks and opportunities (with risks experienced by those who are slow to move, and opportunities able to be captured by those who prepare carefully and take early and strategic action) with the level of 'government ambition' influencing how much of each is experienced, with higher ambition leading to lower risk and greater opportunity.
4) As with other waves of innovation, even in the initial stages, electro-mobility is already causing disruption to existing systems, due in part to the contribution to the increased rate of uptake of distributed energy resources affecting existing grid conditions, and in part to the fact that electro-mobility will see the need for an unprecedented nexus of transport, energy, and development sector interests.

One of the reasons it is difficult to effectively predict the uptake of EVs is due to the fact that there are a range of interconnected factors that may influence uptake and it is not clear what the relative influence will be, which has resulted in varying predictions. For instance, it is not clear what level of public charging facilities will be needed to facilitate greater uptake, with some calling it a major constraint and others saying it will have negligible impact due to extended ranges of newer EV models. It is likely that most electric vehicles will be charged overnight at home using equipment provided with the vehicle to take advantage of off-peak tariffs.

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[43] This section provides an edited extract by of the following report by its lead author: 'Hargroves, K. and James, B. (2021) Perception and Capacity Factors affecting the Uptake of Electric Vehicles in Australia. Project 1.74B - A Report to the Sustainable Built Environment National Research Centre (SBEnrc), Australia.'

However, this is the least advantageous outcome for the energy sector with the batteries in vehicles not available to the grid during the day, but rather increasing the base load requirement overnight – recognised by the Western Australian Government 'Distributed Energy Resources Roadmap' considering "*incentives to promote daytime charging to help make best use of the midday solar generation peak.*"[44] Hence it is likely that if left to ad hoc efforts the early majority of EVs will not be available for storing excess renewable energy during the day, to assist in balancing loads across the grid to compensate for the rapid rise of small-scale distributed energy generation (such as rooftop solar), or to contribute to the grid supply during times of peak demand. This means that because such services are not available at times that make sense to the grid, EV owners and operators will largely miss out on the opportunity to be compensated. In this scenario – effectively a 'Home-Range Scenario' – in the short term there are few implications for Transport Agencies other than to forgo compensation from fleets and to potentially provide long haul rapid charging along intra-city routes (Government of WA, 2021).[45]

It is clear however that Australia will soon move beyond early adopters of EVs and see an increasing rate of uptake due to shifts in three key factors, namely:

1) The running costs of EVs are now some 60 percent lower than internal combustion vehicles (ICV) and the purchase price is decreasing rapidly and will soon reach parity - for instance, the purchase price of the Toyota Camry Hybrid EV being just $3,000 more than the internal combustion version.
2) The median range of EVs is now over 400 km (about 248.55 mi) and maximum range over 600 km (about 372.82 mi), which will dispel concerns around range for the majority of users.
3) The majority of EV owners will be able to charge their vehicles cheaply and easily overnight in their home, dispelling most concerns about the lack of road-side charging options.

Hence as the uptake of EVs increases the opportunity costs associated with overnight charging will increase and this will highly likely lead to a focus on shifting charging (and discharging) to periods where it can be of most utility to the electricity grid (also beneficial to the EV owner) – namely during the day, and especially during times of peak renewable generation and peak grid demand. In the longer term there will be a number of implications for Transport Agencies including:

– The *opportunity to provide daytime charging facilities*, mainly for slow-medium charging in car parking areas throughout the day for commuters (such as public transport parking areas), and for rapid charging at shorter stay destinations such as shopping centres and other hubs for those that cannot access home or work charging options.
– The *opportunity to provide grid services* using out-of-service vehicles such as buses, trains, and government agency fleets that can be connected to the grid to provide storage and balancing services at appropriate times to create value.
– The need to *develop effective road user pricing mechanisms* to allow EV users to contribute to costs associated with the road network that is currently supported through taxes on fossil fuel sales – which will decline over time as EV uptake increases.

However, realising the opportunity cost of having the majority of EVs charging overnight in private homes and facilities by shifting charging to times to suit and optimise the grid will require careful consideration of a number of additional factors, namely:

[44] Government of WA (2019) Distributed Energy Resources Roadmap, Energy Transformation Taskforce, Government of Western Australia.
[45] Government of WA (2021) State Electric Vehicle Strategy for Western Australia: Steering Towards a Clean Energy Future, Department of Water and Environmental Regulation, Government of Western Australia.

- The built environment will need to be upgraded to provide bidirectional charging facilities, mainly in private dwellings, commercial facilities, public short stay destinations, and public and private car parking areas).
- The electricity grid will need to be upgraded to accommodate such bidirectional charging facilities, which will include a mix of slow and fast charging options depending on the location, which will have direct implications for the stability of the grid.

It is clear that the level of government ambition directly affects the rate of uptake of EVs and such ambition can be communicated through a range of mechanisms, including policy, standards, financial incentives, infrastructure investments and awareness campaigns. Various developed nations have initiated incentives, such as Norway reducing taxes and parking fees on Evs, (Fridstrøm, 2021)[46] and each of the G7 countries offering purchase incentives, which have contributed to increasing uptake of EVs (IEA, 2020).[47] Understanding that both monetary and fiscal policy can affect uptake of EVs it is recommended that careful consideration is given to the relative risks and opportunities associated with different levels of government ambition, namely:

1. *A Passive EV Approach*: As part of a passive approach the uptake of EVs is not actively encouraged or supported, with efforts to respond being held until risks manifest, resulting in limited opportunities to capture benefits.
2. *A Pre-Emptive EV Approach*: As part of a pre-emptive approach little is done to actively encourage or support the uptake of EVs, but efforts are initiated early to respond to both perceived short-term risks and opportunities.
3. *A Pro-Active EV Approach*: As part of a pro-active approach the uptake of EVs is actively encouraged and supported, and swift action is taken to respond to short and longer-term risks and opportunities.

Bus Rapid Transit

Guangzhou, Peoples Republic of China[48]

Guangzhou is located in the Guangdong Province in PR China and is one of the country's largest cities, with a population as of 2013 of 13.08 million. In February 2010, the city introduced a Bus Rapid Transit System (BRTS) with the objective of reducing congestion and air pollution. The BRTS comprises of a corridor spanning 22.5kms with dedicated lanes for Rapid Transit Buses. However, buses are not restricted to the 22.5km corridor and some routes extend beyond the corridor resulting in an additional 250km of additional distance for commuters to travel. Approximately 805,500 people make use of the BRTS per day with 350 buses transiting in the same direction per hour (CCAP, 2012).[49]

The BRT was implemented collaboratively between the Guangzhou Traffic Improvement Office, the Guangzhou Public Transport Management Office and The People's Republic of China's Institute for Transportation and Development Policy (ITDP), with support from the City of Guangzhou. ITDP provided technical assistance on bus route network design, rider research and bus frequency scheduling. The collaboration led to construction and implementation of the system in only one year, with key provincial

[46] Fridstrøm, L. (2021) The Norwegian Vehicle Electrification Policy and Its Implicit Price of Carbon. *Sustainability* 2021, 13, 1346.
[47] IEA (2020) Global EV Outlook 2020: Entering the decade of electric drive? International Energy Agency.
[48] Edited extract by the lead author of Hargroves, K., Conley, D., Spajic, L., and Gallina, L. (2018) 'Sustainable Urban Design Co-Benefits: Role of EST in Reducing Air Pollution and Climate Change Mitigation', Background Paper for UNCRD Eleventh Regional EST Forum in Asia, Mongolia, Ulaanbaatar, 2-5 October, 2018.
[49] CCAP (2012) Developing Sustainable Transportation with the Guangzhou Bus Rapid Transit System and Multi-Modal Transport Network, Centre for Clean Air Policy, Washington DC.

and level officials providing official endorsement of the system (ITDP, 2010).[50] The BRT system was also the first of its kind in The People's Republic of China to collaborate with private sector operators and employs multiple competing companies which encourages competition between them on price and service quality, increasing the benefit to the public.

Figure 4.1: Zhongshan Avenue, Guangzhou

The BRT system forms part of a multi-modal transport network situated along Zhongshan Avenue. The system's 26 stations have bike parking and bike sharing facilities available for use, coupled with dedicated walkways, green corridors, and bike lanes to provide greater access to the BRTS for commuters (CCAP, 2012). The BRT was the first globally to co-design and implement cycle ways in conjunction with the BRT. Importantly, the BRTS connects directly with the existing metro system (ITDP, 2010). The 22.5 km corridor passes through multiple land uses such as residential areas, universities, public parks, and industrial areas (Hughes and Zhu, 2011).[51] A reported USD $14 million has been saved by the People's Government of Guangzhou Municipality since the introduction of the BRTS in 2010, which is attributed to the higher efficiency of the system (more riders per bus), leading to fuel savings per person across the fleet (CCAP, 2012). This is before any other benefits such as climate mitigation or health benefits are considered.

In the first year of operation, the system prevented the emission of an estimated 45,000 tonnes of CO2, with this figure estimated to increase to 100,000 metric tonnes by the year 2019 (Hughes and Zhu, 2011). Additionally, the BRTS reduces the amount of particulate matter by an estimated average of four metric tonnes annually, reducing the health implications to humans (CCAP, 2012). From a transport efficiency perspective, the speed of buses travelling in the corridor has increased by 29 percent. The speed of other forms of traffic in the corridor has increased by 20 percent allowing considerable time savings for commuters due to the reduction in congestion (Hughes and Zhu, 2011). This is attributed to the

[50] ITDP (2010) Guangzhou Bus Rapid Transit System. Institute for Transport and Development Policy.

[51] Hughes, C., and Zhu, X. (2011) 'Guangzhou, China Bus Rapid Transit Emissions Impact Analysis', The Institute for Transportation and Policy Development, New York.

segregated BRTS lanes which increase access for commuters to buses and ease of mobility for bus operators. It is estimated that a total of 35 million hours were saved annually for BRTS commuters totalling a benefit to the economy of USD $16 million (Hughes and Zhu, 2011). The implementation of the BRTS received the global Sustainable Transport Award in 2011 (CCAP, 2012).

The BRT extends past city centres with the intention of providing transit access to rural residents to increase employment opportunities. This also has had the co-benefit of increasing tourism to rural areas. Added social benefits have come in the form of reduced out of pocket bus trip costs, by a factor of almost two, and a 50 percent increase in cycling in some areas. The reduction in congestion and disorganized traffic has increased the proportion of the population that feel safe walking around Zhongshan Avenue from 28 percent to 68 percent (Hughes and Zhu, 2011). This corresponds to an increase in walking, further reducing congestion and providing the benefits associated with increase physical modes of transport. Despite the broad success of Guangzhou's BRT, there are some self-reported areas for consideration for cities seeking to implement such an initiative. It is important to balance the overwhelming demand for the BRT system with still maintaining some consciousness of the road system and its users, as adding too many buses can also result in congestion. A thorough operations analysis should be conducted to determine how many routes and segregated lanes should be constructed. Additionally, larger allocations of space to cyclists and pedestrians can be provided to deal with overwhelming demand for the BRT system.

Seoul, Republic of Korea

The BRT system in Seoul has been shown to be a cost-effective system for improving connectivity of city areas for economic and social invigoration of adjacent zones, presenting a lower risk investment for attempts to create new growth as part of a focus on Transport Orientated Development (Hughes and Zhu, 2011).[52] Bus Rapid Transit (BRT) offers a flexible shared transit service which can be integrated with the broader transport system. The use of BRT in Seoul doubled the average speed of public buses across their routes, decreased the number of bus-related accidents, and reduced total travel times. Solutions such as a BRT or a Trackless Tram offer the opportunity for sophisticated shared transit in cities or countries where funds are not available for fiscally intensive systems such as railways and metro systems, while complementing dense populations, especially transport between two densely populated communities.

The BRT system offers flexibility and cost effectiveness from the contrast of rubber-tire buses to fixed-rail train systems. This is especially suitable in low-density population areas, where ridership will be lower and does not need more intensive transport (Cervero and Kang, 2009).[53] Seoul initially operated curbside bus lanes in 1986, however with increasing conflict with traffic entering the corridor and the high flow of buses, the city shifted some curbside lanes to operate as median lanes, in a BRT – helping double the average speed of buses. The improved connectivity and quality of service to areas more distant from city centers via BRT generated more intensive use of land around BRT stations, with increased population density and mixed-use projects. Residential land prices increased 5-10 percent for residents in close proximity to BRT stations, and increased 3-26 for non-residential land (Kwon, 2010).[54]

[52] Cervero, R., and Kang, C. (2009) 'Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea', University of California Berkeley Center for Future Urban Transport.
[53] Cervero, R., and Kang, C. (2009) 'Bus Rapid Transit Impacts on Land Uses and Land Values in Seoul, Korea', University of California Berkeley Center for Future Urban Transport.
[54] Kwon, Y. (2010) 'Seoul BRT', The Korea Transport Institute, Presentation to UNCRD 5th EST Forum, Bangkok.

Hubballi-Dharwad, India

Various Indian cities have introduced BRT systems to provide more reliable and efficient services, such as Ahmedabad. The transport authority operates a website for improved accessibility to BRT services, providing information about service status, trip planning and fares (Ahmedabad Janmarg Limited, n.d.).[55] Hubballi and Dharwad form a twin city, as a paired commercial hub and administrative center. The cities have implemented a new BRT for more effective and safer connectivity, particularly improving safety for women. The buses have a frequency of about three minutes, reducing commute times by 25 percent (Gupta, 2020).[56] The Hubballi-Dharwad BRT found success from a number of planning factors. The corridor was planned along a major road where 70 percent of commuters used city buses, however buses made up less than ten percent of passenger vehicles. Hence the road was widened from 4 to 8 lanes, reserving 3-4 lanes for the BRT system.

Figure 4.2: BRT Station in Ahmedabad, India (*Source*: Ahmedabad Municipal Corporation)

Additionally, the BRT corridor is part of a coordinated comprehensive transport system that prioritizes commuters by: providing dedicated bus lanes; air-conditioned buses; easy boarding portals; easy fare collection; convenient stations in the city; access to complementary city and rural bus services; service information accessibility for passengers via integration with ITS; and modern traffic management systems. The project was comprehensively planned in consultation with public and private stakeholders across commercial, institutional and religious interests, to generate considerate and useable designs, culminating in an apparently rapid project runtime of five years. The project was governed by a single agency, however all stakeholders held equity in the project to motivate best performance and rewards from project success. The cities' primary motivation for the BRT and its successful design and commissioning is the focus of moving people, not providing greater access for private vehicles. Hubballi-Dharwad recognize that the provision of quality shared transit systems will advance their cities by connecting people, spaces and economies – particularly via cost-effective, time-efficient and road-space-efficient solutions like BRT (Gupta, 2020).[57]

Light Rail Transit

Toyama, Japan

Toyama, the capital of Toyama Prefecture is located on the coast about 250 km northwest of Tokyo with an estimated population of just over 415,000 people in 2019 over an area of 1,240 km^2. Toyama is a global role model and is well known for its compact city development and transformation of urban mobility and shared transport systems, however this took a concerted effort to change the situation. Between 1989 and 2004, passenger numbers in railways fell by up to 44 percent, trams by 43 percent and buses by 67 percent. In 2000, Toyama city was facing a range of urban challenges such as low population, low population density, aging and declining population, automobile dependence and poor mobility

[55] Ahmedabad Janmarg Limited (n.d.) Welcome to Ahmedabad Janmarg Limited, Government of India.
[56] Gupta, N. (2020) 'India: New Bus Rapid Transit System makes travel faster, safer and more convenient in Hubballi-Dharwad', World Bank.
[57] Gupta, N. (2020) 'India: New Bus Rapid Transit System makes travel faster, safer and more convenient in Hubballi-Dharwad', World Bank.

accessibility, connectivity with urban sprawl. In response, the city introduced a Central District Revitalization Plan in 2003 and Public Transport Revitalization Plan in 2007. As a result of the plans, new residential properties along the promoted transit lines increased 32 percent from 2004-2009.

These plans focused on investing in shared transit services as part of promoting new urban development along modernized transit corridors in order to regenerate the city, including the redevelopment of the Toyamako Railway Line as a light rail service with responsibilities shared between public and private entities. The tram conversion increased ridership to 5 million passengers in the initial 2.5 years of operation – taking four times the riders during workhours on weekdays (doubling through overall weekdays) and seven times on holidays. The tram conversion has resulted in an increase of elderly ridership with the largest ridership age group aged 50 to 70 years old, and on weekdays passengers older than 50 make up over 54 percent of riders, increasing to 65 percent on holidays – due to high convenience in the high frequency of services (hence no need to check timetables), high-level of accessibility and low fare for seniors. The tram conversion is deemed successful by the breakdown of the new overall ridership profile, having expanded to be 50 percent existing previous Toyamako railway line users, 13 percent and 12 percent shifting from buses and cars respectively, and 20.5 percent entirely new – mostly people who did not have previous access to services, such as the elderly.[58]

Toyama city also introduced a 24-hour bicycle sharing system that operates across 17 stations amongst redeveloped and revitalized precincts including market, cultural and economic hubs. The Toyama development resulted in average city and commercial district land prices increasing by 0.2 and 0.8 percent respectively from July 2013 to July 2014, after two decades of declining land prices.[59] Shared transit ridership increased by 110 percent during weekdays and 240 percent during weekends, highlighting improved connectivity and accessibility of the new services. Another Toyama tram line success is the PORTRAM - an improvement to the JR Toyama port line - which has increased line ridership by 2.2 times during weekdays and 5.3 times on the weekend, while ridership of elderly users over 60 years old increased by 3.5 and 7.4 times in these periods, respectively. The PORTRAM also implements accessibility and urban-environment cohesion to provide improved accessibility (JTPA, 2012).[60]

The success of Toyama stems from collaboration in the plan's vision (coordinating the population's needs amongst private and public stakeholders investments), diverse funding sources (alleviating small city budget constraints, across private and multi-tiered public funding), collaborative place making via value-adding social interactions (engaging local users of space for residence and business with government and agencies to create community and want of place), land use incentives to alleviate challenges in conventional planning and land management laws (such as subsidies, tax structures and improved facilitation) (TDLC, 2015).[61]

The Trackless Tram[62]

There are a suite of new technologies emerging that are set to significantly change many facets of the transport sector. Perhaps-those that receive the most hype are the likes of autonomous driving technologies, which are envisioned to drastically improve the functionality of transport systems. The reality is, however, that autonomous vehicles will not solve the fundamental transport problems,

[58] Muro T. (2009) Forming a Compact City with Light Rail Transit, Japan Railway & Transport Review

[59] Tokyo Development Learning Centre (nd) Forming a Compact City with Light Rail Transit, Government of Japan and The World Bank Group.

[60] JTPA (2012) Japan's Light-Rail Transit, Japan Transportation Planning Association.

[61] TDLC (2015) Forming a Compact City with Light Rail Transit, Tokyo Development Learning Centre Government of Japan and The World Bank Group.

[62] Edited extract by the lead author of 'Hargroves, K., Conley, D., Spajic, L., and Gallina, L. (2018) 'Sustainable Urban Design Co-Benefits: Role of EST in Reducing Air Pollution and Climate Change Mitigation', Background Paper for UNCRD Eleventh Regional EST Forum in Asia, Mongolia, Ulaanbaatar, 2-5 October, 2018'.

especially if they are not operated with greater focus on shared occupancy (image a generous portion of road travel being empty autonomous cars seeking their next passenger). Innovators in ZhuZhou however, are leveraging emerging technologies in a way that overcomes barriers to mass-transit and achieved higher occupancy, electrified, autonomously guided 'Trackless Trams'. The technology can be seen below and is currently being trialled as a substitute for light rail. The trackless tram has the potential to provide a mass transit solution for cities that are struggling with congestion and air pollution, but without the need to construct rails and disrupt cities' transport networks.

Figure 4.3: The Trackless Tram in ZhuZhou, PR China (*Source*: Compliments of CRRC)

Figure 4.3 shows the Trackless Tram in action. The Trackless Tram is capable of carrying between 300 to 500 passengers, depending on the number of carriages that are used (3 or 5), and is capable of travelling at 70km/hour on road surfaces such as is seen in the image. Assuming an average speed of approximately 50km/hour (with stops factored in), there is potential to carry as much as 20,000-30,000 people per hour of lane space (which is more than light rail under the assumption that stops could be spread further out) in comparison to private vehicles' ability to carry an average of 2,500 people per hour of lane space, as shown in Table 4.1.

Table 4.1: Estimations of average patronage capacity for various transport modes. (*Source*: Compiled from Newman and Kenworthy, 1999[63], 2015[64])

Transport Mode	**Average Passengers per hour per lane**	**Multiples of car capacity in a suburban street**
Car in suburban street	1,000	1
Car in freeway lane	2,500	2.5
Bus in traffic	5,000	5
Bus in freeway lane (BRT)	10,000	10
Light Rail or Trackless Tram	20,000	20
Heavy Rail	50,000	50

[63] Newman, P. and Kenworthy, J. (1999) Sustainability and Cities: Overcoming Automobile Dependence. Island Press.
[64] Newman P. and Kenworthy, J. (2015) The end of automobile dependence: How cities are moving beyond car based planning. Island Press.

According to Newman and Hargroves *et al* (2019)[65], three distinctive technical features of the Trackless Tram in comparison to conventional light rail are:

- *Rubber tyres rather than rails:* Rather than running on rails like conventional light rail carriages, the trackless tram runs on rubber tyres (like a bus). Therefore the vehicle is essentially ready to operate on many existing asphalt or concrete road surfaces. From a construction perspective, there is no need to spend extensive time excavating streets, therefore reducing disruption to businesses, homes and traffic. Instead, road space is committed to the Trackless Tram, with this preferably being parking space that can be utilised.
- *Non-polluting electric:* The Trackless Tram is powered by lithium-titanate batteries that are located on the roof of the carriages. The batteries have a 25-year lifespan, charge faster than lithium-ion and perform better in cold conditions. Rapid charging occurs when the vehicle is stopped at stations and can be fully charged at depots. These vehicles also employ regenerative brakes for additional battery recharge.
- *Autonomous:* The Trackless Tram uses guided autonomous 'rail' technology to navigate along a corridor based on GPS and other positioning technologies to detect obstructions such as other vehicles and pedestrians. This allows for precise docking with station platforms, smoother ride quality, and variation in route to avoid over-wearing or rutting of pavements, while allowing a driver to override when needed, such as to drive around an unexpected obstruction.

The capacity of the Trackless Tram and the fully electric nature means that coupled with renewable energy such as solar power at stations for charging, there is a likelihood of reducing the amount of private motorized vehicles travelling down a particular corridor, reducing greenhouse gases and air pollution. Additionally, the Trackless Tram still has fixed stations. This is important because it retains commuter confidence (which bus networks do not achieve as successfully), while also creating land use development potential in surrounding vicinities, enabling TODs to be developed that attract private investment.

High-Speed Rail

Japan operates the first high-speed railway in the world – the Shinkansen since 1964 – with speeds up to 320 kilometers per hour and precision service. The average train delay is just 36 seconds and trains perfectly align to platform markings for improved passenger flow. Automatic train control and automated schedule management used by a disciplined team of operators ensure punctuality. The system hosts earthquake warning systems to immediately halt a train in such an event in earthquake prone Japan. Noise pollution in Japan is heavily mandated and the Shinkansen has been engineered to conform. In the 50 years of operations between Tokyo and Osaka, there was no passenger deaths or injuries due to accidents. This line has a ridership of 420,000 per weekday, making it the busiest in the world. The network services most of the country and moves millions of people per day, connecting directly with other PT services. The total number of passengers served between 1964 and 2009 is 9.2 billion. The network is currently expanding with the construction of the Chuo Shinkansen maglev line, capable of travelling at 505 kilometers per hour (Japan Station, 2022; MLIT, 2008).[66,67]

High-speed rail is a cost-intensive transit mode. Capital costs in the Japanese Shinkansen were minimized by compact design – tunnels are small given train size due to required aerodynamic profile; the carriages have compact layout maximizing space; and distances between tracks is minimal compared to other high-

[65] 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, Scientific Research Publications.
[66] Japan Station (2022) Shinkansen high-speed train network in Japan, Netmobius.
[67] MLIT (2008) 'Shinkansen Japanese High-Speed Rail', Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan.

speed railway designs. Maintenance costs were reduced by installing concrete rail beds – compared to more rapidly degrading gravel beds – returning investment in under 9 years. High-speed rail has provided a range of benefits: lower transit time increasing time for travelers to spend at destinations (often consuming more goods and spending more money); expanding peoples' range of activities (from greater connectivity between people and tourist destinations); and raised real estate value near stations. Economic growth in Kagoshima Prefecture grew by more than JPY46 billion (USD430 million) when the Shinkansen was introduced to the area. More recently, stations have been redeveloped as shopping malls to suit passengers passing through in high volumes. Stations are now hubs of economic and social activity, rather than just transit nodes (Government of Japan, 2014).[68] While Japan has constructed dedicated Shinkansen lines, the conversion of existing railway meant retrofitting the technology. The 'Mini-Shinkansen' largely involved implementing high-speed technology on a narrower gauge than optimal in regular Shinkansen, as well as consideration of narrower railway corridors and tunnels, meaning a maximum train speed of 130 kilometers per hour (Shinkansen Trains, 2022).[69]

PR China has deployed high-speed rail at a pace faster than any other country in the world, installing nearly 38,000 km of lines since 2008, half of which since 2017, to provide access to services at up to 350 km/h to some 75 percent of Chinese cities with populations over 500,000. The network is planned to double to by 2035. PR China has successfully employed its construction abilities to leap-frog network technology progression timeframes of European and American networks, to have one of the world's most comprehensive and leading high-speed networks. PR China has successfully demonstrated efficiency by utilizing modern technologies appropriately, with over 80 percent of tracks elevated above dense city traffic and valuable land. The system has driverless trains, expanded passenger carriage spaces, along with facial recognition for check-in and machine-interface assistance. The network has expanded national design capabilities, with network conditions spanning between -50 degrees to 50 degrees Celsius. PR China is expanding the network as part of the Belt and Road Initiative (BRI), with innovative gauge-changing wheelsets which will allow trains to run directly into adjacent countries' railway systems (Jones, 2022).[70]

Non-Motorized Transport (Walking and Cycling)

Non-motorized Transport (NMT) is defined as an active mode of transport that is fueled by human or animal power which includes walking, biking, skates, rickshaw, animal carts, animal skates, push scooters, human power boats, hand carts and wheelchairs, among others. It is a very sustainable mode of transport and provides first mile and the last mile connectivity. It is extremely attractive and enjoyable too, primarily for short distances. NMT is widely used for short trips and provides better facilities to access job, markets, schools, agricultural fields, and other activities. It is a main sustainable transport mode for urban poor in developing counties that significantly helps their livelihood by providing access to essential utilities, activities, and services.

Walking and cycling are a dominant and active mode of transport that is widely used all over the world. NMT makes up the largest share of urban mobility in developing countries by connecting shared transit systems. Although NMT is widely used in developing countries, it is gaining popularity in developed countries as an active, clean, and green means of transport that has almost no transport externalities like air and noise pollution or GHG emissions. Although a large number of trips are made by NMT in cities in developing countries, bicycle infrastructures and pedestrian facilities have been mostly neglected in these cities. As automobile transportation is a priority, many governments in developing countries have less

[68] Government of Japan (2014) The Shinkansen, Japan's High-Speed Rail, Is Full of Miracles, Government of Japan.
[69] Shinkansen Trains (2022) Shinkansen Trains, Shinkansen Trains.
[70] Jones, B. (2022) Past, present and future: The evolution of China's incredible high-speed rail network, CNN Travel, CNN.

priority for investment in NMT. Therefore, most users of NMT in developing countries are usually urban poor who do not have any other alternative for transport choices.

In recent year, due to widespread awareness of global climate change and the gaining popularity of the use of NMT in developed countries, many developing countries are showing interest in making NMT infrastructure and services. For instance, the Philippines has goals for achieving significant shifts from road-based transport to more sustainable options including active transport such as walking and cycling, developing over 500 km of bike lanes in the past year (UNCRD, 2021).[71] However, in majority of developing countries, the infrastructure for NMT is mostly inadequate and poor in quality.

For smart city development projects, it is essential to make good-quality infrastructure for NMT. Therefore, smart city policymakers and planners in developing regions should consider the NMT as an essential part of their transport system and make necessary investments for appropriate NMT infrastructure development. Improvement in NMT transport infrastructure and services can attract new users by shifting from motorized transport to NMT which helps to reduce transport externalities. NMT-further help for achieving safe and clean mobility for all.

There are several co-benefits of NMT which include-

- Lower the air and noise pollution
- Reduce traffic congestion and road accidents and fatalities
- Energy conservation
- Reduce vehicular emissions/GHG emissions
- Improve public health and fitness
- Increase travel options that improve the urban mobility
- Attractive and livable communities
- Increase local property value
- Social integration and social interaction
- Local area vibration and increased aesthetic value of the local community
- User enjoyment and cost-saving
- Socioeconomic development
- Reduce crime and improve safety and security
- Encourage land use panning

[71] UNCRD (2021) 'Next Generation Transport Systems for Achieving SDGs and Carbon Neutrality – for a Safer, Affordable, Accessible and Resilient Asia - Forum Summary', 14th Regional Environmentally Sustainable Transport Forum in Asia, 18-20 October 2021, Aichi, Japan (Hybrid Online Forum)

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- Government of WA (2019) Distributed Energy Resources Roadmap, Energy Transformation Taskforce, Government of Western Australia.
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Module 5: City Scale Smart Mobility Options

Educational Aim

The aim of the Module is to discuss how portfolios of smart mobility choices can be combined to deliver city wide smart mobility options. The Module discusses the use of land value capture around station precincts as a viable method to attract private finance to develop new shared transit corridors in cities and provides examples from PR China, India and Iran.

Learning Points

1. Taking a city scale approach to mobility is not a new concept with a number of Asian cities railway companies augmenting transport revenue through real estate development and management around stations to create travel demand.
2. One of the challenges being faced by governments all over the world is a lack of finance for infrastructure projects, calling for innovative ways to obtain finance for shared transit services. There are a number of ways this can be done, however overwhelmingly the best opportunity is to capture value from the increases in land values that occur when transit is provided.
3. Accessibility is also influenced by walkability and nearby destinations within mixed-use development, and higher land prices are correlated with greater accessibility, which can be redirected to finance the transit itself.
4. Common approaches include charging property owners with additional land based taxes, charging based on a foreseeable increase in property tax, collecting a one-off fee from developers associated with new development, and self-imposed taxes to contribute to the capital cost of infrastructure improvements that will benefit the entire district - with most options discouraging land development.
5. Government agencies are encouraged to consider how to harness cross-departmental collaboration (especially between land use and transport agencies) to leverage private sector finance, innovation, and knowledge to achieve truly integrated smart mobility outcomes across cities.
6. One approach is the creation of a 'joint development' where the public and private sector collaborate to deliver shared transit. There is a direct incentive for the private sector to create well-designed and integrated station precincts that will draw in patrons for the transit service, and further increase land and development value.
7. In Asia, such public private partnerships for transit and land use development can be lucrative given that average car use is comparatively low in Asian cities and cities are growing at a comparatively rapid pace - both strongly contributing to the likelihood of transit lines attracting development around stations, and such developments being in high demand.
8. Tokyo's commuter train network is among the world's best and is uniquely privately financed and operated in partnership with the government who provide regulatory oversight and support for innovation. For decades, the development of railways has been undertaken in conjunction with 'new town' development and urban regeneration, as the private sector is incentivised to build and operate railways due to the lucrative opportunity of developing mixed-use station precincts.
9. In Gurgaon, India, alternative to land development have been used on an urban rail project which was fully privatized under a 'Design Build Finance Operate Transfer' (DBFOT) agreement with a 99-year concession period. Project revenue sources include fare-box collection, advertisement, and leasing of

shops within the station area. The developer secured just over 60 percent of the total revenue in 2014-16 by auctioning naming rights for the stations and advertisement space on the inside and exterior of the train carriages.

10. Tehran Municipality in Iran have developed a strategic vision for the city, 'Tehran 2025' that focuses on a nationally supported extensive rail network as the core of the transport system, complemented by Bus Rapid Transit (BRT), standard bus services, walking and cycling. A walkway ring around Tehran's traditional Bazaar area was implemented to prioritize walking rather than cars, creating a vibrant entertainment and shopping district.

Background Information

Leading city scale efforts

Thailand Transport Development Strategy

The 20 Year Thailand Transport Development Strategy spans through to 2037 provides the framework to implement a range of efficient, inclusive and green transport system upgrades via improved management and increased innovation. The plan aims to create a standardized ITS which provides effective traffic management and shared transit services by incorporating logistical information and systems, AV management, commercial vehicle operations (freight) and traffic area management (OTP, 2019). [72]

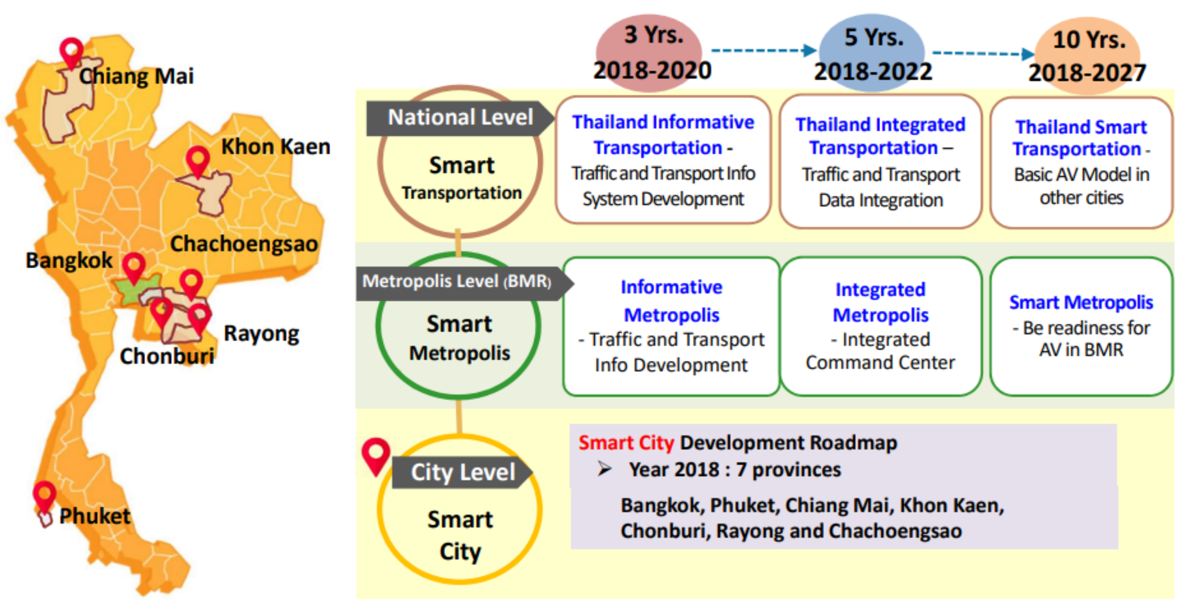

Figure 5.1: Thailand Transport Development Strategy (*Source*: OTP, 2019)[73]

In 2019 Thailand approved an ITS Development Master Plan and created a committee responsible for developing and implementing the plan. The plan spans from 2018 to 2028 and categorizes initiatives by regions of cities and national across development phases of up to 5 years. The plan aims to avoid overlapping project development and resource redundancy, with collaboration and utilization of information and smart systems from agencies of law enforcement, traffic systems and public transport. Choosaun *et al* 2021 highlight that the plan also utilizes non-ITS architecture and is not standardized, leaving gaps for capacity in the whole system, and their paper suggests the government addresses and

[72] OTP (2019) Intelligent Transport System (ITS) in Thailand, Office of Transport and Traffic Policy and Planning, Ministry of Transport, Seoul.
[73] OTP (2019) Intelligent Transport System (ITS) in Thailand, Office of Transport and Traffic Policy and Planning, Ministry of Transport, Seoul.

clarifies inclusive policy statements, pilot projects and standardization for improved system capacity and policy efficacy.[74]

Moscow Smart City Lab

In 2020 the Russian Federation Government committed to reducing the country's GHG emissions by 70 percent from 1990 levels by 2030, and near-total reduction by 2050. Transport emission mitigation is considered in their strategy in the development of lower emission modes of transport such as electric and gas fueled public transport, shared electro-mobility (including bicycles), and supporting EV and alternative fueled vehicle uptake with infrastructure investment. The Russian Federation Government intends to fully utilize data facilities for improving services and mitigating GHG emissions via range of solutions alongside technological shifts, such as monetizing emissions.[75] The Moscow Smart City Lab (SCL) was established in 2016 to develop technological smart city solutions, such digital platforms for municipalities to engage the public for optimized development and operation of city services; and digital interfacing hardware for city system digital twinning and management.[76,77,78] The SCL offers turnkey solutions, such as Alphalogic CITY – a platform that coordinates and manages all city infrastructure. The platform acts as a node between all city services – including transport, utilities, buildings and security systems – and users and stakeholders including citizens, government and facility managers. The system raises accessibility and feedback citywide, to improve service quality and coordinate development. The LCS has been involved in over 300 smart building projects, development of 10 cottage villages (planning 50,000 buildings across 10 communities worth $100 million), development of the smart city Astana, and Moscow transport management (with over 10,000 vehicles registered). Implementing transport management in Moscow had positive effects including: an increased traffic speed of 12 percent; reduction of parking violations by 64 percent; private car visits to Moscow's inner city Garden Ring decreasing by 25 percent; and parking spot turnover increasing 4 times.[79]

ITS Strategic Plan for Singapore[80]

Singapore recognizes that their population growth and level of car dependence is straining land availability in their city-state – there is opportunity to improve efficiency of land use by transport with an ITS, leading to the government's development of 'Smart Mobility 2030 – ITS Strategic Plan for Singapore'. With this, Singapore aims to shift into a more connected and interactive city. The strategy segments into information services (facilitating quality and effective data use), interactivity (people-machine-machine-people), inter-assistive networks (creating transparency between all facets for efficient flow), and green mobility (towards zero carbon and low material intensity).[81]

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[74] Choosakun, A., Chaiittipornwong, Y., and Yeom, C. (2021) Development of the Cooperative Intelligent Transport System in Thailand: A Prospective Approach. Infrastructures 2021, 6, 36.
[75] UNCRD (2021) 14th EST Forum Aichi Japan UN
[76] Intechnology Smart Cities (nd) Intechnology Smart Cities, Intechnology plc
[77] Artem S (nd) Moscow Smart City Lab, Russian Federation, UNECE
[78] Behance (nd) Smart City Lab Moscow, Behance.
[79] Artem S (nd) Moscow Smart City Lab, Russian Federation, UNECE
[80] Singapore Government (2022) 'Digital Government', Smart Nation Singapore, Singapore Government.
[81] Ong, G. and Keong, C. (2015) 'Smart Mobility 2030 – ITS Strategic Plan for Singapore', Journeys.

Financing Sustainable Transport through Land Development[82]

Taking a city scale approach to mobility is not a new concept. Such an approach has been used in Hong Kong Administrative Regions of PR China as part of the development of the metro and in Japan as part of the development of the private suburban railways. In a number of Asian cities railway companies have augmented transport revenue through real estate development and management around stations. Land was provided to institutional users such as hospitals or universities at concessional rates at the outer terminal stations, creating demand for travel in the reverse direction from central business district commuting patterns (Cervero, 1998).[83] The private railways had to diversify in this way to survive, as the Japanese Government had partially nationalized the 16 industries to create the Japan National Railway. Private companies were forbidden from building railways which interfered with the national railway's operations and were mostly restricted to areas with low population. This forced them to build their own catchment population around their railways (Saito, 1997)[84], making the best use of the assets at their disposal. This is a good example of a 'Transit Activated Corridor' (TAC) as described in Module 3 that was privately created but had significant benefits to the wider community.

One of the challenges being faced by governments in not only Asia, but all over the world, is a lack of finance for infrastructure projects. In order to provide sustainable transportation, governments must look for innovative ways to obtain finance for shared transit services. There are diverse ways this can be done, however overwhelmingly the best opportunity is to capture value from the increases in land values that occur when transit is provided. This demonstrates the importance of the integrated nature of land use and transport planning. By introducing a transit station, the accessibility to surrounding land markets increases as citizens in these zones can now reach much more desired destinations and vice-versa. Accessibility is also influenced by walkability and nearby destinations within mixed-use development, and higher land prices are correlated with greater accessibility. By creating such value through sustainable transit-oriented development, some of this value can be redirected to finance the transit itself.

A common approach to capturing the value of land around stations is through a land-based levy or tax. Examples of these mechanisms can include (Lari *et al*, 2009):[85]

- *Land Value Tax*: Property owners pay a tax based on increases in land value (LVT has had success in US, Canada, and Australia, however less success in developing countries, with cities such as Jakarta struggling to ensure compliance given less accurate land records and lower levels of land taxation).
- *Tax Increment Financing*: Property owners pay based on an increase in property tax that is forecast given the likelihood of attracting development in the future (Such as in Chicago where the Randolph/Washington station, Subway-Lake/Wells and other Central Loop transit projects received $13.5 million, $1.2 million, and $24 million in TIF funds respectively).
- *Development Impact Fees*: A one-off fee collected from developers for the purpose of financing public infrastructure that is associated with new development (these have been applied in most localities in the United States for several types of infrastructure – including roads, water, drainage, parks, police etc. – with transit being a public asset class that could justify such as cost recovery mechanism).

[82] This section provides an edited extract by of the following report by its lead author: Hargroves, K., Conley, D., Spajic, L., and Gallina, L. (2018) 'Sustainable Urban Design Co-Benefits: Role of EST in Reducing Air Pollution and Climate Change Mitigation', Background Paper for UNCRD Eleventh Regional EST Forum in Asia, Mongolia, Ulaanbaatar, 2-5 October, 2018.

[83] Cervero, R. (1998) The Transit Metropolis: A Global Inquiry. Washington: Island press.

[84] Saito, T. (1997) *'Japanese private railway companies and their business diversification'*, Japan Railway and Transport Review, vol. 10, pp. 2-9.

[85] Lari A., Levinson, D., Zhao, J., Iacono, M., Aultman, S., Vardhan, D., Junge, J., Larson, K., and Scharenbroich, M. (2009) Value capture for transportation finance: Technical research report. University of Minnesota, Center for Transportation Studies.

- *Betterment taxes/Special assessments*: Districts benefiting from transit provision chose to self-impose a tax to contribute to the capital cost of infrastructure improvements that will benefit the entire district.

There is a critical need to incentivise dense land development around transit stations to create station precincts that can significantly decrease automobile use, encourage active modes of commuting, and reduce air pollution and transport related climate change impacts. The challenge with many of the value capture strategies above is that they may discourage this necessary land development through increased land development costs. While land-based levy approaches can often be implemented by government using established processes and do not require multi-agency collaboration or changes to the established planning approach, they lack the ability to propel the type of development around stations required to create functional station precincts. Instead, government agencies need to consider how to harness cross-departmental collaboration (between land use and transport agencies) to leverage private sector finance, innovation, and knowledge to achieve truly integrated outcomes. In Malaysia, approximately 93 percent of households own a private vehicle, the third highest rate of car ownership in the world, with residents of Kuala Lumpur spending 250 million hours a year in traffic (Kennedy-Cuomo, 2018).[86] The planned 300km Bus Rapid Transit system in Iskandar has been designed to respond to the challenge of automobile dependence and is 40 percent financed from the federal government, with the remainder coming from the private sector.

Another approach to innovative finance for transportation projects is through a 'joint development' approach where the public and private sector collaborate to deliver public transit with the private sector 'investing' in the transit infrastructure to then develop the surrounding land. In this approach, there is a direct incentive for the private sector to create well-designed and integrated station precincts because they have 'bought in' to the process with the increased future land values as their reward. Cervero (1994)[87], compared projects in Washington D.C. and Atlanta that were undertaken in this PPP Joint Development fashion, to equivalent TODs which were not undertaken through public-private partnerships. The study demonstrated that much better outcomes were achieved through joint development, including:

- Higher rents, from generally more retail space.
- Lower vacancy rates and higher absorption rates, because developers strategically prefer locations with already low vacancies (indicating expanding office submarkets).
- Higher densities, due to joint developments resulting in greater air-rights and developer anticipation of benefits.
- Higher economic growth in TOD areas compared with the average surrounding regional developments, as transit spurs growth and developers also are drawn to collaborate within high growth areas.

In Asia, such public private partnerships for transit and land use development are even more lucrative. Firstly, the average car use across the population is much less in Asian cities than in Western countries (Newman and Kenworthy, 2015),[88] meaning that there is more of the population reliant on public transportation and as a result additional transit induces a greater increase in accessibility (Salon and

[86] Kennedy-Cuomo, C. (2018) The Case for Sustainable Urban Transportation for Malaysia, The Jeffrey Sachs Center on Sustainable Development, Sunway University, Malaysia.
[87] Cervero, R. (1994) Rail Transit and Joint Development: Land Market Impacts in Washington, D.C. and Atlanta. *Journal of the American Planning Association*. 60:1, 83-94.
[88] Newman P. and Kenworthy, J. (2015) The end of automobile dependence: How cities are moving beyond car based planning. Island Press.

Shewmake, 2011).[89] Secondly, Asian cities are growing at a rapid pace when compared to Western cities (Chauvin *et al*, 2017).[90] These two features of cities in Asia both strongly contribute to the likelihood of transit lines attracting development around stations, and such developments being in high demand.

Cities such as Tokyo and the Hong Kong Special Administrative Region of China have long leveraged this approach to deliver world-class railway networks. For example, the Hong Kong city Mass Transit Railway Corporation (MTR) is a quasi-private, quasi-public organisation and under its 'Rail + Property' model collaborates with private developers to finance urban rail through the difference between 'pre-rail' and 'post-rail' prices (Sharma and Newman, 2017).[91] The difference between these two prices is directly proportional to the incentive for private involvement. Therefore, to maximise financing potential, planning of transport networks may need to shift to public-private consideration of maximum transit-activated land use development opportunity, as discussed in the following section.

In Japan, Tokyo's commuter train network is among the world's best, and is uniquely privately financed and operated in partnership with the government who provide regulatory oversight and support for innovation. Tokyo's rail network features connectivity across rail lines and the integration of multi-track routes which can ease congestion compared to single track routes. For decades, the development of railways has been undertaken in conjunction with 'new town' development and urban regeneration, as the private sector is incentivised to build and operate railways due to the lucrative opportunity of developing mixed-use station precincts.

Transit Activated Development, India[92]

Until recently India has adopted a policy of slow urbanisation while encouraging economic growth. Despite comparatively low urbanisation (32.8%), India has the second-largest urban population in the world (377 million). The per capita income (in PPP terms) has grown rapidly since 2000 from US$2,130 to US,$5,748 in 2015 (World Bank, 2019).[93] However, the income levels are still below PR China. In Indian cities significant share of travel is with non-motorized modes, that is walking, and bicycling (around 40%), about 15 percent use shared transit, and 36% use private transport of which, 20 percent is by motorcycle. The land use in cities in India has been characterised as having high density, low rise and with mixed land use. In Delhi, the number of Vehicles/1,000 persons increased from 125 vehicles/1,000 persons in 2001 to 441 in 2011. In 2008, 39 percent of total trips in Delhi were made using NMT modes (35% by walking), 38 percent by public transport (31% by Metro/bus and the rest by auto-rickshaw and cycle-rickshaw) and 13 percent trips were made using private motorized modes of transport (9% by car). Delhi's metro has grown rapidly since this period (Sharma and Newman, 2018).[94]

Delhi has been trying a range of partnership approaches to try and help build new transit systems like the Metro. Other Indian cities have been doing likewise. In the case of Gurgaon, the urban rail project is fully privatised under a 'Design Build Finance Operate Transfer' (DBFOT) agreement with a 99-year concession period. The private developer financed the project through private loans and equity raising. The

[89] Salon, D. and Shewmake, S. (2001) Opportunities for value capture to fund public transport: A comprehensive review of the literature with a focus on East Asia. SSRN.

[90] Chauvin, J., Glaeser, E., Ma, Y., and Tobio, K. (2017) What is different about urbanization in rich and poor countries? Cities in Brazil, China, India and the United States. *Journal of Urban Economics*, Volume 98, March 2017, Pages 17-49.

[91] 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.

[92] This section provides an edited extract from an author of: Newman, P., Conley, D., and Hargroves, K. (2019) 'Bridging the Urban Transport Infrastructure Gap: In the Context of Smart and Resilient Cities – the Role of Private Sector and Public-Private-Partnerships', Background Paper for UNCRD Twelfth Regional EST Forum in Asia, Hanoi, Viet Nam, 28-31 October, 2019.

[93] World Bank (2019) *'GDP per capita (current US$) - India'*, World Bank.

[94] Sharma, R., and Newman, P. (2018) *'Does urban rail increase land value in emerging cities? Value uplift from Bangalore Metro'*, Transportation Research Part A: Policy and Practice, vol. 117, pp. 70-86.

government provided an existing right of way for the rail line, however access to the station and transport interchange facilities as well as land acquisition for stations was undertaken by the private developer. Project revenue sources include fare-box collection, advertisement, and leasing of shops within the station area; however, no land development was involved. The private developer conducted an aggressive advertising campaign which resulted in 61 percent of the total revenue in 2014-16 through the auctioning of the naming rights for the stations (even before the stations were opened) and advertisement space on the inside and exterior of the train coaches. The private developer operates 'free' feeder bus service to adjacent industrial hubs from stations to increase fare-box revenue. The feeder service benefits the commuters by providing comfortable last mile connectivity. This case shows that full private participation results in innovative revenue strategies and greater public benefit however it is very unusual not to have used land development opportunities and it remains to be seen whether the project can survive without this.

In other Indian cities there are clearly lessons that can be learned for Delhi. In Mumbai, a new rail line was built based entirely on the private owner paying for it from the fare box, but this was never enough, even in Mumbai where rail is so important. In Bengaluru, the value of land around Metro stations increased by 25 percent in the area going out between 500m and 1km and more significantly a 'before' and 'after' from the commencement of the metro rail operations shows a price uplift of 4.5 percent across the whole city; this indicates a major agglomeration economic event resulting in substantial economic value increase of USD 306 million from the metro rail's accessibility (Sharma and Newman, 2017).[95] Hyderabad Metro involves significant land development. It is built on a DBFOT agreement wherein a private developer was provided about 10 percent of the capital cost as grant (equity) from the federal government of India and the state/provisional government granted air-rights for commercial development of about 12.5 million sq. ft. over the three depots and 6 million sq. ft. at the 25 select stations. The private developer has raised capital through loans and equity. The private developer's concession period is for 35 years. The project was operational in mid-2017. The private developer started renting the spaces before the rail is operational. This case shows the private sector's active approach towards enhancing revenue streams.

Integrated Transport Provision, Tehran[96]

Tehran, the capital of Iran has a population of 8.3 million people, with a population density of around 10,720/km. It is surrounded by satellite cities and towns that constitute a population of 15 million. One of Tehran's major challenges is air pollution, of which nearly 90 percent is caused by private motorized vehicles, with surrounding mountain ranges restricting natural air ventilation. At certain times of the year, Tehran experiences temperature inversions in the cold season which exacerbates air pollution further. In order to combat this the Tehran Municipality have developed a strategic vision for the city, 'Tehran 2025' that focuses on a nationally supported extensive rail network as the core of the transport system, complemented by Bus Rapid Transit (BRT), standard bus services, walking and cycling. The goal of the city is to create an "*integrated, available, safe, easy, comfortable and clean transportation system*" (UITP, n.d.).[97]

Tehran has been ambitiously implementing sustainable transport interventions in-line with the targets set out in their vision. In 2009, Tehran had 159km of urban railway, which increased to 236km in 2010,

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[95] 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.

[96] Edited extract from Hargroves, K., Conley, D., Spajic, L., and Gallina, L. (2018) 'Sustainable Urban Design Co-Benefits: Role of EST in Reducing Air Pollution and Climate Change Mitigation', Background Paper for UNCRD Eleventh Regional EST Forum in Asia, Mongolia, Ulaanbaatar, 2-5 October, 2018.

[97] UITP (n.d.) Transport and Traffic Strategic Framework for Tehran, International Association of Public Transport.

increasing passenger trips by 17 million per year to a total of 459 million trips per year in 2010 (ITDP, 2011).[98] Daily ridership has now increased to more than 2 million passengers per day (Omid and Maryam, 2018).[99] Tehran's extensive rail network is estimated to cover 56.7 percent of the city with the ambition to have this coverage increased to 80 percent. In 2017, 22kms was opened on Tehran's latest Line 7, a line which will be 31km long with 34 stations at it is expected completion in 2018 (Tehran Municipality, n.d.).[100] The satisfaction of passengers on the metro has also been increasing each year, with 90 percent of the commuters satisfied with the system in 2016.

While the railway system in Tehran remains the backbone of the transit network, the city has also integrated Bus Rapid Transit (BRT) to service more of the population with mass transit. After visiting the TransMilenio BRT in Bogotá, Columbia in 2007, the municipality of Tehran introduced the first BRT system which drew on experiences in Bogota but also adapted certain features to suit the local conditions such as rights-of-way and pre-payment of tickets. In the first year of implementing the BRT, daily passengers grew from 214,000 to 380,000 between 2007 and May 2008 – a 77 percent increase. Since then, Tehran has expanded the BRT network to 10 lines totalling 130km, which carries approximately 2 million passengers per day – or 24 percent of the cities' population (BRTDATA, 2018).[101] This ridership share of the population is now among the highest in the world.

Figure 5.1: Tehran BRT System *Source*: ITDP, 2011[102]

Tehran has increasingly endeavoured to collaborate with the private sector in order to finance and operate these public transport initiatives at a high quality, quicker than what the government could have provided. In 2002, there were no privatised buses in Tehran, however by 2011 over 40 percent of the fleet (which had grown much larger by that time in both public and private ownership) was privatised. Currently

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[98] ITDP (2011) Sustainable Transport Award cities: Tehran, Institute for Transportation and Development Policy.
[99] Omid, A. and Maryam, A. (2018) A Study on the Development of Transportation Systems City of Tehran between 2006 and 2016, International Journal of Emerging Engineering Research and Technology, 6(3), pp.76-79.
[100] Tehran Municipality (n.d.) Tehran opens new metro line, Tehran Municipality.
[101] BRTDATA (2018) Global BRT Data - Tehran, BRTDATA.
[102] ITDP (2011) Sustainable Transport Award cities: Tehran, Institute for Transportation and Development Policy.

approximately half of the railway network is operated by the private sector through a 'Build, Operate and Transfer' model, with the municipal government giving the private sector opportunity to develop the land around the stations.

In efforts to encourage walkability, a walkway ring around Tehran's traditional Bazaar area was implemented, which created a walkable environment where pedestrians prioritized shared transit over cars. This significantly reduced pollution and traffic congestion in this area, while also creating a more vibrant district with entertainment, shopping, parks, and shopping malls (Allen, 2011).[103] Tehran is focusing efforts on increasing the bicycle mode share to 12 percent by 2030. Infrastructure improvements are being coupled with a congestion charging scheme to disincentivize car use, which the city has had in place since 1981. It is important when implementing such a scheme whether alternative modes of transport are available for the population to travel into these areas.

Walkable areas such as the Bazaar have achieved almost total air pollution reductions and the removal of vehicles. Allen (2011)[104] highlights some of the benefits of The Bus Rapid Transit systems have also have remarkable success, with BRT line 1 enabling a 46 percent decrease in air pollutants along the corridor. Similarly, BRT line two is estimated to save approximately 1.5 million litres of fuel from reduced automobile and motorcycle use in its corridor – directly reducing air pollution. The Ghods Square-Rahahan Square BRT achieved a 27 percent conversion of trips from cars to the new bus facilities, with an estimated reduction of 140 tonnes a year in emissions including NO_x, CO, SO_2, and particulate matter (Allen, 2011).[105]

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[103] Allen, H (2011) An Integrated Approach to Public Transport, Tehran, Islamic Republic of Iran, Case study prepared for Global Report on Human Settlements 2013.

[104] Allen, H (2011) An Integrated Approach to Public Transport, Tehran, Islamic Republic of Iran, Case study prepared for Global Report on Human Settlements 2013.

[105] Allen, H (2011) An Integrated Approach to Public Transport, Tehran, Islamic Republic of Iran, Case study prepared for Global Report on Human Settlements 2013; Hashemi, M. (2010) Tehran transportation and traffic system, A background paper prepared for Institute Transportation Development Policy (ITDP), Sustainable Transport Awards 2010.

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Module 6: Smart Mobility Best Practice and Case Studies

Asia's transport sector will be facing several critical challenges in future due to the existing and emerging challenges like climate change, increasing frequency and magnitude of natural disasters and health emergencies like COVID-19 pandemic. Resiliency has to be an integral part of transport policies, plans, programs, budget, including transport infrastructure design and development in Asian countries and cities. Transformative policies, institutions, programs, and investment decisions in the transport sector are necessary to put the countries and cities on the path of resilience. Public-private partnerships can play a very vital role in this direction (UNCRD, 2021).[84] However, the transport sector cannot work on its own. Transport agencies should diligently work with the city planning agencies as a collective effort is needed to decarbonize the sector. It is imperative that the international community address the growing challenges that cities face and draw blueprints for livable urban areas for the future. It is also clear that post COVID-19 cities must be more resilient to sudden shocks, such as pandemics, and to gradual changes, such as climate change. It will be important for cities to access capacity building programs to support strategies to achieve smart mobility with a focus on inclusion, sustainability, and connectivity (UNCRD, 2021).[85] This Module provides a summary of a number of leading case studies to assist in knowledge sharing to build capacity in the area.

Smart and Sustainable City Planning, Nagoya, Japan

Nagoya is one of the best livable cities in Japan, with a population of 2.22 million across an area of 326 km^2. In 2008 Nagoya was appointed a 'City of Design' by UNESCO for its efforts to integrate humanism into its urban development – aiming to create a healthier, livable, people–friendly city. Located in the middle of Japan, Nagoya is the capital of Aichi Prefecture and a hub for automobile businesses. The city is home to world-class industrial technologies in the automotive, aircraft, robotics, and machine tool fields. The city has a strong economic, social, and environmental concentration of commercial and service industries typical of large cities and stable employment supported by a strong economy. The urban design and infrastructure development of Nagoya city is quite advanced and the city functions well keeping socio-economic and environmental sustainability. As a smart and livable city, Nagoya offers world-class safe, efficient, comfortable, affordable, and accessible shared transit for all - including venerable groups. The city is the center of a wide multi-modal transport system with automated Maglev trains, guided bus systems, mass rapid transit, expressways, waterways, and high-speed railways - the Shinkansen (City of Nagoya).[106]

Nagoya has generated a Master Plan for 2023, outlining its planned systems for managing the cityscape and urban environment by using the city's existing strengths and understanding and incorporating evolution in the city, such as social behavior and demographic shifts. The plan envisions a city enabling human rights and freedom of life choice; a child-friendly city; a city resilient to natural disasters and emergencies for secure living; a city in harmony with the natural environment; and an appealing city attracting the attention of the global community. Based on the urban planning policy 2030, Nagoya city has a future vision for the city of: making healthy lives for elderly people and disabled people; safe, secure, and prepared for natural climatic and climate impacts, a place where children and young people are protected and can shine where all the urban system and services should be enhanced to make them people and environmentally friendly.

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[106] City of Nagoya (2015) *'Nagoya City Next Comprehensive Plan'*, Planning Division, General Affairs Bureau, City of Nagoya.

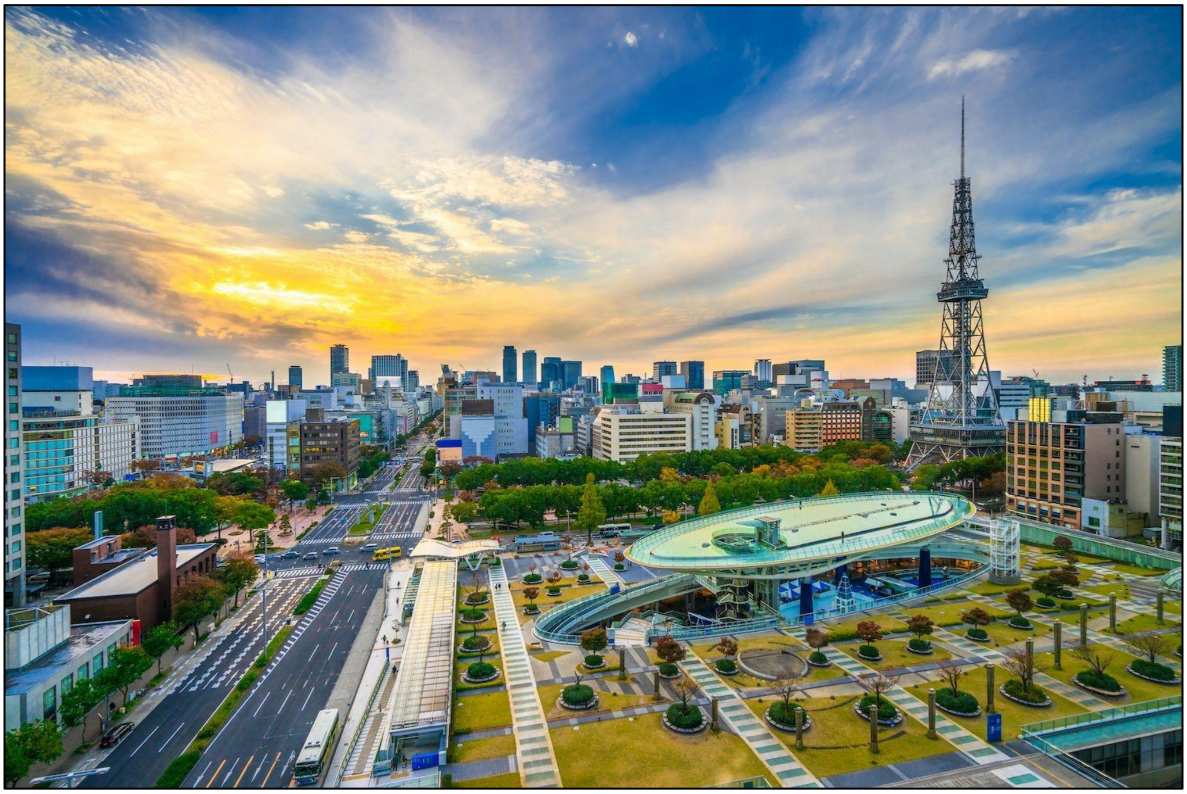

Figure 6.1: The City of Nagoya, Japan (*Source*: Travel Lens)

The plan was generated in collaboration with the city's communities and citizens (as well as foreigners), employing surveys of all demographics in various formats over the past three years from 2017 to 2019, with reviews and continued public commentary, culminating in the plan published in late 2019. This is one of the best examples that show how smart cities involve their community and diverse stakeholders to implement the smart city project development. In this regard, the International Design Centre Nagoya is acting as a collaboration center and bringing different stakeholders including the Aichi prefectural government, Nagoya city government, and the private and business sectors to endorse design practices and art to facilitate the flow of ideas and creativity in the ideation of a range of enterprises to realize the proposed plan by 2030 (Edgington, 2000).[107]

To complement the urban development of Nagoya, the city has investigated rejuvenating and restructuring its local economies via design and information systems to create a highly cohesive city across livability and economic performance – providing a high-quality lifestyle while adding value to its products and services. The city is making more resilient and robust infrastructure to tackle the threat of natural disasters and climate change impact, especially in the context of the rising of massive earthquakes that will be occurred in the Nankai Trough in the next 30 years (City of Nagoya, 2015).[108] Meanwhile, the city is modernizing with the use of smart technology such as IoT, AI, robots, and self-driving cars. Nagoya has proposed the following Urban Planning Policy for 2030:

a. Establishing Nagoya as an appealing global destination.

b. Establishing Nagoya as a leading city in the maglev era.

[107] Edgington, D. (2000) *'New directions in Japanese urban planning: a case study of Nagoya',* Japan after the Economic Miracle, pp. 145-168.
[108] City of Nagoya (2015) *'Nagoya City Next Comprehensive Plan'*, Planning Division, General Affairs Bureau, City of Nagoya.

c. Restoring Nagoya as a global touristic destination.

d. Protecting lives and industries from major natural disasters to secure safety and reassurance in everyday living.

e. Attracting people, goods, capital, and information to create new values and sustainable economic growth.

f. Deepening collaboration and ties with countries and cities throughout Asia and abroad to establish Nagoya as a true international hub for international exchange of culture, art, a wealth of knowledge, and technology transfer.

g. Creating a strong economy, vibrant society, and sustainable environment by achieving SDGs.

Smart City Initiative, Bangkok, Thailand

As the capital of Thailand, the Thai government has taken positive steps to realize a digital economy to make Bangkok a smart city through the ASEAN Smart City Network (ASCN). However, as a historic city, Bangkok faces a number of challenges, such as insufficient and aging infrastructures, and an underdevelped sharted transit system. Addressing these issues will involve significant improvements to urban infrastructure and the transport system that can be enhanced thorugh the use of smart technologies and solutions. The Thailand Transport Development Strategy presents 20 years visionary plan for Bangkok to 2037 to implement a more efficient, inclusive, and green transport system via improved management and increased innovation. The plan aims to create a totally standardized ITS which provides effective traffic management and public transport by incorporating logistical information and systems, smart shared transit, commercial and freight vehicle operations, and traffic area management (Seoul Ministry of Transport, 2019).[109]

In 2019 Thailand approved an ITS Development Master Plan and created a committee responsible for developing and implementing the plan. The plan spans from 2018 to 2028 and categorizes initiatives by regions of cities across the nation over development phases of up to 5 years. The plan aims to avoid overlapping project development and resource redundancy, with collaboration and utilization of information and smart systems from agencies of law enforcement, traffic systems, and public transport. The plan also utilizes non-ITS architecture and is not standardized, leaving gaps for capacity in the ystem, and it has been suggested that the government addresses and clarifies inclusive policy statements, pilot projects, and standardization for improved system capacity and policy efficacy (Choosakun *et al* 2021).[110]

The Government of Thailand making an extraordinary effort to take urban mobility and public transport to the next level. According to World Bank as estimated 60 percent of the Thai population will live in urban areas, particularly around the Bangkok area, by 2050. To address a range of issues accosiated with such growth, plans are underway to improve Bangkok's shared transit share from 40 to 60 percent by 2050 (Gnanasagaran, 2018).[111] Railways network expansion can help in this regard, so the government is expanding the rail network in the greater Bangkok area by about 500 km by 2029 and continuously expense the network in the future.

Thailand has proposed the 20 years energy efficiency development plan (2011-2030) in which Thailand aims to reduce energy consumption by 20 percent by 2030 by adopting smart policies and strategies including a new building energy code (BEC). It is expected that over the next 20 years, the BEC strategy

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[109] Ministry of Transport (2019) *'Intelligent Transport System (ITS) in Thailand',* Ministry of Transport, Seoul, Republic of Korea.

[110] Choosakun, A., Chaiittipornwong, Y., and Yeom, C. (2021) Development of the Cooperative Intelligent Transport System in Thailand: A Prospective Approach. Infrastructures 2021, 6, 36.

[111] Gnanasagaran, A. (2018) '*Smart City Spotlight: Bangkok',* The Asean Post.

will save about US$ 1.5 billion (Gnanasagaran, 2018).[112] The Thai Board of Investment had launched a smart city promotional scheme that will focus on enhancing safety and security, the developing an efficient and well-connected shared transit system, improving social equity in all sectors of the society, improving ease of doing business, fast and efficient public services, reduce energy consumption, better management of natural resources to achieve the sustainable development. As a part of sustainable living focus, the city of BangkokBankcok plans to develop eight hectares of dedicated green open spaces that will set a good example for people and environmentally friendly sustainable smart city living.

Figure 6.2: The City of Bangkok, Thailand (Source: Dreamstime.com).

Railway Network Governance, Russian Federation

Russian public rail transport is owned and operated by a government owned agency and its subsidiaries. Rail transport is regulated by: the Ministry of Transport (to define and implement policy and regulation); the Federal Agency of Rail Transport (FART) (executing services, managing property, and cataloguing equipment); the Federal Service for Supervision in the Sphere of Transport (FSSST) (supervising and controlling transport functions); and the Russian Railways Joint Stock Company (regulating some aspects of transport such as technical specifications and design documentation for government railways). Regulatory approval for a rail transport provider requires obtaining a license; access to rolling stock; qualified staff; and an agreement for railway infrastructure use. In addition, a license is needed for passenger transport, hazardous materials transport, and handling of hazardous materials. Licenses in Russia are provided by the FSSST, and the documentation and costs are made by government regulation.

Rail transport provider (RTP) competition is regulated by the Federal Antimonopoly Service (FAS) to prevent monopoly in the transaction of a RTP assets, if: the value of assets or revenue of a party involved exceeds an amount defined by the FAS; the rail transport provider is subject to a natural monopoly and the sale of assets exceeds 10 percent of the provider’s equity capital; or the assets of the provider are

[112] Gnanasagaran, A. (2018) ’*Smart City Spotlight: Bangkok’,* The Asean Post.

worth more than 10 percent of the authorized capital being transacted. Special approval is needed for foreign investors to acquire assets in railways, in consideration of national security. New railway line rules have general rules governed by town planning code and the land code (for obtaining land and construction rights), and specific rules outlined by federal law (private railway railways by a special commission, and public by general federal law). Private railway construction is approved by local constituents. In the case of constructed railways connecting with private railways, construction is approved by the owner of the existing railway, while connection with public railways requires approval from FART. Additionally, the Ministry of Transport regulates project design and construction of public railways.

Discontinuing a public service requires a voluntary closure procedure by the Ministry of Transport, however a private service does not require special approval. The public closure procedure involves MoT approval stemming from a FART report, after the rail company's submission of various documents including a railway closure feasibility study. Grounds for closure by authorities include breaches of license (and then suspension or rescinding of license), from death or injury of person, harm of animals, environment and property, or risk of violating transport rules. In the case of insolvency, operations must continue unless a court decides otherwise. Competition is regulated to prevent monopolies and regulate services and fees for all parties (especially consumers), however the MoT does not have power to enforce competition regulation laws. Prices are regulated by the Federal Tariff Service imposing upper and lower limits on prices for transport services. All parties can challenge price limits (including passengers challenging prices) by approaching the FAS. Public transport providers are federally mandated to provide similar prices across their entire service.

Network access is guaranteed in public systems for public service providers – access is only denied if a usage agreement cannot be made. Pricing must be accessible and affordable between service providers, railway owners and users, as mandated by federal law. Service standards are protected in public transport systems; however, a provider can deny service if unable to provide it. Passengers must be provided with free use and maximum provision of accessibility services (such as toilets and wheelchair access). Insufficient service quality can be challenged to bring remedies, reduction of price or reimbursement. Safety for individuals and property is regulated in designs of infrastructure, as well as ongoing operations, with inspections occurring between 1-10 years depending on the asset, by the MoT and FSSST. Manufacturing of equipment is regulated by the Customs Union Commission. Specific rules pertain to infrastructure and equipment for train systems operating above 140 km/h. Accidents are investigated by MoT, involving relevant asset owners informing the FSSST about incidents. Liability is exercised in Russian Civil Law; however, the Rail Transport Charter sets an upper limit of compensation for passenger death of 2 million rubles. Financial support for service providers is available from the government, particularly to public service providers. Loss of income of providers due to government tariffs or consumer benefits is typically subsidized by the government. Requests for support require approval of details of income loss, with monthly income report submissions (Yurchik and Chichkanova, 2019).[113]

A Smart Living City, Singapore

Singapore is a well-known smart city and won the title of the *smart nation* in the world. With a 5 million op population and 721 square kilometers of area, Singapore enjoys its status as a living, breathing laboratory and digital city where over 94 percent of all services are in a digital form (Singapore Government, 2022).[114] The main aim of the digitization of Singapore is an effective means for the government services to solve the problems of citizens with great empathy through designing policies and services that are inclusive, seamless, and personalized for all. Singapore would like to introduce new traffic

[113] Yurchik, V. and Chichkanova, K. (2019) Rail Transport in Russia, Dentons, Lexology.
[114] Singapore Government (2022) 'Digital Government', Smart Nation Singapore, Singapore Government.

control systems, and data analysis modes, and digitize health, education, and commerce emphasizing sustainable transport as a primary and essential part of living at the core of efficient and sustainable urban development and economic growth.

Singapore recognizes that their population growth and level of car dependence are straining land availability in their city-state – there is an opportunity to improve the efficiency of land use by transport with an ITS, leading to the government's development of 'Smart Mobility 2030 – ITS Strategic Plan for Singapore'. With this, Singapore aims to shift into a more connected and interactive city. The strategy segments into information services that facilitate quality and effective data use, interactivity between people and machines, inter-assistive networks creating transparency between all facets for efficient flow, and green mobility towards zero carbon and low material intensity (Ong and Keong, 2015).[115] The outcomes for building digital governance services involve the efforts of every government agency to improve operations and management to deliver services through smart information and communication technologies and smart solutions.

Singapore has a vision for a traffic-free city, this can be realized to reduce traffic to zero through massive digitalization and the development of an efficient public transport network. For achieving this vision, Singapore is initiating "*Vehicle-to-Everything*" (V2X) project that allows residents to move through self-driving traffic on all of Singapore's streets. This project is the most technically advanced project of its kind in the world that is expected to be functioned by 2025 (Webuildvalue, 2021).[116] As an experimental level, this project is underway in Singapore to enable vehicle-to-vehicle and vehicle-to-infrastructure dialogue, smart traffic light dialogue, and even for drivers and pedestrians to inform and alert passing emergency vehicles and ambulances to pass the road and they need to clear the road. In addition, the government is also investing in low-carbon transport system solutions, particularly for light rail transit, subways, and railways. It is expected that after the full phase of implementation of these projects traffic congestion will be reduced, and road safety will be increased significantly. The introduction of low carbon and e-mobility options reduces air pollution and GHG emissions considerably and makes the nation truly human-friendly and sustainable. All this will be possible with the integration of the smart advanced technologies such as information and communication technologies (ICT), the Internet of Things (IoT), Intelligent Transport System (ITS), robotics, and sensor camera surveillance technologies. All these technological advancements and robust high-quality infrastructure development required large-scale investment and finance.

The government is putting a lot of resources into the realization of the projects. For instance, the government has allocated an estimated US$43.5 billion investment in the sustainable development of subways and railways alone. Under these projects, two subway lines, the North-East line and the Downtown line to be completed by 2025, and subsequently follow the expansion of the circle line that connects Marina Bay with Harbor Front. The other two lines, the Jurong Regional Line and Cross Island Line will be finished by 2029. In total, after the completion of these projects, the total metro-railways network would be 360 kilometers. At the end of the project year 2030, about 80 percent of Singapore residents will live within walking distance of the train station (Webuildvalue, 2021).[117] Moreover a lot of other advanced projects like the creation of aerial networks for drones and testing carrying packages, letters, and information, automated walking projects for physically challenged, children and elderly; self-driving wheel-chairs, digitization of information, big data for road transport and road safety improvement, adoption of the facial recognition system all that making them a world-leading car-free city by achieving

[115] Ong, G. and Keong, C. (2015) 'Smart Mobility 2030 – ITS Strategic Plan for Singapore', Journeys.
[116] Webuildvalue (2021) The future of sustainable mobility in Singapore, Webuildvalue.
[117] Webuildvalue (2021) The future of sustainable mobility in Singapore, Webuildvalue.

the highest level of railways connectivity exceeding the level of world-leading cities such as New York, Hong Kong Administrative Regions of PR China, even Tokyo city (Singapore Government, 2022).[118]

[118] Singapore Government (2022) 'Digital Government', Smart Nation Singapore, Singapore Government.